The Cambridge Handbook of

Formal Semantics

edited by **Maria Aloni** and **Paul Dekker**

The Cambridge Handbook of Formal Semantics

Formal semantics – the scientific study of meaning in natural language – is one of the most fundamental and longest-established areas of linguistics. This handbook offers a comprehensive yet compact guide to the field, bringing together research from a wide range of world-leading experts. Chapters include coverage of the historical context and foundation of contemporary formal semantics, a survey of the variety of formal/logical approaches to linguistic meaning, and an overview of the major areas of research within current semantic theory, broadly conceived. The handbook also explores the interfaces between semantics and neighbouring disciplines, including research in cognition and computation.

This work will be essential reading for students and researchers working in linguistics, philosophy, psychology, and computer science.

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Preface

Humans characteristically use language, and a characteristic feature of the use of language is that it is meaningful. Semantics is the study of meaning, of the structural ways in which it is realized in natural language, and of the formal logical properties of these structures. The area of formal semantics finds its roots in logic and the philosophy of language and mind, but it has also become deeply entrenched in linguistics and the cognitive sciences.

This *Cambridge Handbook of Formal Semantics* constitutes a comprehensive guide to contemporary formal semantics, and it provides, among other things, a historical context and foundation of the field, a survey of the variety of formal/logical approaches to linguistic meaning, an overview of the major areas of research within current semantic theory, and a presentation of the interfaces between semantics and other domains of linguistic inquiry, broadly conceived.

This handbook is intended for everyone interested in the understanding of meaning. It presents a broad view of the semantics and logic of natural language and, as a helpful tool, of the logical languages employed.

The twenty-five chapters constituting this handbook have been grouped together into five major parts, and we hope the handbook can thus be seen to cover, in a systematic and transparent way, both the broad and the varied scope of the domain as well as the width and variety of the perspectives adopted. The contributions are subsumed under the following headings:

I The landscape of formal semantics.
II Theory of reference and quantification.
III Temporal and aspectual ontology and other semantic structures.
IV Intensionality and force.
V The interfaces.

The first and the last parts are more of a methodological or programmatic nature. The first part gives a general sketch of the frameworks in and perspectives from which semantic research is conducted. The last part focuses on the intimate and intrinsic relationships with bordering academic disciplines. The three middle parts are concerned with more or less established major domains of linguistic research: the nominal domain (Part II) and the verbal or predicative domain (Part III). Both domains are studied with logical and (natural language) ontological interests. Part IV gives an overview of the various moods and modalities in language, ranging from negation, to modals, questions and other moods.

All contributors to the handbook are senior researchers working in logic and linguistics who are widely recognised as experts on the topics assigned to them. All contributions have been thoroughly reviewed by expert colleagues.

This handbook is aimed at graduate and PhD students, but it is also meant for a wider audience, and hopes to serve as a manual and source book for senior lecturers and researchers alike. All five parts center around formal semantic issues but are intended to be of interest to linguists in general, descriptive semanticists, philosophers of language, and those who work on dialogue systems, cognitive grammar, and computation.

This work is intended to document the background and development of the main currents in formal semantics. It is not intended as a textbook, although the individual chapters may figure well in introductory and advanced courses, supplying required overviews and suggestions for further reading. For more detailed introductions to the various frameworks and formalisms, we are confident that readers can find their way among a wealth of standard textbooks. (The following list is incomplete.) G. Chierchia and S. McConnell-Ginet, *Meaning and Grammar* (1990), L. T. F. Gamut, *Logic, Language and Meaning* (1991), A. Kratzer and I. Heim, *Semantics in Generative Grammar* (1998), S. Löbner, *Understanding Semantics* (2002), B. Partee, A. ter Meulen, and R. Wall, *Mathematical Methods in Linguistics* (1990), W. Sternefeld and T. E. Zimmermann, *Introduction to Semantics* (2013), Y. Winter, *Elements of Formal Semantics* (2015).

A handbook like this would of course not have been possible without the help of the publisher, and we would like to thank especially Helen Barton for her continuous support during the lengthy process. Peter van Ormondt has proven extremely valuable as the technical editor, who, it must be emphasized, also contributed his valuable expertise on substantial matters. All of this is greatly appreciated. We are also very grateful to the reviewers of the individual chapters, whom we would have liked to list if the reviews had not been done anonymously. Their acute and timely comments have surely increased the value of the various contributions even more. Lastly, we would like to thank the individual and collective authors, for enabling us to make this broad subject, with the help of their expertise, views, and findings, accessible to a wide audience.

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Part I

The landscape of formal semantics

1

Formal semantics

Barbara H. Partee

1.1 Formal semantics: what is it?

Formal semantics is an approach to semantics, the study of meaning, with roots in logic, the philosophy of language, and linguistics. The word *formal* in "formal semantics" is opposed to *informal* and reflects the influence of logic and mathematics in the rise of scientific approaches to philosophy and to linguistics in the twentieth century. Distinctive characteristics of this approach (see also Pagin, Chapter 3) have been truth conditions as a central part of meaning; (usually) a model-theoretic conception of semantics; and the methodological centrality of the Principle of Compositionality: "The meaning of a whole is a function of the meanings of its parts and their mode of syntactic combination." Most formal semantics is model-theoretic, relating linguistic expressions to model-theoretically constructed semantic values cast in terms of truth, reference, and possible worlds or situations (hence, formal semantics is *not* "formal" in the sense of Hilbert, 1922). And most formal semanticists treat meaning as mind-independent (and abstract), not as concepts "in the head"; formal semanticists distinguish semantics from knowledge of semantics (Lewis, 1975b; Cresswell, 1978).

This sets formal semantics apart from approaches which view semantics as relating a sentence principally to a representation on another linguistic "level" (*logical form*) (May, 1985) or a representation in an innate "language of thought" (Fodor, 1975) or "conceptual representation" (Jackendoff, 1992). The formal semanticist could accept such representations as an aspect of semantics but would insist on asking what the model-theoretic semantic interpretation of the given representation-language is (Lewis, 1970). Kamp's Discourse Representation Theory is an exception, since as noted in Section 1.3.3 below, it includes as essential an intermediate level of representation with claimed psychological reality. Formal semantics is centrally concerned with *compositionality* at the syntax–semantics interface (see Sailer, Chapter 21), how the meanings of larger constituents are built up from the meanings of their parts on the basis of their syntactic structure.

The most important figure in the history of formal semantics was undoubtedly Richard Montague (1930–1971), whose seminal works in this area date from the late 1960s and the beginning of the 1970s. Other important contributors will also be discussed below. Since the 1980s formal semantics has been a core area of linguistic theory; important contributions also continue to come from philosophy, logic, cognitive science, and computational linguistics.

In the last thirty years formal semanticists have become increasingly concerned with issues at the interface between semantics and pragmatics, including context-dependence, information structure, and the semantics/pragmatics of dialogue (see Asher, Chapter 4; Ginzburg, Chapter 5; Schlenker, Chapter 22; Vallduví, Chapter 23). These broadening concerns have led to a range of newer approaches that treat meaning as something more than truth conditions, but still including truth conditions, possibly derivatively, as a central part of what semantics is to capture.

In this chapter we briefly trace the history of formal semantics (Section 1.2) and discuss some of its central principles, debated issues, and divergences within the field (Section 1.3). Since issues concerning the syntax–semantics interface are so crucial to the central working hypothesis of compositionality, we include some brief case studies relating to the syntax–semantics interface in Section 1.4; fuller treatments of related issues will be found in Brasoveanu and Farkas, Chapter 8, and Sailer, Chapter 21. In Section 1.5 we describe the increasing attention to the role of context and to language use and the consequent blending of formal semantics and formal pragmatics (see also Schlenker, Chapter 22). In Section 1.6 we come back to the foundational question of whether meanings are in the head and how formal semantics, which has traditionally rested on the assumption that they are not, connects to cognitive science and studies of language processing and language acquisition. In the final Section 1.7, we mention some of the relatively recent contributions of formal semanticists to issues of language universals and language typology.

1.2 The history of formal semantics

1.2.1 Semantics in linguistics before 1970

Linguistics had partly different beginnings and different emphases in Europe and in America, growing in considerable part out of philological-historical work in Europe and out of that plus anthropological studies in America. Semantics in early linguistics was mainly lexical; lexical semantics and principles of semantic change and semantic drift were important for historical and comparative linguistics. Structuralism arose first in Europe, and de Saussure was influential for structuralism, for putting synchronic grammar into the foreground, and for conceiving of grammar as connecting form and meaning. Bühler's *Sprachtheorie* (1934) included an early treatment of indexicality and perspective shift. Jespersen made lasting contributions to semantics as well as syntax (1924); while in the Netherlands, Evert Beth was laying foundations (1947, 1963) for the cooperation among logicians and linguists that has made the Netherlands one of the major contributors to the development of formal semantics.

Semantics was rather neglected in early and mid-twentieth-century American linguistics, for several reasons. Early American anthropological linguistics depended on fieldwork, where phonetics came first, then phonology, morphology, perhaps a little syntax, and usually no semantics beyond a dictionary. Another reason was the influence of logical positivism and behaviorism: meaning was viewed as an unobservable aspect of language, not fit for scientific study. And the Chomskyan revolution concentrated on syntax: there was much talk of the creativity of language and of language as a window on the mind, but it was all about syntax, investigating finite recursive mechanisms that could characterize the infinite class of sentences of a natural language, and trying to solve the mystery of first-language acquisition.

In 1954, the philosopher Yehoshua Bar-Hillel wrote an article in *Language* (1954) urging cooperation between linguists and logicians and arguing that advances in both fields made the time ripe for combining forces to work on syntax and semantics together. However, Chomsky immediately replied (1955), arguing that the artificial languages invented by logicians were too unlike natural languages for any methods the logicians had developed to have any chance of being useful for developing linguistic theory. Real cooperation of the sort that Bar-Hillel urged began only after Montague's work.

The first efforts to add semantics to Chomsky's generative grammar were made by Katz and Fodor (1963), who were the first to use the term *compositionality* (although in most of their work they speak rather of *projection rules*), proposing rules that first interpret underlying phrase-markers, bottom-up, and then interpret the result of applying transformations. A little later Katz and Postal (1964) proposed that all semantically relevant information should actually be contained in the underlying phrase-markers and that transformations should preserve meaning. The Katz–Postal hypothesis was adopted in Chomsky (1965) as part of what Chomsky later dubbed "the standard theory," with Deep Structure as the input to semantics.

But very soon the "discovery" of quantifiers spoiled the illusion of meaning-preservingness for many transformations; I illustrate with a few key examples without giving the rules or the structures. In each case the (a) example illustrates the apparently meaning-preserving transformation when the NPs are proper names, but in the (b) example, application of the same rule does not preserve meaning. We will come back to some of these examples in discussing the syntax–semantics interface in formal semantics.

(1) a. John wants John to win $\Longrightarrow$ John wants to win
b. Everyone wants everyone to win $\Longrightarrow$ [!?] Everyone wants to win

(2) a. John voted for John $\Longrightarrow$ John voted for himself
b. Every candidate voted for every candidate $\Longrightarrow$ [!?] Every candidate voted for himself

(3) a. Three is even or three is odd $\Longrightarrow$ Three is even or odd
b. Every number is even or every number is odd $\Longrightarrow$ [!?] Every number is even or odd

The discovery that quantifiers, negation, and conjunctions were not properly interpretable at the level of Deep Structure as conceived in 1965 was one important factor in the genesis of the "Linguistic Wars". Generative Semanticists (Lakoff, McCawley, Ross, and others, cf., Huck and Goldsmith, 1995) responded by making Deep Structure "deeper", closer to "logical form", which for linguists then meant more closely resembling first-order predicate logic. Interpretive Semanticists (Jackendoff, Chomsky) kept the syntax closer to the "standard theory" and added additional interpretive mechanisms at various syntactic levels.

During all this time, the notion of semantic interpretation was in a rather primitive state. Katz, Fodor, and Postal worked with "semantic markers" modeled on phonological distinctive features, treating sentence meanings as bundles of semantic markers. The Generative Semanticists added first-order logic and uninterpreted but supposedly universal predicates and operators such as "CAUSE" and "BECOME". The reaction of philosophers of language was most notably formulated by David Lewis (1970).

> But we can know the Markerese translation of an English sentence without knowing the first thing about the meaning of the English sentence: namely, the conditions under which it would be true. Semantics with no treatment of truth conditions is not semantics. (Lewis, 1970, p. 1)

To linguists, concern with *truth* looked puzzling. Linguists were trying to figure out mental representations that could underlie linguistic competence.

"Actual truth" was (correctly) considered irrelevant, and truth *conditions* were not understood or appreciated.

1.2.2 Semantics in logic and philosophy before 1970

In the meantime great progress was made in semantics in logic and philosophy of language. The greatest foundational figure for formal semantics is Gottlob Frege (1848–1925). He made crucial advances to the analysis of variables and quantifiers, and introduced the distinction between *Sinn* and *Bedeutung*, sense and reference, the precursor of the modern intension–extension distinction. Frege is also credited with the Principle of Compositionality,[1] a cornerstone of formal semantics, and a principle quite universally followed in the design of the formal languages of logic, with a few interesting exceptions.[2]

> The Principle of Compositionality: the meaning of a complex expression is a function of the meanings of its parts and of the way they are syntactically combined.

Further advances were made by Russell, Carnap, and others. Wittgenstein (1922) first articulated the idea that "To know the meaning of a sentence is to know what is the case if it is true" (*Tractatus*, 4.024). Tarski (1902–1983) formalized *model theory* inside set theory and provided the first formal model-theoretic semantics for logical languages (Tarski, 1944; Feferman and Feferman, 2004); his goals concerned metalogic and the avoidance of semantic paradoxes, not semantics itself (Etchemendy, 1988).

Around that time, there was a major dispute within philosophy, the "Ordinary Language" vs. "Formal Language" war, concerning the role of natural language in philosophical argumentation, including the question of whether the analysis of natural language could be a source of philosophical insights, or whether natural language was too unruly and needed to be replaced by a suitably constructed formal language for purposes of exact argumentation. The Ordinary Language philosophers, including late Wittgenstein, Austin, Ryle, and Strawson, were a new generation who rejected the formal approach and urged closer attention to the functions of ordinary language and its uses, including much more attention to language in context, i.e., to pragmatics. In his critique of Russell in "On Referring", Strawson (1950) said, "Neither Aristotelian nor Russellian rules give the exact logic of any expression of ordinary language; for ordinary language has no exact logic." Russell rejected Strawson's critique, but added "I agree, however, with Mr. Strawson's statement that ordinary language has no logic" (1957). It is noteworthy that both sides in this "war" (as well as

[1] Not without some controversy; see Janssen (1983). And see Hodges (2001) for a discussion of the relation between compositionality and contextuality in Frege, and Pelletier (2001) for a third evaluation.

[2] It has been observed in a number of works (I learned it from Tarski, p.c., 1971) that the usual semantics for the quantifiers of first-order logic in terms of satisfaction and assignments is not strictly compositional.

Chomsky) were in agreement that logical methods of formal language analysis did not apply to natural languages.

The response of some formally oriented philosophers was to try to analyze ordinary language better, including its context-dependent features. Within philosophical logic, the foundational work of Frege, Carnap, and Tarski had led to a flowering of work on modal logic and on tense logic, on conditionals, on referential opacity, and on other philosophically interesting natural language phenomena. Quine had rejected modal and intensional notions as incurably unclear, but Kripke (1959), Kanger (1957a,b), and Hintikka (1962) revolutionized the field by providing a model-theoretic possible-worlds semantics for modal logic. And first Reichenbach (1947) and then Prior (1967) made great progress on the development of the logic of tenses, a notorious source of context-dependence in natural languages; Thomason (1996) identifies Prior as an important contributor to "natural language semantics logicism".

Paul Grice (1913–1988) contributed in a quite different way to the eventual resolution of the war. His work on conversational implicatures (Grice, 1975) showed that explanatory pragmatic principles can allow semantics to be simpler, so that the apparent gap between the "logicians' meaning," even in terms of standard, extensional first-order logic, of words like *the* and *if* and *or* and their ordinary-language meaning might be much less than had been supposed. And although not all of his proposals for the semantics of such words have survived, his methodological lesson and his pragmatic principles became highly influential for formal and informal semantics alike. Once his lessons sunk in, it became obligatory in studying semantics to also think about pragmatics, although whether and how pragmatics "belongs in the grammar" has remained controversial for decades (Horn, 2006).

1.2.3 Montague's work

Montague had been an important contributor to these developments in philosophical logic. Montague was a student of Tarski's, and at UCLA was a teacher and then a colleague of David Kaplan, co-authored a logic textbook with his colleague Donald Kalish, and was an active part of a strong logic group. As a logician, Montague built on the Frege–Tarski–Carnap tradition of model-theoretic semantics of logic and developed an intensional logic with a rich type theory and a possible-worlds model-theoretic semantics, incorporating certain aspects of "formal pragmatics", including the treatment of "indexical" words and morphemes like *I, you* and the present tense (Montague, 1968, 1970b). This was accomplished in part by treating both worlds and times as components of "indices", then generalizing from times to "points of reference", that is, complexes of relevant features of contexts, and treating intensions as functions from indices (not just possible worlds) to extensions. He generalized intensional notions such as property, proposition, individual concept, into a fully typed intensional logic, extending the work of Church (1951), Carnap (1956), and Kaplan (1964), putting together the function-argument structure common to type theories since Russell with the treatment of intensions as functions from indices to extensions.

In the late 1960s, Montague turned to the project of "universal grammar", which for him meant a theory of syntax and semantics encompassing both formal and natural languages, a groundbreaking project that became *Montague Grammar*,[3] and to which his last three papers were devoted, with plans for a book-length treatment interrupted by his untimely death in 1971.

That project evidently grew out of his work on the development of a higher-order typed intensional language suitable for doing philosophy. His paper "On the Nature of Certain Philosophical Entities" (NCPE) (Montague, 1969) contains a great deal that can be considered as much a matter of semantics as of philosophy, and foreshadows some of his work in his three final "language" papers. An important passage in that paper with respect to Montague's program occurs on pages 154–156, explaining his change from believing that philosophy should be done in the framework of set theory to believing that it should be done in the framework of intensional logic, and announcing his claim that he has constructed an adequate intensional logic.

> One system of intensional logic now exists which fully meets the objections of Quine and others, which possesses a simple structure as well as a close conformity to ordinary language, and concerning the adequacy of which I believe no serious doubts can be entertained. (Montague, 1969, p. 156)

This big "framework" change in Montague's approach to logic and philosophy is described and discussed in Cocchiarella (1981).

His attitude toward his work on natural language was ambivalent. On the one hand, he considered it worthwhile to demonstrate that "The syntax and semantics of certain not insignificant fragments of English can be treated just as formally and precisely as those of the first-order predicate calculus, and in very much the same manner" (Montague, in Staal, 1969, p. 274). However, at the same time, he asserted that "it would appear more important to extend the scope of constructed systems than to discover the exact rules of natural languages" (Staal, 1969, p. 275). As Thomason (1996) notes, Montague's quest for a "formal philosophy" grounded on his intensional logic remains unfulfilled and possibly quixotic, and his legacy is ironically rather in the "rather easy and not very important"[4] project of the analysis of ordinary language.

[3] The term entered the Oxford English Dictionary in 2002, the first citation being to Rodman (1972), a collection of papers by participants in a seminar taught at UCLA by the author.

[4] This unpublished quotation from Montague's notes, as well as evidence that Montague might have later revised his "rather easy" assessment, is discussed in Partee (2011, 2013).

Montague's work on the formal treatment of natural languages is all in his last three papers, "English as Formal Language" (EFL) (1970a), "Universal Grammar" (UG) (1970b), and "The Proper Treatment of Quantification in Ordinary English" (PTQ) (1973b). The one that had the most impact on linguists and on the subsequent development of formal semantics was PTQ: short, but densely packed (see Partee, 1975, 1997b; Janssen, 1994). Montague Grammar has often meant what Montague did in the fragment in PTQ and the extensions of PTQ by linguists and philosophers in the 1970s and 1980s. But it is the broader algebraic framework of UG that constitutes Montague's theory of grammar.

Before Montague, linguists took as the task of semantics the explication of ambiguity, semantic anomaly, and synonymy: the key questions were how many readings a sentence has, and which sentences share readings. The individuation of "readings" had always been problematic, though, and there was often crucial disagreement about data. Intuitions about "readings" undoubtedly rested in part on judgments concerning truth conditions, but truth conditions were never explicitly discussed. The methods used in early linguistic semantics primarily involved lexical decomposition in terms of *semantic features*, plus hypothesized abstract tree structures displaying scope relations and other aspects of *semantic structure*. The introduction of truth conditions as the basic semantic property of a sentence that a semantic theory should capture profoundly affected the adequacy criteria for semantics and led to a great expansion of semantic research.

Montague's (1970) paper, UG, contains the most general statement of Montague's formal framework for the description of language. The central idea is that anything that should count as a grammar should be able to be cast in the following form: the syntax is an algebra, the semantics is an algebra, and there is a homomorphism mapping elements of the syntactic algebra onto elements of the semantic algebra. In the PTQ grammar for a fragment of English, the syntax is not explicitly presented as an algebra, but if it were transformed into one, the elements would be the analysis trees.

The choice for the semantic elements is totally free, as long as they make up an algebra. The semantic elements, or *semantic values* as they are often called, could be taken to be the model-theoretic constructs of possible-worlds semantics as in Montague's fragments of English and most "classical" formal semantics, or the file change potentials of (Heim, 1982), or the game strategies of game-theoretical semantics, or the simple extensional domains of first-order logic, or hypothesized psychological concepts, or expressions in a "language of thought", or anything else; what is constrained is not the "substance" of the semantics but some properties of its structure and of its relation to syntactic structure. It is the homomorphism requirement, which is in effect the compositionality requirement, that provides the most important constraint on UG in Montague's sense, and it is therefore appropriate that compositionality is frequently at the heart of controversies concerning formal semantics.

Stokhof (2006) summarizes two important characteristics of Montague's theory as defined in UG and illustrated in PTQ:

a. Semantics is syntax-driven, syntax is semantically motivated. (Compositionality)
b. Semantics is model-theoretic.

A methodological principle implicit in Chomskyan syntax in the 1960s, encouraged although not required by the Katz–Postal hypothesis that meaning is determined at Deep Structure, and carried to extremes in Generative Semantics, was the principle that sameness of meaning should be reflected in sameness of syntactic Deep Structure. However, from the perspective of Montague Grammar, sameness of meaning does not require identity at any syntactic level (see Thomason, 1976): semantics is model-theoretic, not representational, not "syntactic".

In formal semantics, the core of sameness of meaning is sameness of truth conditions; and it does not require sameness on any syntactic level for two sentences to end up having the same truth conditions. Thus, formal semantics removed much of the motivation for that aspect of Generative Semantics. Its semantic goals could apparently be met, even exceeded, in a formal semantic approach, offering greater explicitness and compatible with more "conservative", less abstract, syntax. Thus, the rise of Montague Grammar was one factor in the decline of Generative Semantics and the fading away of the linguistic wars.

Details of Montague's analyses have in many cases been superseded, but in overall impact, PTQ was as profound for semantics as Chomsky's *Syntactic Structures* was for syntax. Emmon Bach (1989, p. 8) summed up their cumulative innovations thus: Chomsky's Thesis was that English can be described as a formal system; Montague's Thesis was that English can be described as an *interpreted* formal system.

1.2.4 Other contemporaneous work

While Montague clearly occupies a preeminent position in the history of formal semantics, he did not work in a vacuum. Works that influenced his thinking, as evidenced in his papers and in his seminars from 1967 and later, include, among others, Quine (1960b), Geach (1962, 1967) for puzzles of intensionality; Frege (1892b), Davidson (1965, 1967a, 1970), Kripke (1963), and various works of and/or conversations with Alfred Tarski, David Lewis, David Kaplan, Dana Scott, Rudolf Carnap, Alonzo Church, Yehoshua Bar-Hillel, J. F. Staal, Terence Parsons, and Barbara Partee, and several of his students including Hans Kamp, Dan Gallin, and Michael Bennett.

Independently, on the other side of the country, Donald Davidson and Gil Harman were both at Princeton from 1967 to 1969, interacting intensely, optimistic about the potential fruitfulness of linguistics–philosophy interactions and about the prospects of Generative Semantics, with its underlying structures somewhat resembling the structures of first-order logic. Together they produced some exciting conferences and the influential edited collection (Davidson and Harman, 1972). Davidson was also influential in urging a truth-conditional semantics for natural language, arguing from learnability that a finitely specifiable compositional semantics for natural languages must be possible (Davidson, 1967b). Davidson differed strongly from Montague in wanting to stay with first-order logic and to eschew such model-theoretic constructs as possible worlds and intensions. One of Davidson's contributions to semantics was the idea that the interpretation of most ordinary sentences includes an existentially quantified event argument, making sentences partly analogous to indefinite NPs (Davidson, 1967a); after the work of Terence Parsons (1990), the event argument became widely adopted.

There were major early contributions to formal semantics in Europe starting in the early 1970s. Renate Bartsch had come to UCLA to work with Montague just about at the time of his death; she and I had many fruitful discussions, but much more significant was her collaboration with Theo Vennemann, which began then at UCLA and continued in Germany (Bartsch, 1972; Bartsch and Vennemann, 1972b). Arnim von Stechow was an early and influential contributor to the rise of formal semantics in Germany and Europe, as well as to Generative Grammar and the integration of semantics and syntax (Kratzer et al., 1974; von Stechow, 1974). A number of formal semanticists[5] in other European countries point to von Stechow as the source of their earliest acquaintance with Montague's work. And influential contributions came from C. L. Hamblin in Australia (Hamblin, 1973) and M. J. Cresswell in New Zealand (Cresswell, 1973).

The earliest international conference on formal semantics (construed broadly) of natural language was organized by Ed Keenan at Cambridge University in 1973; eighteen of the twenty-five published contributions (Keenan, 1975) were by European scholars, including Östen Dahl, Hans Kamp, Peter Seuren, John Lyons, Renate Bartsch, Arnim von Stechow, Franz von Kutschera, Carl Heidrich, and Theo Vennemann. The biennial Amsterdam Colloquia, still a major forum for new results in formal semantics, started up in the mid-1970s and became international in the late 1970s. In the 1970s there were four textbooks on Montague grammar published in Germany, the last and best being Link (1979); all four were reviewed in Zimmermann (1981).

Other research that was not "Montague Grammar" in a narrow sense but which also fed into the development of formal semantics included Terence Parsons's combinatorial-based formal semantics of English (1972), David Lewis's influential paper (1970), which included a compositionally interpreted transformational fragment with a categorial grammar base, the work of the New Zealand philosopher and logician M. J. Cresswell (1973), who had

[5] Personal communication from several semanticists in Scandinavia and elsewhere; more details will be included in (Partee, in preparation).

been a participant in UCLA's famous "logic year" in 1967–1968, and the work of the American linguist Edward Keenan (1971a,b).

And there were of course other important early contributors to the development of formal semantics as well (for more on the early history of formal semantics, see Cocchiarella, 1981; Thomason, 1996; Partee, 1997b, 2011; Abbott, 1999; Cresswell, 2006; Stokhof, 2006; Janssen, 2011).

1.3 Central principles, issues, and points of divergence

1.3.1 The Principle of Compositionality and the theory-dependence of its key terms

At the heart of formal semantics are the principle that truth conditions form a core aspect of meaning and the methodologically central Principle of Compositionality.

For Montague, the compositionality requirement was the requirement of a homomorphism between syntax and semantics. The theory spelled out in Montague's UG (Montague, 1970b) requires that a grammar should take the following form: the syntax is an algebra, the semantics is an algebra, and there is a homomorphism mapping elements of the syntactic algebra onto elements of the semantic algebra. Montague's very general and formally very explicit definition leaves a great deal of freedom as to the nature of these algebras. For a logical language, the elements of the syntactic algebra can be the well-formed expressions. However, for a natural language, ambiguity makes that impossible, since the homomorphism requirement means that each element of the syntactic algebra must be mapped onto a unique element of the semantic algebra. So for a natural language, the elements of the syntactic algebra are usually taken to be expressions together with disambiguating structural descriptions, typically trees of some sort.

Differences among approaches can often be traced to three crucial theory-dependent terms in the Principle of Compositionality: "The *meaning* of a whole is a *function* of the meanings of its *parts* and the way they are syntactically combined." We discuss *meanings* in Section 1.3.2, the means by which meanings compose in Section 1.3.3, and *parts*, i.e., *syntax*, in Section 1.3.4, with more on the syntax–semantics interface in Section 1.4. The concept of *function* common to almost all semantic theories is the familiar set-theoretic one, but theories may differ in what further constraints they add on allowable functions.

1.3.2 What are meanings?

David Lewis provided a famous strategy for thinking about what meanings are: "In order to say what a meaning is, we may first ask what a meaning does, and then find something that does that" (1970, p. 22). There are different proposals about what to count as meanings (or as the linguistically relevant aspects of meanings) within formal semantics.

An *extensional language* is one in which compositionality holds for extensions: the extension of the whole is a function of the extensions of the parts and the way they are syntactically combined. In a simple case for such a language, the extension of a sentence is a truth value, the extension of a predicate expression (common noun phrase, simple adjective, verb phrase, predicative prepositional phrase) is a set of individuals; the extension of a proper name or a pronoun can be an individual. (See any formal semantics textbook, such as Gamut, 1991; Heim and Kratzer, 1998; and Chierchia and McConnell-Ginet, 2000).

Natural languages are at least intensional: the extension of the whole in some cases depends on intensions as well as extensions of parts, and the intension of the whole depends on the intensions of the parts.[6]

Within a decade, the importance of context-dependent expressions was increasingly recognized and led to increasing integration of formerly "pragmatic" matters into formal semantics (or "formal semantics and pragmatics"). Kaplan (1979) introduced the *character* of an expression, a function from contexts to intensions, and gave an account on which a sentence like *I am here now* is always true when spoken but is not a necessary truth. Kamp (1981b) and Heim (1982) formalized Karttunen's notion of a *discourse referent* introduced into the local context by the use of an indefinite NP (Karttunen, 1976) (see Brasoveanu and Farkas, Chapter 8) and built on Stalnaker's notion of a *common ground* established and constantly updated during the course of a conversation, resulting in two different but similar theories often collectively referred to as *dynamic* semantics,[7] treating meaning as a function from contexts to contexts. (See Section 1.5 below and Schlenker, Chapter 22.) An alternative conception of dynamic semantics was developed by Groenendijk and Stokhof (1990, 1991) and Veltman (1996), building in part on work by van Benthem, and with further linguistic development by Chierchia (1995a), and others.

6 Because any two sentences with the same truth conditions have the same intension on standard possible-worlds analyses, intensions have often been said to be too weak to serve as meanings. There are various proposals for treating some constructions as *hyperintensional* and making use of a richer concept of *structured meanings* to handle them, an idea that has roots in Carnap's *intensional isomorphism* (Carnap, 1956) and in (Lewis, 1970) and was further developed in the pioneering work of Cresswell and of von Stechow (Cresswell, 1975, 1985; Cresswell and von Stechow, 1982; von Stechow, 1982; see also Duží et al., 2010). Montague formalized *intensions* of sentences as functions from possible worlds and variable assignments to truth values. And more generally, the intensions of all other categories of well-formed expressions are formalized as functions from possible worlds and variable assignments to the corresponding extensions.

7 The common description of the Kamp–Heim approach as involving a dynamic conception of meaning may be challenged (M. Stokhof, p.c.) as a simplification or as misleading. In DRT, at least, it is the "construction rules" that build discourse representations that are dynamic; the model-theoretic interpretation, which involves the embedding of a discourse representation into a model, is static and classical. In the Amsterdam dynamic semantics of Groenendijk, Stokhof, Veltman, et al., classically constructed syntactic descriptions are dynamically interpreted.

In an independent refinement, Barwise and Perry (1983) and Kratzer (1989) argued for replacing possible worlds by (possible) *situations*, which for Kratzer are *parts* of possible worlds, enabling more fine-grained analysis of meanings (see Kratzer, 2011a).

There are other formalizations of what meanings are in contemporary formal semantics; see, for example, Hintikka's game-theoretic approach (Hintikka and Sandu, 1997), "Glue Semantics" (Asudeh and Crouch, 2002). Another important approach is that of of constructive type theory, as developed by Per Martin-Löf and applied to natural language semantics by Aarne Ranta (Ranta, 1995)[8]. See also Pagin, Chapter 3 in this respect.

1.3.3 How do meanings compose?

How are meanings put together? How does the compositional mapping from syntax to semantics work? The question of what sorts of functions are used to put meanings of parts together is inextricably linked to the questions of what meanings are, and of what count as syntactic parts. Frege (1892b) took the basic semantic combining operation to be *function-argument application*: some meanings are construed as functions that apply to other meanings. With a syntax such as categorial grammar providing the relevant part-whole structure, especially in the case of a simple extensional language, Frege's function-argument principle could be enough; with other kinds of syntax, other operations may be needed as well. (See Sailer, Chapter 21.) In the fragment in Montague's PTQ, the simple grammatical relations are all treated as intensional and are all interpreted by function-argument application (the function applies to the intension of the argument to give the extension of the result); some other special syntactic rules, especially ones that are partly "transformation-like," have more complex corresponding interpretation rules. Other possible approaches to meaning composition include unification (Bouma, 1988; Carpenter, 1992) and Glue Semantics, already mentioned. The possibility of type-shifting processes and various kinds of coercion complicates the picture and complicates the definition of compositionality (Pagin and Westerståhl, 2010a,b; Partee, 2007).

Formal semanticists also differ on whether a level of *semantic representation* is hypothesized to mediate between syntax and model-theoretic interpretation. Montague's own work exemplified both *direct model-theoretic interpretation* (1970b) and two-stage interpretation via translation into a language of Intensional Logic (1973b). Many but not all formal semanticists make use of an intermediate semantic representation in some formal language, either as a convenience ("for perspicuity," as Montague put it) or with the hypothesis that it might represent a "linguistically real" level of representation. Either approach can be compositional: a two-stage interpretation procedure is compositional if the syntax-to-semantic-representation mapping

8 I am grateful to Martin Stokhof for bringing Ranta's work to my attention.

rules are compositional and the model-theoretic semantics of the representation language is also compositional. When those conditions are met, the intermediate language is, from a model-theoretic perspective, in principle eliminable. Linguists who hypothesize that it has some psychological reality would still want to keep such a level: it may represent an aspect of the means by which humans compute the mapping between sentences and their meanings. But it is a major challenge to find empirical evidence for or against such a hypothesis.

It is worth noting that it is possible to advocate direct model-theoretic interpretation without being anti-psychologistic, via the notion of *mental models* (Johnson-Laird, 1983). But approaches using mentally represented "formulas" (logical forms, conceptual representations) and computations on such formulas, as advocated by Jackendoff for many years, are preferred by many Chomskyan linguists.

Kamp in his Discourse Representation Theory (DRT) (1981b) proposed Discourse Representation Structures (DRSs) as a *non-eliminable* intermediate level of representation, with claimed psychological reality: Kamp hypothesized that his DRSs could be a common medium playing a role both in language interpretation and as objects of propositional attitudes. Kamp argued against full compositionality; he was challenged by Groenendijk and Stokhof (1991), who argued that a fully compositional *dynamic semantics* could accomplish what Kamp could do with DRT. Muskens (1993) proposed a reconciliation with his Compositional Discourse Representation Theory.

1.3.4 Part-whole structure: syntax

Logicians typically specify the syntax of a formal language as a recursive definition; in that case the requirement of compositionality as homomorphism can be satisfied by giving the semantics in the form of a parallel recursive definition. The "derivation trees" that correspond to the steps in applying a recursive definition become the elements of the syntactic and semantic algebras, and the homomorphism requirement says that each syntactic derivation must be mapped onto a unique semantic derivation.

The simplest linguistic examples take the elements of the syntactic algebra to be (sub)trees generated by a context-free grammar, and semantic interpretation to specify how the interpretation of a given subtree is computed from the interpretations of its immediate "daughter" subtrees; in this case the algebraic conception can be taken as compatible with and an improvement on what Fodor and Katz, and Katz and Postal, were aiming at with their Projection Rules.

Some formal semanticists argue in favor of having a *monostratal grammar* for the syntactic component, that is, a grammar with a single level of syntax and no transformations, such as Generalized Phrase Structure Grammar (GPSG), Head-Driven Phrase Structure Grammar (HPSG), Lexical-Functional Grammar (LFG), Categorial Grammar, Tree-Adjoining Grammar (TAG).

Others who work with a Chomskyan syntax take the syntactic input to the semantic component to be a specified level of semantically relevant syntactic representation called LF (a term meant to suggest "logical form", but defined purely theory-internally).

The relation between the preceding issues and syntax shows up clearly in debates about *direct compositionality*: some linguists argue that a directly compositional model-theoretic semantics can apply to non-abstract surface structures (see the debates in Barker and Jacobson, 2007), without abstract syntactic representations, movement rules, or a level of Logical Form. Advocates of direct compositionality use an enriched arsenal of semantic combining rules, including not only function-argument application but also function composition and a number of type-shifting operators. There may or may not be an inevitable tradeoff between optimizing syntax and optimizing semantics; it is a sign of progress that many linguists work on syntax and semantics with equal concern for both.

1.4 From Montague Grammar to contemporary formal semantics

1.4.1 Issues in combining formal semantics with syntax

The earliest works in Montague Grammar followed Montague's pattern of giving the syntax as a simultaneous recursive definition of expressions of all syntactic categories, and the semantics as a corresponding recursive definition of the interpretations of those expressions. In the first papers by linguists and philosophers, collected in Rodman (1972),[9] the form of the syntax was close to Montague's; Partee took on the challenge of trying to combine Montague Grammar (MG) with Transformational Grammar (TG) (Partee, 1973b, 1975), trying to recast transformational rules into recursive definitions that could be interpreted compositionally. On Partee's approach to the MG–TG combination, a syntactic derivation worked bottom-up with phrase structure rules as the basic building rules and with transformations applying whenever their conditions are met; Partee (1980) suggested that a grammar thus organized might be able to meet a constraint that all generated expressions be well formed, unlike the common practice in then-current transformational grammar to generate tree structures that had to be subjected to obligatory transformational rules to produce well-formed expressions.

The task of putting MG and TG together was made difficult by the fact that within TG, the "building blocks", or "kernel sentences", were closed sentences, while in MG, the syntax includes "indexed pronouns" (Montague's $he_0, he_1, \ldots$), interpreted as variables. (See later uses of PRO, *pro*, and traces in

[9] That first collection resulted from Partee's winter–spring 1972 seminar on Montague Grammar at UCLA, and contains papers by Partee, Bennett, Bartsch, Rodman, Delacruz, and others.

generative grammar.) One of Montague's innovations was the use of lambda abstraction as the central device involved in the interpretation of variable-binding constructions, possible only if well-formed expressions can contain elements interpreted as variables. And one immediate obstacle to synthesis was the existence of various "deletion rules" in TG. In classical TG, (4a) was derived from something like (4b) by "Equi-NP Deletion".

(4) a. Mary was eager to win.
    b. $[_S$ Mary was eager for $[_S$ Mary to win$]]$

But given the principle of compositionality, and given the way MG works by building up the meanings of constituents from the meanings of their subconstituents, this derivation seemed to present a problem. The syntactic derivation uses deletion, but the semantic derivation cannot: there is no permissible operation that would "delete" a piece of a meaning of an already composed subpart. Recall the discussion in Section 1.2.1 of the consequences of analyses like (4b) for sentences like (5a). The presumed Deep Structure (5b) would clearly give the wrong meaning.

(5) a. Everyone was eager to win.
    b. $[_S$ everyone was eager for $[_S$ everyone Tns win$]]$

The MG–TG resolution suggested in Partee (1973b, 1975) was that the "underlying" subject in the embedded sentence should be a bindable variable.[10] Partee followed Montague's line and bound it by lambda abstraction to make a VP type, as in (6a), assuming that the complement of the adjective *eager* is a VP. Others have proposed an S type for the infinitive, with the variable bound by the lambda abstract associated with the higher quantifier, as in (6b). In this very simple example, the VP in (6a) could alternatively just be base-generated and interpreted directly; Partee's "Derived VP rule" was motivated by VPs like *to see herself* or *to be elected*, which she derived transformationally from open sentences like she_0 *sees* her_0*self* and he_1 *elects* her_0.

(6) a. $[\![\text{to win}]\!] = \lambda x[\text{win}(x)]$
    b. alternatively: everyone$'$ $(\lambda x[x$ was eager for $[x$ to win$]])$

In Chomskyan syntax, a corresponding change was eventually made. The first step, influenced by Reinhart (1976, 1983), involved replacing the "identical NP" by the special null element PRO, interpreted as a bound variable. A considerably later step, probably influenced by Heim (1982), introduced functional heads that could be interpreted as abstraction operators rather than assuming that indexed quantifiers themselves were responsible for binding. Other syntactic theories, like GPSG, HPSG, and LFG, and modern versions of Categorial Grammar, were developed after the quantifier and binding issues had become well known, and their design included mechanisms to deal with those problems.

[10] A similar proposal had already been made within Generative Semantics by McCawley (1968b).

There were other obstacles to combining Transformational Grammar and Montague Grammar, since some transformational rules were neither meaning-preserving nor easily reformulated as rules interpretable by a uniformly meaning-changing function, but the problem just described is a good example of an important problem in principle, whose resolution requires rethinking parts of the architecture of one theory or the other. In any case, the goal of combining TG with MG lost some of its urgency as various linguists began to realize that with a powerful semantics to do some of the work, some kinds of transformations – possibly all – might be eliminated.

Dowty (1978) argued in favor of eliminating all "governed transformations" (those whose application depended on the presence of a particular lexical class, such as the *easy*-class of adjectives implicated in the rule of "*Tough*-movement" mapping [structures corresponding to] *It's tough to solve this problem* to *This problem is tough to solve*) and replacing them by lexical rules which in effect transform the argument structure of a given lexical item (with or without some morphological change) and spell out the corresponding change in semantic interpretation.

Gazdar (1982) proposed that all transformations could be eliminated, so that the syntax could be context-free. He and colleagues developed his approach into Generalized Phrase Structure Grammar (GPSG) (Gazdar et al., 1985). Transformations were replaced by meta-rules that extended the grammar; for instance, in place of the passive transformation, a meta-rule specified how for each phrase structure rule generating a phrase containing a transitive verb and an object, plus possibly more constituents, a phrase structure rule should be added generating a corresponding passive verb phrase. And for each such meta-rule, there was a uniform semantic meta-rule mapping the compositional interpretation rules for the original phrase structure rules onto compositional interpretation rules for the derived phrase structure rule. So instead of a transformation mapping active sentences to passive ones, there would be a meta-rule mapping certain VP rules onto other VP rules, with corresponding semantics. This was the first of several proposals for a non-transformational syntax with a compositional formal semantics. Extended Categorial Grammar (Bach, 1981, 1984) was developed around the same time, and HPSG followed soon after (Pollard and Sag, 1994). LFG had been invented a little earlier (Kaplan and Bresnan, 1982); a compositional formal semantics interpretive component for it was proposed by Halvorsen (1983), and in the intervening years there have been other proposals such as the earlier mentioned Glue Semantics.

1.4.2 Case study: noun phrases, quantifiers, and relative clauses

Much of the discussion in this article has been at an abstract level; in this section we will look at some examples that illustrate a number of issues.

One of the reasons that so many philosophers and linguists had agreed earlier that linguistic structure and logical structure were very different was the apparent mismatch between the syntax and semantics of noun phrases (NPs).[11] Russell considered it an illogicality of English that expressions semantically so different as *Jones*, *a philosopher*, *every student*, *no man*, and *the king* have largely the same syntactic distribution,[12] and thus evidently belong to the same syntactic category (NP).

A major legacy of PTQ was the very important and influential analysis of noun phrases as uniformly denoting generalized quantifiers. Part of the appeal of this analysis for linguists was that it captured the important semantic differences among NPs headed by different determiners, as in generative semantics treatments, while at the same time giving all NPs a similar syntactic structure and an interpretation of the same semantic type, interpreting them all as generalized quantifiers, denoting sets of properties of entities (see Westerståhl, Chapter 7). Because most linguists had earlier known nothing about type theory, certainly nothing about generalized quantifiers, those who wanted to capture meaning at Deep Structure had been led to posit abstract deep structures that resembled first-order logic; dependence on first-order logic had made it impossible for linguists to imagine giving an explicit semantic interpretation for *the* or *a/an* or *every* or *no* that didn't require decomposition into formulas with quantifiers and connectives, more or less like the translations one finds in logic textbooks. The Generative Semanticists embraced such structures and made underlying structure look more like first-order logic (Lakoff, 1971a,b; McCawley, 1970), while Chomsky and Jackendoff rejected putting such logical decompositions into the syntax and devised various proposals for how some sort of semantic component could interpret the combination of deep and surface structure (Chomsky, 1971; Jackendoff, 1972). One can speculate that the rift might never have grown so large if linguists had known about generalized quantifiers earlier; the productive teamwork of Barwise and Cooper (1981) is a classic early example of how formal properties and linguistic constraints and explanations can be fruitfully explored in tandem with the combined insights and methodologies of model theory and linguistics, and generalized quantifiers have continued to be a fertile domain for further linguistically insightful work exploiting formal tools (Peters and Westerståhl, 2006; Szabolcsi, 2010; Keenan and Paperno, 2012).

In recent decades the differences among different noun phrase interpretations, including differences among referential, predicative, and quantificational uses, have led many semanticists to a less uniform treatment of the semantics of NPs, to the exploration of type-shifting mechanisms to help keep the best properties of a uniform analysis while doing justice to the apparent flexibility of natural language interpretation (Partee, 1986; Hendriks, 1993; Szabolcsi, 1997), and to innovative proposals for many aspects

[11] I use the older term NP in a broad sense, to include the contemporary syntactic categories NP and DP.

[12] If I say *Scott was a man*, that is a statement of the form "x was a man", and it has *Scott* for its subject. However, if I say *the author of Waverley was a man*, that is not a statement of the form "x was a man" and does not have *the author of Waverley* for its subject. (Russell, 1905, p. 488)

of NP (or DP) interpretation. Recent and current work focuses on such topics as the mass-count distinction, plurality, weak and strong quantification, indefinites, vagueness and gradability among modifiers and quantifiers, modal and temporal aspects of NP and DP interpretation, and more. (See Dekker and Zimmermann, Chapter 6; Westerståhl, Chapter 7; Brasoveanu and Farkas, Chapter 8; Nouwen, Chapter 9; and Cohen, Chapter 10.) Quantification and related issues in the interpretation of NPs and DPs have also proven to be extremely fertile ground for cross-linguistic and typological studies in formal semantics (Bach et al., 1995; Chierchia, 1998b; Kratzer, 2005; Matthewson, 2001; von Fintel and Matthewson, 2008).

Here we give an illustration of the methods of formal semantics and their impact on the resolution of the "mismatch" between logical and linguistic structure by considering one aspect of the analysis of restrictive relative clauses like *that Pat had lost* in (7a) and (7b) and their interaction with the semantics of various quantifiers and determiners.

(7) a. Mary found a hat that Pat had lost.
 b. Mary found every hat that Pat had lost.

In the 1960s, there were debates about whether the relative clause combines with the common noun phrase (today's NP), as in structure (8), or with the full DP *a hat, every hat*, as in structure (9).

(8) Mary found [$_{DP}$ a/every [$_{NP}$ [$_{NP}$ hat][that [Pat had lost ___]]]]

(9) Mary found [$_{DP}$ [$_{DP}$ a/every [$_{NP}$ hat]][that [Pat had lost ___]]]

There were also debates about the semantics of the relative clause, with some arguing that in (7a) *that Pat had lost* means *and Pat had lost it*, whereas in (7b) it means *if Pat had lost it,* creating tension between the uniform surface structure of *that Pat had lost* in (7a) and (7b) and the very different "underlying" semantic interpretations posited for them (see Stockwell et al., 1973), inspired by the structure of their translations into first-order logic, as in (10a) and (10b).

(10) a. $\exists x(\text{hat}(x)\ \&\ \text{lost}(\text{Pat}, x)\ \&\ \text{found}(\text{Mary}, x))$
 b. $\forall x((\text{hat}(x)\ \&\ \text{lost}(\text{Pat}, x)) \rightarrow \text{found}(\text{Mary}, x))$

The formal semantics perspective suggests searching for a unitary syntax and meaning for *that Pat had lost* and locating the semantic difference between (7a) and (7b) in the semantics of *a* and *every*. The solution (due to Quine (1960b) and Montague (1973b)) requires structure (8): the noun and relative clause denote sets, and their combination denotes the intersection of those two sets. Then the phrase *hat that Pat had lost* denotes the set (11a), whose characteristic function is denoted in the lambda-calculus by (11b).

(11) a. $\{x : x \text{ is a hat and Pat had lost } x\}$
 b. $\lambda x.\text{hat}(x)\ \&\ \text{lost}(\text{Pat}, x)$

Different theories of the semantics of determiners give different technical implementations of the rest of the solution, but that first step settles both the syntactic question and the core of the semantics. Nouns and common noun phrases (NPs) denote sets (or their characteristic functions), and restrictive relative clauses also denote sets (or their characteristic functions); in extensional type theory, they are both of type $\langle e, t\rangle$. Restrictive relative clauses uniformly combine with an NP to give a new NP; the semantics is just set intersection (12) or its equivalent in the lambda calculus as shown above in (11b).

(12) $\|[_{\text{NP}}\ \text{NP REL}]\| = \|\text{NP}\| \cap \|\text{REL}\|$

In the treatment of DPs as generalized quantifiers, the determiner or quantifier is interpreted as a function that applies to a set and gives as a result a generalized quantifier of type $\langle\langle e, t\rangle, t\rangle$, a set of sets of individuals.[13] In the classic treatments of Montague and of Barwise and Cooper, the interpretation of a DP of the form *a NP* is the set of all those sets that have a non-empty intersection with the *NP* set, and the interpretation of a DP of the form *every NP* is the set of all subsets of the set denoted by *NP*.

As a result, sentence (7a) asserts that the set of hats that Pat had lost and the set of hats that Mary found overlap; (7b) says that the set of hats that Pat had lost is a subset of the set of hats that Mary found. Thus the apparent difference in the interpretation of the relative clause in the two DPs turns out to be the predictable result of the semantic difference between the two determiners; there is no need to give the relative clause a non-uniform interpretation, and no reason to give the DPs syntactic structures resembling the formulas of first-order logic. See Partee (1995) for a fuller argument, and Barwise and Cooper (1981) for a fuller treatment of the classical formal semantics of determiners.

1.4.3 Varieties of syntax and semantics combinations

As noted above, formal semantics can in principle be combined with many kinds of syntax, but different syntactic frameworks may require differences in how the semantics is structured if compositionality is to be observed. We illustrate with a thumbnail review of how quantifier scope ambiguities have been handled in a number of different approaches, omitting most details.

Quantifier scope ambiguity is a major challenge for compositionality. A sentence like (13) is semantically ambiguous, but there has never been much evidence for it being syntactically ambiguous; the challenge is to try to find an analysis which is both compositional and syntactically well motivated.

[13] Within generalized quantifier theory, this functional treatment of determiners can be equivalently replaced by a treatment of determiners as denoting a relation between two sets; the two approaches are interdefinable. The relational interpretation is often logically more perspicuous, the functional treatment more faithful to natural language compositional structure.

(13) Every student read one book.

There were at least six kinds of solutions proposed from the 1960s to the 1980s, even before the introduction of choice functions and various non-quantificational analyses of indefinites, and in the ensuing decades more proposals have been made than I can list.[14]

Generative Semantics

The first serious attempts to account for quantifier scope ambiguity in generative grammar came from Generative Semantics; there was great progress in uncovering some of the principles that govern possible quantifier scope, bound variable anaphora, and related phenomena. Classic works include Bach (1968); Lakoff (1971b); McCawley (1970). Generative Semanticists proposed underlying structures that looked similar to the structure of first-order logic, plus a transformation of Quantifier Lowering so that a quantifier that starts as a sentence operator can end up as a determiner on an NP. The actual data about scope possibilities were controversial, as pointed out by Carden (1976), who was an early advocate of and pioneer in experimental methods in semantics. The perceived need to constrain derivations so that scope in English corresponds to surface c-command (now considered incorrect for English but probably correct for some languages) led to transderivational constraints (Lakoff, 1973), observed by Langendoen (2001) to be an early example of optimality-theoretic-like devices.

Interpretive Semantics

Interpretive Semanticists, led by Jackendoff and Chomsky, maintained an "autonomous syntax" and argued that different semantic phenomena were to be accounted for at various different syntactic levels: argument structure is determined at Deep Structure, but quantifier scope and variable binding may depend on structures at various levels, possibly including surface structure. Classic works include Chomsky (1971); Jackendoff (1972). Cooper and Parsons (1976) showed how a basic version of the scope mechanisms of Generative Semantics, Interpretive Semantics, and Montague Grammar (see below) were intertranslatable.

Montague's Quantifying-In rule

Montague's rule-by-rule approach is illustrated by the rule of "Quantifying-In" in Montague (1973b), which combines an NP with a sentence *S* by

[14] Martin Stokhof asks how this proliferation of proposals sits with the assumed empirical nature of the problem. Indeed, the quantifier scope problem is puzzling precisely because there is no independent debate about the syntax; in this way it differs from constructions for which the demands of compositionality can help to constrain choices among syntactic analyses, as with the attachment of relative clauses or the internal structure of comparative constructions. The choices in this case are between different kinds of theoretical apparatus in the syntax and semantics, and evaluation is of necessity theory-wide more than construction-specific.

substituting that NP for an indexed pronoun (interpreted as a variable) in *S* and substituting appropriate pronouns for further occurrences of the same indexed pronouns. The given NP is semantically interpreted as a generalized quantifier, and that generalized quantifier takes as argument the property expressed by a representation obtained by lambda-abstracting over the corresponding variable in the formula corresponding to *S*. For sentence (13), there are different derivations that differ in the order in which the two NPs are quantified into the structure, with correspondingly different scopes in the semantics. On this approach, a single surface syntactic structure may be derived via distinct derivations; compositionality is homomorphism between syntactic and semantic derivations, not between some levels of syntactic and semantic representations. But as Cooper and Parsons (1976) showed, one could algorithmically convert a Montague-style analysis into a Generative Semantics or Interpretive Semantics analysis, and vice versa (in this particular domain).

Cooper storage

Robin Cooper (1975) proposed an approach that would treat sentence (13) as syntactically unambiguous while analyzing it as semantically ambiguous, and maintaining a quasi-compositional semantics. His idea was to amend the syntax–semantics interface so as to non-deterministically derive a *set* of interpretations for each syntactic structure; interpretation was compositional apart from the element of non-determinism. In the process of semantic interpretation (bottom-up, like the syntactic derivation), when you hit a quantifier phrase, you optionally "store" it, and then you may "retrieve it" from storage when you hit a suitable higher node, such as an S or a VP, at which point you interpret the combination of the NP with the S or VP as in Montague's treatment. Scope islands represent points in the derivation where the storage register must be empty. It is of interest that the monostratal syntactic theory GPSG (Gazdar et al., 1985) uses a context-free grammar with a semantics that is quasi-compositional in just this way: straightforwardly compositional but with the use of Cooper storage to interpret sentences like (13).

Quantifier Raising

Later versions of Chomskyan generative grammar added a syntactic level of "LF" or "Logical Form", intended to provide the syntactic input to semantic interpretation. One early proponent of such a level was Robert May (May, 1977, 1985). His syntactic rule of Quantifier Raising, roughly inverse of the Generative Semanticists' Quantifier Lowering, produces a derived syntactic structure in which the various quantifiers are adjoined to the clause that represents their immediate scope. In this and a number of other respects, the LF approach may be approximately regarded as "Generative Semantics upside down".

Type-shifting

David Dowty, whose dissertation followed the Generative Semantics approach but who soon became a leading Montague Grammarian and formal semanticist, suggested in the 1970s that many transformations, especially "governed" ones, should be eliminated and replaced by lexical rules (Dowty, 1978, 1979). This is a very early example of the idea that much of the "grammar" is really contained in the lexicon, and rules that map lexical items onto related lexical items can often be interpreted semantically in terms of diathesis changes. Herman Hendriks (Hendriks, 1988) applied this perspective to quantifier scope ambiguity. His analysis does not require any "movement"; he derives alternative readings via type-shifting of verbs and other functors so as to change relative "function-argument command" relations, extending the kinds of "function-argument flip-flop" shifts introduced by Partee and Rooth (1983). Relative scope is then reflected in local function-argument hierarchical structure rather than requiring some level with attachment to higher S or VP nodes. Using a type-shifting approach to quantifier ambiguity rather than movement rules is one good example of direct compositionality, as discussed in Section 1.3.4.

Underspecification

For Montague, relative scope was captured at the level of derivation trees. Muskens (2004), influenced by work in computational linguistics on underspecification of the parsing process, and by Reyle's work (1993) on underspecification in Discourse Representation Theory, takes that idea a step further to provide a formalism that underspecifies syntactic and semantic ambiguity analogously, with the help of descriptions in the object language. Muskens provides underspecified derivation trees with constrained possibilities for how they may be completed. Each corresponding complete derivation tree generates the given sentence with one of its possible readings. One of the appeals of this approach, not so far taken up in the psycholinguistic literature as far as I know, is its potential for solving the problem of the "psychological reality" of quantifier scope ambiguity. Not only is there no perceived syntactic ambiguity in a sentence like (13), but there is little evidence of the kind of combinatorial explosion of ambiguity that is otherwise predicted for sentences with more than two quantifiers, and little evidence that ordinary speakers are very sensitive to the large numbers of quantifier scope readings that linguistic analyses have classically predicted. Underspecification might very well be a psychologically as well as computationally reasonable approach: the information is "there", but it need not always be "computed" in actual processing.

Pseudoscope

All of the approaches discussed above were designed to account for quantifier scope ambiguity in its "classical" form, with the distinct readings the same as in standard predicate logic. The differences all concerned how the syntax–semantics interface works to generate the sentences and derive the readings. But starting in the 1980s, with some even earlier suggestions, the nature of the readings was challenged, particularly but not only for indefinite NPs like *a book*. The relation between semantic wide scope and semantic or pragmatic notions of *specificity* was questioned by linguists in several frameworks (Fodor and Sag, 1982), and the idea that indefinite NPs are always to be interpreted via existential quantifiers was particularly strongly challenged in the work of Kamp and Heim discussed in Section 1.5.2 below. The importance of non-quantificational analyses of indefinites was emphasized in Kratzer (1998b); see also Brasoveanu and Farkas, Chapter 8.

1.5 The increasing role of context: formal semantics and pragmatics

1.5.1 Early views on the autonomy of context-independent semantics

The term *pragmatics* is due to the philosopher and semiotician Charles Morris (1938). Within semiotics, the general science of signs, Morris distinguished three branches: syntactics (now syntax), the study of "the formal relation of signs to one another"; semantics, the study of "the relations of signs to the objects to which the signs are applicable" (their designata); and pragmatics, the study of "the relations of signs to interpreters" (Morris, 1938, p. 6). Semantics in the work of Formal Language philosophers such as Russell is pure semantics, just as is the semantics of first-order logic; no consideration was paid to indexicals or demonstratives. The need for attention to context-dependence in interpretation was one of the concerns of the Ordinary Language philosophers.[15] One of the first aspects of context-dependence on which logicians made progress was tense, where Prior and Reichenbach were pioneers. And as noted in Section 1.2.3, Montague was an important contributor to these developments, developing a higher order typed intensional logic that unified tense logic and modal logic, and more generally unified "formal pragmatics" with intensional logic.

In early Montague Grammar (e.g. as reported in Partee, 1984a), context-dependence was recognized and treated by the use of free variables. Montague's own PTQ included indexed pronouns like he_3; these were normally replaced by ordinary gendered pronouns in the course of a derivation as part of some rule that involved variable binding, but they could also remain

15 As Martin Stokhof has reminded me, the kind of context-dependence of interpretation that Ordinary Language philosophers were concerned with was much wider ranging than the type of context-dependence that is exhibited by indexicals. I neglect the deeper issues here.

free, in which case it was suggested that they could provide the interpretation for pronouns without antecedents (demonstratives, indexicals, and anaphoric pronouns without sentence-internal antecedents), to be interpreted by a variable assignment considered as part of a context of use. Other early examples of "free variables" to be interpreted via assignment functions coming from the context of use came from work on tense and aspect that appealed to one or sometimes two or more temporal indices corresponding to "now" and possibly to additional "reference times" (Kamp, 1971, 1979; Vlach, 1973). Implicit arguments were often treated as covert free variables, and a free relation variable was suggested as part of the interpretation of genitive constructions like *Mary's team* (Barker, 1995; Partee, 1997a).

In such work, the assumption was that the output of semantic interpretation is something like a Kaplanian "character," a function from contexts to an intension. This makes the semantics autonomous in the sense that the compositional interpretation process is context-independent, and a complete sentence can be interpreted semantically, and then "handed over" to a pragmatic component to fill in the values of the context-dependent variables. For tense and other indexical expressions, such an approach seems perfectly appropriate: we understand the invariant meaning of *I am alone here now*, and we know how to take contextual information to fill in the values of speaker, time, and place to arrive at a specific proposition.

But by the early 1980s, evidence of more complex interactions between semantic interpretation and context-dependence was accumulating to the point where Lewis's dictum, "In order to say what a meaning is, we may ask what a meaning does, and then find something that does that" (1970, p. 22), called for considering some aspects of context-dependence, traditionally thought of as pragmatics, as integral parts of meaning. What is generally referred to as *dynamic semantics* was a first result.

1.5.2 The beginnings of dynamic semantics

A landmark innovation in the integration of context-dependence into semantics came with the dynamic semantics[16] of Kamp (1981b) and Heim (1982). Consider the contrasting mini-discourses in (14) and (15):

(14) A baby was crying. It was hungry.

(15) Every baby was crying. #It was hungry. ("#" means "anomalous".)

On the Kamp–Heim theory, an indefinite NP like *a baby* in (14) introduces a "novel discourse referent" into the context, and the pronoun *it* in the second sentence of (14) can be indexed to that same discourse referent, whose "life span" can be a whole discourse, not only a single sentence. The discourse

[16] An even earlier example of interpretation via a context that is systematically built from denotations of expressions can be found in Groenendijk and Stokhof (1979).

referent introduced by an essentially quantificational NP like *every baby* in (15), however, cannot extend beyond its clause, so the pronoun *it* in (15) is anomalous. The Kamp–Heim theory also includes an account of the famous "donkey"-sentences of Geach, variants of which are given in (16a) and (16b).

(16) a. If a farmer owns a donkey, he always beats it.
b. Every farmer who owns a donkey beats it.

These sentences had previously resisted compositional analysis, including with the tools of Montague Grammar and its early extensions. On Kamp's and Heim's theories, the indefinite *a donkey* introduces a *discourse referent* into the local context, but has no quantificational force of its own; it ends up being bound by the "unselective quantifiers" *always* in (16a) and *every* in (16b). The theories involve the interdependent areas of quantification and anaphora, and the relation of sentence semantics to discourse semantics and pragmatics, giving rise to much new work in these areas. See Brasoveanu and Farkas, Chapter 8.

1.5.3 Further developments in formal pragmatics and semantics

In subsequent work in formal semantics, the treatment of context-dependent phenomena has been a central concern. Other aspects of formal pragmatics such as the treatment of presupposition and focus-sensitivity have also long been recognized as central to the study of meaning, so that "formal semantics and pragmatics" has increasingly come to be seen as a single field, as described in Kadmon (2001) and as evidenced by the online journal *Semantics and Pragmatics* founded in 2007. The integration of pragmatics and semantics has been further supported with arguments that the interpretation of pragmatic implicatures occurs interspersed with semantic interpretation (Chierchia, 2004).

Information structure has also played an important role in the development of formal pragmatics; notions such as topic, focus, presupposition, and discourse structure have been central concerns of linguists and philosophers of many different theoretical inclinations since before Montague's work, and have loomed large in discussions of pragmatics and semantics and the border between them (see Beaver, 1997; Karttunen and Peters, 1979; Roberts, 1998; Rooth, 1992; von Heusinger and Turner, 2006). The formalization of Gricean implicatures and Potts's (2005) proposal to treat conventional implicatures as part of semantics have also led to active research areas.

Semantics and pragmatics are both involved in recent work on Optimality-theoretic semantics and bidirectional OT, as well as in game theoretic approaches; these and other approaches to formal pragmatics are not well represented in this book, but see Hintikka and Sandu (1997), Chierchia (2004), Benz et al. (2005), Blutner et al. (2006), von Heusinger and Turner (2006). (See also Schlenker, Chapter 22.)

1.6 Formal semantics and psychology: the Frege–Chomsky conflict

The relation of linguistics to psychology is nowhere more controversial than in semantics. While it is easy enough to argue that the syntax of a person's language is directly a function of what is in that person's head, the parallel claim for semantics is highly controversial. The clash between Frege and Chomsky on the issue of "psychologism" and the notion of semantic competence has led to a conflict in the foundations of formal semantics, sometimes expressed as the question of whether semantics is a branch of mathematics or a branch of psychology (Partee, 1979, 1988b; Thomason, 1974).

Frege, whose ideas were part of the foundation of Tarski's and Montague's work, took an anti-psychologistic view of meanings, and so did many other logicians and philosophers, including Russell (sometimes), Tarski, Carnap, and Montague. Their tradition of "objective" (though abstract) meanings contrasts with the psychologistic view of meanings "in the head" (Fodor, Lakoff, Jackendoff, and all psychologists). The psychologistic view fits into the Chomskyan tradition of focusing on linguistic competence, defined in terms of the implicit knowledge of a native speaker.

Most formal semanticists who are linguists are very much concerned with human semantic competence. Some formal semanticists have advocated following David Lewis (1975b) in distinguishing semantics from knowledge of semantics, making semantic competence interestingly different from syntactic competence (Partee, 1988b).

In recent decades the question of whether meanings are "in the head" has taken an interesting turn as a result of work in the philosophy of mind. The early arguments by Kripke and Putnam (Kripke, 1972; Putnam, 1975) against a purely "internalist" account of meaning were arguments based on a narrow view of psychological states common at the time, a view later epitomized by Fodor's *methodological solipsism* (1980). However, philosophers working on the philosophy of mind in subsequent decades have increasingly argued that much of psychology, including perception as well as belief and other psychological states, needs to be viewed relationally, concerning the individual and her environment (Burge, 1992, 2003; Stalnaker, 1989). As Stalnaker puts it, meanings may be "in the head" in the way that footprints are "in the sand"; it's a perfectly reasonable way of speaking, but a footprint clearly isn't a footprint without a certain relation to causal history, and meanings probably aren't either. What is semantic competence? For formal semanticists, it is common to take the fundamental characterization of semantic competence to involve knowledge of truth conditions: given a sentence in a context, and given idealized omniscience about the facts concerning some possible situation, a competent speaker can judge whether the sentence is true or false in that situation. From that basic competence, allowing idealizations about computational capacity, it follows that a competent native speaker can also make judgments about entailment relations between sentences; so idealized semantic competence is widely considered to consist in knowledge of truth conditions and entailment relations of sentences of the language.

Many linguists have resisted the relevance of truth conditions and entailment relations to natural language semantics, and some still do. Some of the objections to truth conditions are countered by arguing that part of human semantic competence is the matching of sentences with their truth conditions relative to possible worlds (including fictional worlds), with no necessary reference to the "actual world".

Entailment is a central semantic concern in logic and remains so in formal semantics. Given the distinction between meaning and knowledge of meaning, there is no contradiction between taking entailment relations as central to meaning while acknowledging that human language users are not logically omniscient and hence do not always know whether a given sentence of their language entails another. In this sense it may not be unreasonable to say that speakers can't know their language; logical fallibility may be considered a sort of "performance limitation". The real problem arises if the semantic value of a proposition is taken to be its truth conditions, and propositions are analyzed as the objects of verbs like *believe*; then we get the unwelcome conclusion that sentences with the same truth conditions should be substitutable in belief-contexts. This is the problem of *hyperintensional contexts* (see Pagin, Chapter 3). And it is this problem that has motivated richer notions of meaning such as the structured meanings mentioned earlier.

Cognitive semanticists replace concern with logical entailment by concern with human inference; formal semanticists see the relation of entailment to actual human inference as indirect. However, semanticists of many stripes agree about the importance of revising the formal logics invented by logicians to model the "natural logic(s)" implicit in the semantics of natural languages.

A number of linguists still think of semantics in terms of a "level of representation" of expressions analogous to a syntactic or phonological level. A representational view of semantics is quite congenial to the popular computational theory of mind. But David Lewis's objection that semantics without truth conditions is not semantics remains in force, so that formal semanticists consider such representational views at best incomplete. The contrasting model-theoretic view that is dominant in formal semantics takes semantic interpretation to relate expressions to elements of models (possibly mental models; see Johnson-Laird, 1983) defined in terms of constituents such as possible situations, entities, properties, truth values. Whether some level of representation plays an intermediate role in interpretation, as in the two-stage method of interpretation discussed in Section 1.3.3, remains an open question that so far is not obviously an empirical one.

For further issues in the relation of formal semantics to cognitive science, see Baggio, Stenning and van Lambalgen, Chapter 24.

1.7 Other issues

1.7.1 Natural language metaphysics, typology and universals

The issue of "Natural Language Metaphysics" (Bach, 1986b) is an important foundational area that connects cognitive issues with formal semantics and linguistic typology. What presuppositions concerning the constitution and structure of the world as humans conceive it are built into human languages, and how, and which are universal? These questions may concern both semantic structure and semantic content, from the semantic difference between nouns and verbs to the content of color terms or whether time is discrete or continuous. Their investigation may challenge the lines between semantic knowledge and other kinds of knowledge. Formal semantics, following the logical tradition, initially employed relatively "austere" model structures; recent investigations, particularly into lexical semantics, have led to richer model structures.

Formal semantics has steadily expanded its scope to include work on a wide variety of languages, and semantic fieldwork is an increasingly active and well-developed field. Semanticists have made significant contributions in recent decades to the study of linguistic universals and linguistic typology (Bach et al., 1995; Bittner, 1994; Keenan and Paperno, 2012; Matthewson, 2010; von Fintel and Matthewson, 2008). Typological investigations, especially but not only in the domains of quantification and of tense, aspect and mood, have included the distribution of nominal vs. adverbial quantification, the semantics of languages that lack a determiner category, and the range of tense and aspect systems. Recent work on the formal semantics of sign languages has led to enriched perspectives on the semantics of demonstratives, variable binding, propositional attitudes, quotation, and other domains (Quer, 2005; Schlenker, 2011e).

1.7.2 Experimental, corpus-based, and computational formal semantics and pragmatics

Respected early work on applications of formal semantics to computational linguistic tasks included some in North America (Gawron et al., 1982; Halvorsen, 1983; Hobbs and Rosenschein, 1978; Schubert and Pelletier, 1982) and some in Europe (Cooper, 1987; Hirst, 1986; Scha, 1976). One of the most successful and large-scale efforts was the Rosetta project led by Jan Landsbergen at Philips Eindhoven in the 1980s (Rosetta, 1994), which grew out of earlier work by Landsbergen and by Scha. Recently, there have been advances in methods for making formal semantics computationally tractable, and interest in computational formal semantics has increased to the point that there are textbooks and courses in the field (Blackburn and Bos, 2003, 2005; Bunt and Muskens, 1999). A few companies have begun to offer computational linguistic products that use formal semantics and others are exploring the possibility of doing so. For some kinds of natural language processing problems, such as the solving of the kinds of logic puzzles found on the Graduate Record Exam (GRE), formal methods can offer important advantages and have been implemented (Lev et al., 2004). Connecting computational linguistics, psychology, and formal semantics, there is current research aimed at combining the best of statistical/probabilistic and formal approaches, exemplified by the work of Joshua Tenenbaum's Computational Cognitive Science group at the Massachusetts Institute of Technology (Tenenbaum et al., 2011).

There has always been an interest in acquisition and processing of semantics, often together with syntax, and in recent decades there has been a significant amount of research in these areas specifically connected with formal semantics and pragmatics (see, for instance, Chambers et al., 2002; Chierchia et al., 2004; Crain et al., 1996; Crain and Thornton, 2011; Frazier, 1999; Papafragou and Musolino, 2003; Philip, 1995). The emerging area of "experimental pragmatics" is represented by (Noveck and Sperber, 2007; Sauerland and Yatsuhiro, 2009).

Computational and experimental methods in and applications of formal semantics and pragmatics are developing very quickly, and neither this introductory chapter nor this handbook is pretending to try to do justice to them.

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2

Lexical semantics

James Pustejovsky

2.1 Introduction

Lexical semantics is the study of what words mean and how their meanings contribute to the compositional interpretation of natural language utterances. The lexicon can be seen as that component of the grammar that encodes both the information required for composition in the syntax and the knowledge for multiple levels and types of semantic interpretation. Lexical entries are richly structured objects that act as triggers both to compositional operations and to entailments and implicatures in the context of larger discourses. Because any semantic interpretation requires access to knowledge about words, the lexicon of a grammar must provide a systematic and efficient way of encoding the information associated with words in a language.

Four key questions arise when determining how to model the meanings conveyed by words:

(i) What are the semantic components that constitute word meaning?
(ii) How are word meanings differentiated and how are they related to each other?

(iii) How does the meaning of individual words drive the compositional process to make semantically coherent sentences?
(iv) When is a component of word meaning considered "lexical" rather than "world" knowledge?

As the linguistic phenomena associated with lexical semantics become better understood, several theoretical assumptions have emerged across most current models of word meaning. These can be summarized roughly as follows:

- Lexical meaning involves a kind of componential analysis, either through predicative primitives or a system of types.
- The selectional properties of words must be explained in terms of the lexical semantics of predication.
- An understanding of the semantics of nouns and the contribution that verbal arguments play in composition is crucial for an adequate model of how lexical semantics contributes to compositionality.

As we will see below, the first point makes an explicit connection between predicate decomposition theories (such as Lakoff, 1965/1970; Levin and Rappaport-Hovav, 1995) and type-theoretic approaches to lexical semantics (Dowty, 1979; Pustejovsky, 1995; Davis and Koenig, 2000; Asher and Pustejovsky, 2006; Asher, 2011). This in turn directly influences the manner in which selectional constraints are encoded. Finally, we will observe the central role of Aktionsarten and event typing in the determination of sentence meaning in composition.

There are essentially four strategies to lexical specification that have been adopted in the literature. These approaches can be defined in terms of how, or whether, they provide an intermediate level of interpretation from expressions in the object language to their denotations in the model. The interface defines the logical forms associated with lexical items in the language, and it is these expressions which are interpreted in the model.

The four approaches can be defined as follows:

Atomic predication: No interface language is provided, and there is direct interpretation of an object expression into the model.

Relational models: The interface is a relational structure, which is interpreted in the model.

Feature-based decomposition: Component-based features are used to classify an expression in the object language into distinct concepts in the model.

Structural decomposition: Component-based features are organized as a graph structure, with associated compositional interpretations in the model.

Atomic predication refers to non-decompositional approaches to lexical semantic interpretation, such as the early type-theoretic semantics of

Montague (1974), where the lexical items are primitives in the object language, or the "language of thought" proposed by Fodor (1975).

This view assumes a very tight coupling between the lexical semantics of a word and the syntactic projection associated with it. One consequence of this position is that there are as many lexical entries for a word as there are senses for it in the object language.

Relational models also start with the assumption that words are treated as primitives, but unlike atomic predication theory, they can have arbitrarily complex relational structures that facilitate semantic inferences. Such approaches are not as strict about introducing arguments that are visibly expressed in the syntax of the language, as is done with atomic predication models. Perhaps the best-known example of this strategy is Davidson's addition of the event variable to action predicates (Davidson, 1967a), as well as most subsequent work assuming an event variable for eventuality predicates in language. Computational models for linguistic inference also often invoke this strategy in order to perform reasoning within established logical systems. Hobbs et al. (1993), for example, working within a framework of first-order abductive inference, adds any additional parameters to the argument structure of a predicate that are needed for an inference.

Feature-based decomposition has been used for discriminative analysis of natural language semantics since Nida (1949), and then, significantly in the 1960s, when the Katz and Fodor (1963) and Katz and Postal (1964) models within early generative grammar gained currency within the field. All expressions in the object language are decomposed into sets of binary-valued features, distinguishing concepts such as gender, number, age, marital status, and so on. Recently, some of these ideas have come back into vogue, where vector-based representations of word meaning have emerged as a way to handle some long-standing problems in the computational interpretation of language. These distributional semantic models utilize far more sophisticated techniques for identifying word distributions and computing similarity and relatedness with them (Schütze, 1993; Schütze, 1995; Landauer and Dumais, 1997; Padó and Lapata, 2007; Erk and Padó, 2008).

Finally, structural decomposition is the approach currently adopted by many lexical semanticists working in the interface between syntax and semantics. Words are defined as restricted algebraic structures, with primitive predicates as atomic elements. This approach has been adopted broadly, from Dowty (1979) in his model-theoretic interpretation of generative semantics (Lakoff, 1965/1970), to Van Valin Jr. (2005), Jackendoff's Conceptual Structure (Jackendoff, 1983, 1990), and variants of this model (Levin and Rappaport-Hovav, 1995, 2005). Both Generative Lexicon Theory (Pustejovsky and Boguraev, 1993; Pustejovsky, 1995) and semantic interpretations for Head-Driven Phrase Structure Grammar (HPSG) (Davis and Koenig, 2000; Ginzburg and Sag, 2000) can also be seen as assuming a rich, structural decomposition as the foundation for their models.

In this entry, after a brief history of research in lexical semantics, we review the major issues confronting models of word meaning. Then we examine more closely the meaning components of individual words, beginning with word classes and types, and moving on to different strategies for encoding lexical meaning, focusing on polysemy and argument selection. Next we consider the role played by event semantics in the determination of meaning and survey approaches to decomposition and semantic roles. After a brief introduction to qualia structure, we conclude with an examination of the ways that word meanings contribute to the compositional mechanisms responsible for building sentence meanings.

2.2 The history of lexical semantics

Interest in the meaning of words goes back as far as philosophical thought and speculation about the natural world. Aristotle, for example, in his *De Interpretatione* (McKeon, 1968) outlines a broad theory of language meaning, framed within a context of determining truth in the service of reasoning. As part of his general characterization of nature, Aristotle proposes a classification of thoughts and the words that convey them using a systematic set of dimensions called *aitia*. Applied to verbs and their corresponding activities, this allows one to distinguish between *telic* (goal-completive) and *atelic* (non-goal completive) eventualities. This has both influenced work in lexical aspect and Aktionsarten within linguistics and provided much of the conceptual background for *qualia structure* (Pustejovsky, 1995), see Section 2.7.

With the exception of Locke (1690), Hume (1938), and Reid (1764), there was very little in the way of serious or systematic theorizing about word meaning until late in the nineteenth century. At this time, language researchers in Germany and France began focusing on lexical semantics from a psychological perspective, looking at the relation between words and concepts. Bréal (1897), for example, considered polysemy (a term he coined) to be a necessary creative component of language, claiming that this phenomenon better than most others in semantics illustrates the cognitive and conceptualizing force of the human species. Similarly, German semasiologists viewed the lexicon, word meaning, and mechanisms of polysemy as illustrative of the "life force" of human language (see Erdmann, 1900).

In the early twentieth century, European Structuralists introduced the distinction between syntagmatic and paradigmatic processes. Syntagmatic relations refer to the influence of "horizontal" elements on a word or phrase (co-occurrence), in contradistinction to paradigmatic processes, which refer to "vertical" or alternative substitutions in a phrase. The terms had significant currency in early and mid-twentieth-century linguistics from de Saussure on and helped to define the formal study of syntax as widely practiced today. The Structuralists saw paradigmatic relations encoded in the various lexical systems of a language, and this was elaborated into a framework of componential analysis for language meaning (Nida, 1949; Jakobson, 1973). Componential analysis, used by anthropologists to study kinship terminology, is a method for breaking down the meanings of lexical items into a set of features, thereby illustrating similarities and differences of meaning between the items. The goal of such analysis was simply to classify the lexical items in the language with some finite set of features, its ultimate contrastive elements. These contrastive elements are then structured in a matrix, allowing for dimensional analyses and generalizations to be made about lexical sets occupying the cells in the matrix. Hjelmslev (1943/1961), for example, decomposed lexical items into "paradigms" which pattern the same way distributionally in the language. The componential analysis of lexical items entails a decomposition into distinctive features: *man* as [+adult, +male], *woman* as [+adult, −male], *girl* as [−adult, −male], and so forth. Similar distinctions are made in Nida (1949) for distinguishing morphological patterns.

In the early days of generative linguistics, many of the ideas of the Structuralists found their way into the first formulations of lexical knowledge for transformational grammars. Of particular importance was Katz and Fodor's (1963) and Katz and Postal's (1964) theory of feature-based semantics, where the meanings of words were composed entirely of sets of features with Boolean values. In line with Chomsky (1957), the role of meaning was limited: to detect semantic anomalies and determine the number of readings associated with a sentence. The theory offered proposals for the decomposition of sentences and lexical items, with explicit rules for linking items to syntactic structure. While influential in the short term, this theory had no adequate theory of compositionality and was seen to be too weak as a model for natural language semantics (see Weinreich, 1972).

At the same time as features were being introduced into linguistic analyses, the role of a predicate's *valence* in relation to syntactic expressibility began to be studied. Valence, a term introduced by Tesnière (1959), is a characterization of the number and semantic nature of arguments carried by a verb or other predicative expressions. In the late 1960s and early 1970s, alternatives to the Katz and Fodor model began to emerge that incorporated many of the characteristics and principles of valence-based grammars. These theories attempt to respect the relational structure of sentence meaning while encoding the named "semantic functions" of the arguments in the lexical entries for predicates (Lakoff, 1965/1970; Fillmore, 1968a, 1969; Gruber, 1976; Jackendoff, 1972).

Fillmore (1968a, 1977a), for example, uses an enriched notion of valence to account for how arguments bind to syntactic positions in the sentence. From these early accounts of *case grammar*, Fillmore and colleagues developed a broader notion of *frame semantics* (cf. Fillmore, 1976, 1982), where human activities are conceptualized as lexically encoded frames. A semantic frame specifies the conditions under which a predicate combines with its possible arguments, seen as the participants in the event which that predicate denotes.

Some of these ideas were incorporated into lexically rich, feature-based semantics, in an attempt to explain how the semantic properties of predicates predict syntactic expressibility and behavior. One version of this grew into the framework known as *generative semantics* (Lakoff, 1965/1970; McCawley, 1968a), where the input to semantic interpretation was the deep structure of a sentence. While this started as an attempt to explain the selectional preferences imposed by verbs on their arguments, the scope of the theory expanded to account for all semantic interpretation from deep structure.

This view changed with Chomsky's and Jackendoff's *lexicalist* work in the 1970s, where the role of the lexicon became more central to grammatical processes, and generalizations could be made in terms of what properties were shared by lexical items (Chomsky, 1970; Jackendoff, 1972). While the *Aspects*-model of selectional features restricted the relation of selection to that between lexical items, work by McCawley (1968a) and Jackendoff (1972) showed that selectional restrictions must be available to computations at the level of derived semantic representation rather than at deep structure. Later work by Bresnan (1982), Gazdar et al. (1985), and Pollard and Sag (1994) extended the range of phenomena that can be handled by the projection and exploitation of lexically derived information in the grammar. In these frameworks, the lexicon plays a central part in the way compositional processes are carried out in the grammar.

Before the mid-twentieth century, there was little interest in word meaning within traditional philosophy. While linguistic semantics can trace its roots back to both Frege (1892b) and Russell (1905), these and other authors were less interested in word meaning and linguistic behavior than they were in how words were used as the medium through which judgments can be formed and inferences made. Frege's focus lay in formulating the rules which create meaningful expressions in a compositional manner, while also introducing an important distinction between an expression's sense and its reference. However, because of the descriptive bias in linguistics at the time, linguists largely failed to appreciate the role that systematic models of compositionality might play in language generally. Not until mid-century, with Montague's synthesis of grammatical description and intensional type theory, were these issues addressed in a comprehensive (and influential) manner.

Montague (1970a,b) introduces a bold new program for semantic interpretation in natural language, based on formal logic with a model-theoretic interpretation. Some of the most influential contemporary work on lexical semantics is based on this foundation, as we shall see in the sections below. In Dowty (1979), a model-theoretic interpretation of the decompositional techniques introduced by Lakoff, McCawley, and Ross was developed. Dowty's work, together with Partee (1975)'s seminal article on how

Montague semantics was compatible with syntactic models familiar to linguists at the time, helped introduce formally grounded approaches to semantics to the mainstream of the field.

Over the past two decades, there have been serious efforts to create a synthesis of lexical semantics and compositional mechanisms within linguistic theory. What has emerged is a new view of the role played by the lexicon regarding how composition is directed. Further, there is a new understanding of how contextualized aspects of interpretation impact the design decisions for what semantics is attributed to lexical items.

Examples of this approach can be seen in varieties of Generative Lexicon Theory (Pustejovsky, 1995; Bouillon and Busa, 2001), and in work by Jackendoff (1997, 2002). These developments have helped to characterize the approaches to lexical design in terms of a hierarchy of semantic expressiveness. There are at least three such classes of lexical description, defined as follows: *Sense Enumerative Lexicons*, where lexical items have a single type and meaning, and ambiguity is treated by multiple listings of words; *Polymorphic Lexicons*, where lexical items are active objects, contributing to the determination of meaning in context, under well-defined constraints; and *Unrestricted Sense Lexicons*, where the meanings of lexical items are determined mostly by context and conventional use. It seems clear that the most promising directions seem to be a careful and formal elucidation of polymorphic lexicons, and this will form the basis of our subsequent discussion.

2.3 Issues in lexical semantics

In this section, we look more closely at a set of phenomena in language that are of particular relevance to how lexical meaning is encoded and applied through compositional mechanisms in the grammar. We focus on four specific problems here: (a) the semantic distinctions between lexical ambiguity and systematic polysemy; (b) the nature of selectional preferences in verb-argument composition; (c) the polymorphic behavior of argument selection by predicates; and (d) the question of lexical representation, more generally construed.

2.3.1 Ambiguity versus polysemy

Given the compactness of a lexicon relative to the number of objects and relations referred to in the world, lexical ambiguity would seem inevitable for any language. Furthermore, the cultural, historical, and linguistic blending that contributes to the meanings of our words tends to make lexical ambiguity – when a word carries more than one meaning – appear arbitrary as well. Hence, *homonymy* – where one lexical form has many meanings – is to be expected in a language. Examples of homonyms are illustrated in the sentences below:

(1) a. Mary strolled along the *bank* of the river.
    b. This company is the largest *bank* in the city.

(2) a. The doctor *treated* the woman with antibiotics.
    b. He always *treats* his guests well.

(3) a. First we leave the gate, then we *taxi* down the runway.
    b. John saw the *taxi* on the street.

(4) a. The judge asked the defendant to approach the *bar*.
    b. The defendant was in the pub at the *bar*.

The senses of each noun in the examples above are arguably unrelated to each other; such lexical distinctions have also been called *contrastive ambiguities* (cf. Weinreich, 1972). For this reason, it is assumed that homonyms are represented as separate lexical entries within the organization of the lexicon. Words with multiple senses are simply listed separately in the lexicon, but this does not seem to compromise or complicate the compositional process of how words combine in the interpretation of a sentence.

We can compare this to the phenomenon known as *polysemy* (cf. Apresjan, 1973). Polysemy is the relationship that exists between related senses of a word, rather than arbitrary ones, as in the above examples. For example, the noun *book* is polysemous and can refer to either a physical object or the information contained in it, as illustrated in (5) below.

(5) a. Mary carried *the book* home.
    b. Mary doesn't agree with *the book*.

Unlike the homonyms above, these two senses are logically related to each other by the very concept of *book*. Similarly, the noun *lunch* can refer to the food intended for consumption at a meal or the actual meal itself, as seen in (6).

(6) a. Mary has *her lunch* in her backpack.
    b. The phone rang during *my lunch* yesterday.

In (7), a similar logical relation exists between the two senses of *flight*; in (7a), it refers to the event of flying, while in (7b) it refers to the plane engaged in flying.

(7) a. *The flight* lasted three hours.
    b. *The flight* landed on time in Los Angeles.

While the two senses of the noun *bank* in (1), as well as of the other nouns in examples (2)–(4), are not related (except by phonological form), each of these examples indicates a formal relation between the lexical senses. It is the role of the lexicon to distinguish such ambiguities, and to establish what this logical relation is.

Polysemy is not an isolated phenomenon in language, but rather is associated with every major category in the lexicon, within all languages. For example, adjectives such as *good*, *dangerous*, and *fast* can be viewed as polysemous, where the sense is modulated slightly, depending on the noun being modified.

(8) a. John is a *a good teacher*.
b. *A good meal* is what we need now.
c. Mary took *a good umbrella* with her into the rain.

In each of these sentences, *good* is a manner modifier whose interpretation is dependent on the noun it modifies; in (8a) it means "to teach well", in (8b), it means a "tasty meal", and in (8c), it means "something keeping you dry". Similar remarks hold for the adjective *dangerous*.

(9) a. This is *a dangerous road* at night.
b. She used *a dangerous knife* for the turkey.

That is, the road is dangerous in (9a) when "one drives on it", and the knife is dangerous in (9b) when "one cuts with it". Finally, the adjective *fast* in the sentences below acts as though it is an adverb, modifying an activity implicit in the noun; that is, *programming* in (10a) and *driving* in (10b).

(10) a. Mary is *the fastest programmer* we have on staff.
b. The turnpike is *a faster road* than Main Street.

The exact nature of how adjectives are interpreted relative to the head is discussed in Pustejovsky (1995), and Busa (1996).

A somewhat related phenomenon involving adjectival scope instead of true polysemy can be seen in the sentences in (11), where the adjective can modify the agentive nominal activity or the nominal as an individual.

(11) a. Mary is *a beautiful dancer*.
b. Jones is *a good judge.*

This problem has been studied by several researchers (Landman, 1989b; Pustejovsky, 1995; Busa, 1996; Larson, 1998), and while not involving polysemy, it does highlight the need for a potentially richer semantic content of agentive nominals than is typically assumed.

As mentioned above, polysemy is a phenomenon exhibited by all the major categories in language, including verbs. Because verbal polysemy is arguably the most common form of systematic sense relatedness, we cover it in more detail below.

What is important to realize from the data shown here, for both nouns and adjectives, is that simply listing the senses of these words will not always account for their creative use in novel contexts in language. Accounting for the behavior of polysemy in language is one of the most difficult problems facing a theory of the lexicon, and we take up the solutions to this problem in Section 2.8.

2.3.2 Selectional constraints

To demonstrate the interaction of the lexicon with the other components of grammar, let us examine how lexical information is accessed and exploited by syntactic and semantic operations, a process generally referred to as *selection*.

By far, the most widely studied type of selection process involves the constraints imposed on neighboring phrases by a word, by virtue of its lexical properties. One of the most important properties of a verb is an encoding of what phrases it can appear with in the language. In general, this is the problem of determining how many arguments a verb can appear with in the syntax and is referred to as *argument selection*. There is a general rule of thumb that the number of arguments that the predicate allows in the syntax corresponds to the number of participants an event has.[1] That is, the argument structure of a word loosely reflects the underlying relational meaning associated with that word.

For example, consider the behavior of one argument (intransitive), two argument (transitive), and three argument (ditransitive) verbs in English. The *arity* (number of arguments) information is encoded in the verb's *argument structure*. The verbs *laugh*, *see*, and *give* are simple examples in English.

(12) a. The man *laughed*.
b. The girl *saw* a bird.
c. The boy *gave* a treat to the dog.

The argument structure for the verbs in these sentences can be represented as follows:

(13) a. **laugh**(arg_1)
b. **see**(arg_1,arg_2)
c. **give**(arg_1,arg_2,arg_3)

The lexicon plays an important role in determining whether a linguistic expression in a language is well-formed, and selection is the mechanism through which this is accomplished. For example, it is because of the argument structures in (13) that these verbs do not appear in the wrong grammatical contexts, such as (14) below.

(14) a. *The man *laughed* the ball.
b. *A bird *saw*.
c. *The boy *gave* to the dog.

One of the most important themes when studying the lexicon is to establish just what role lexical information plays in determining whether an expression is well-formed or not.

[1] We will see below that this is not always the case, however, and there are more complex relations between semantic representations and the syntactic structures that may appear.

Although the argument structure indicates how many arguments to expect with a verb in the syntax, it says nothing about what *kind* of arguments these should be. This can be accomplished by adding *selectional constraints* to the arguments of the verb. A selectional constraint is a requirement on an argument that must be satisfied for the verb to be interpreted properly. The most important constraint imposed on an argument by a predicate is its *syntactic category*, that is, whether it is a Noun Phrase (NP), Verb Phrase (VP), Adjective Phrase (AP), or sentence (S). For example, both *write* and *think* are transitive verbs and have the argument structure in (15):

(15) $V(arg_1, arg_2)$

However, their arguments have different syntactic requirements, as we can easily see in (16).

(16) a. The girl *bought* [$_{NP}$ some books].
b. The girl *thinks* [$_{S}$ her brother is funny].

This can be encoded as part of the argument structure for that verb if we make a list of features for each argument. In our representation, this list will be shown directly following the argument it is associated with. So, for example, let `cat` be the feature for the category of the argument; then we have the following distinct argument structures for these two verbs.

(17) a. **buy**(arg_1[cat=NP], arg_2[cat=NP])
b. **think**(arg_1[cat=NP], arg_2[cat=S])

Lexical information impacting the grammar Thus far, the lexical information needed to interface to the syntax is of two sorts:

- *Argument structure* of a verb: this determines the number of phrases in the syntactic construction associated with the verb.
- *Syntactic category* of each argument: this identifies the actual syntactic phrase associated with the argument.

There are other selectional phenomena captured by constraints. For example, observe the differences in the sentences below.

(18) a. The man / *the rock laughed.
b. The man / the rock fell.

The constraints imposed on the subject by a verb such as *laugh* would include the feature of `animacy`, while a verb like *fall* does not. Since this is a lexical property of these verbs, their argument structures should reflect this distinction. Hence, the verb *laugh* has a selectional constraint indicating that the subject must be animate, as shown in (19).

(19) **laugh**(arg_1[cat=NP,animacy=+])

Similarly, the feature of `number` is important for selecting the appropriate subject for verbs such as *assemble*, *gather*, and *disperse*; namely, the subject must be plural.

(20) a. The students *gathered* in the courtyard.
b. The children *assembled* in the gym.
c. The fans *dispersed* from the stadium.

Notice that it can be either *grammatically* plural, as in (20) above, or *semantically* plural, as with the subjects in (21).

(21) a. The class *gathered* in the courtyard.
b. The team *assembled* in the gym.
c. The crowd *dispersed* from the stadium.

That is, the nouns *class*, *team*, and *crowd* can all be considered as non-atomic, from the point of view of the verb and the grammar. Hence, the argument structure for these verbs must reflect this phenomenon by adding a selectional constraint referring to `number`, ranging over the values "singular" and "plural".

(22) **assemble**(arg_1[cat=NP,num=plural])

It is interesting to ask whether these selectional constraints are independent or whether they interact with one another. Let us look a little more carefully at the verbs in (20) and (21) above. We saw that the subject for each of these verbs must be plural. How does the feature `number` interact with `animacy`? Notice that both *disperse* and *gather* allow non-human subjects, while *assemble* does not.

(23) a. The clouds *gathered* in the sky.
b. *The clouds *assembled*.
c. The clouds *dispersed* quickly.

To ensure that a structure such as (23b) is not licensed by the grammar, there must be an encoding of how the structural conditions are being violated. Notice that this can already be done using the constraints we've discussed, namely the combination of `number` and `animacy`, as illustrated in (24) below.

(24) **assemble**(arg_1[cat=NP,num=plural,animacy=+])

It would appear, then, that the verb *assemble* requires the plural subject to be animate, while the very similar verbs *gather* and *disperse* do not.

Selectional constraints, in fact, can determine the acceptability of arguments in any positions in the grammar; consider the distinction between the verbs *force* and *convince*. Although they are synonyms in many contexts, *force* and *convince* have different selectional properties, the latter requiring that the "convinced" be a cognitive agent.

(25) a. John *forced* the guest to leave.
b. John *convinced* the guest to leave.

(26) a. John *forced* the door to open.
b. *John *convinced* the door to open.

Verbs select for different spatial prepositions as well; verbs involving spatial manner descriptions, for example, are quite specific for the kinds of prepositions they allow. Consider, for example, *on* and *in* versus *over* in the sentences below, when selected by the verb *lie*.

(27) The cat is lying on the floor / in the box / *over the floor / . . .

Selectional constraints can also be enlisted to determine the appropriate selection of *manner adverbials* for verbs, as well. Notice that in (28), without some sort of adverbial phrase associated with the verbs *behave* and *perform*, the sentences below are ungrammatical.[2]

(28) a. Mary *behaved* *(badly).
b. John *performed* *(admirably).

We see from this brief discussion that selection is an important part of how lexical information is conveyed to the syntactic operations in the grammar.

Lexical information impacting the grammar From what we discussed, there are at least three types of lexical information which interface to the syntax:

- *Argument structure* of a verb: this determines the number of phrases in the syntactic construction associated with the verb.
- *Syntactic category* of each argument: this identifies the actual syntactic phrase associated with the argument.
- *Selectional constraints* of each argument: these identify specific grammatical and semantic features of the argument being selected by the verb. Selectional constraints have been used to encode all manner of lexical and syntactic restrictions in grammar. As such, they are part of the meaning of words and have direct effects on the syntax, morphology, and semantics of the language.

2.3.3 Verb meaning and mapping to syntax

We saw in the previous section the role that the lexicon plays in ensuring that a linguistic expression is well-formed. Recall that it is the argument structure that prevents verbs from ending up in the wrong syntactic contexts in sentences (Levin, 1993). That is, if the lexicon says it is so, then the grammar follows.

[2] It should be noted that (28a) does have a default reading of "behave well", when no adverb is present.

(29) a. **laugh**(arg_1) $\Longrightarrow$ The man *laughed*.
b. **see**(arg_1,arg_2) $\Longrightarrow$ The girl *saw* a bird.
c. **give**(arg_1,arg_2,arg_3) $\Longrightarrow$ The boy *gave* a treat to the dog.

Or does it? Notice that there are contexts for each of the verbs in (29), which exploit properties of the verb, giving rise to constructions not allowed by the original argument structure.

(30) a. The man *laughed* himself sick.
b. The girl *saw* a bird fly into the room.
c. The man *gave* at the office.

In each of these sentences, the argument structure for the verb has been violated in some way. In (30a), there is an additional NP object to the verb *laugh*, and a predicate modifying the object NP *himself*. In (30b), what the girl saw was not just a bird, but what the bird did; namely, "flying into the room", described as an additional VP. Finally, in (30c), both of the expected arguments are missing, and presumably inferred from the context of the utterance.

These illustrate one aspect of the phenomenon of *verbal polysemy*. Polysemy, as defined in the previous section, is the term given to an ambiguity where the different meanings of the word are logically related to each other. Many verbs can appear in multiple contexts taking a different number of arguments in each, a phenomenon known as an *alternation*. For example, the verbs *break*, *roll*, and *sink* all have intransitive and transitive forms, as shown in the sentences below.

(31) a. The glass *broke*.
b. Mary *broke* the glass.

(32) a. The ball *rolled* down the slide.
b. The boy *rolled* the ball down the slide.

(33) a. The ship *sank*.
b. The torpedo *sank* the ship.

How does the lexicon represent such ambiguities? The simplest way would be to list the different argument structures for each verb, as shown in (34).

(34) a. $\textbf{break}_1$(arg_1); $\textbf{break}_2$(arg_1,arg_2)
b. $\textbf{roll}_1$(arg_1); $\textbf{roll}_2$(arg_1,arg_2)
c. $\textbf{sink}_1$(arg_1); $\textbf{sink}_2$(arg_1,arg_2)

Note that the semantic role of the intransitive subject is the same as the transitive object NP in each one of these verbs. That is, it is the *undergoer* or *patient*.

This kind of alternation does not apply to all intransitive verbs, of course, and the lexicon must somehow prevent verbs like *arrive* and *die* from becoming transitive.

(35) a. Your package *arrived*.
b. *The mailman *arrived* your package.

(36) a. My computer *died* yesterday.
b. *The storm *died* my computer yesterday.

The question arising from such cases is this: what allows for an alternation to occur for some verbs while not for others? Is this part of the lexicon or some other rule or strategy in the grammar?

Verb alternations are quite prevalent in language and pose a difficult problem to lexicon designers. For example, how many different argument structures do we have for a verb like *sweep*?

(37) a. John *swept*.
b. John *swept* the floor.
c. John *swept* the dirt into the corner.
d. John *swept* the dirt off the sidewalk.
e. John *swept* the floor clean.
f. John *swept* the dirt into a pile.

Such alternating patterns typically apply to more than just one verb; hence, it would be more efficient to have a general strategy for how these word senses are related rather than simply listing the different senses for each verb.

Lexical information is sensitive to both the syntax and the discourse context. Although a verb may be lexically specified to have a certain number of arguments, there are many situations in which this can be violated. We saw this above in (30c) with the verb *give*. In fact, this is quite common but appears to be governed by systematic rules, and not just pragmatic information. For example, while (30c) is grammatical, for most speakers (38b) below is not.

(38) a. The woman *donated* her car to the foundation.
b. *The woman *donated*.

Similarly, *eat* and *drink* can appear without their direct objects, but *devour* and *gulp* cannot (at least for most speakers).

(39) a. The girl *ate* her lunch quickly.
b. The girl *ate* quickly.

(40) a. The dog *devoured* the bone.
b. *The dog *devoured*.

(41) a. The boy *drank* his milk quietly.
b. The boy *drank* quietly.

(42) a. The boy *gulped* his milk quietly.
b. *The boy *gulped* quietly.

This type of alternation is typically called *indefinite NP deletion* and is related to other “pragmatic deletions”, such as those shown below.

(43) a. John *tried* to call his mother yesterday.
b. John *tried* yesterday.

(44) a. John *attempted* to call his mother yesterday.
b. *John *attempted* yesterday.

The ability to ignore part of the argument structure in the syntax seems to be a lexical property, one which is idiosyncratic to each verb.

Finally, we consider a kind of verbal polysemy not involving argument alternation, but a *syntactic category alternation*. Recall from our discussion above (see (17)) that we motivated a way to distinguish between different syntactic types for an argument; that is, *buy* and *think* have different category values associated with their second arguments:

(45) a. **buy**(arg_1[cat=NP],arg_2[cat=NP])
b. **think**(arg_1[cat=NP],arg_2[cat=S])

What happens, however, when the syntactic distinction involves the same verb? Consider the sentences below, where the verb *begin* appears in three distinct syntactic contexts.

(46) a. Mary *began* to read the novel.
b. Mary *began* reading the novel.
c. Mary *began* the novel.

Verbs like *hate* and *love* in English can appear in even more contexts, as seen in (47) below.

(47) a. John would *hate* Bill to leave.
b. John *hates* (it) that Bill left.
c. John *hated* to lose the game.
d. John *hated* losing the game.
e. John *hated* that he lost the game.

The examples above in (46) and (47) bring up the issue of how to make generalizations in the lexicon; that is, is there a “compact” manner in which to express that the verb *begin* means the same thing in each sentence in (46), and likewise for the verb *hate* in (47).

2.4 Event semantics

In this section, we look at the notion of event in lexical semantics. There are two traditions to examine when studying the role of events in the semantics of language:

Event typology: Predicates in language have an *event variable* that can be treated as a first-order individual in the semantics, to enable logical inference (Davidson, 1967a).

Aktionsarten: Predicates in language can be classified according to their event type or aspectual class, in order to specifically capture grammatical and semantic behaviors (Vendler, 1957).

The move by Davidson to introduce a first-order event variable in the representation was mainly motivated by the need to provide a coherent analysis of adverbial modification in the interpretation of sentences. Under this proposal, two-place predicates such as *eat* and three-place predicates such as *give* contain an additional argument, the event variable, e, as depicted below.

(48) a. $\lambda y \lambda x \lambda e[\text{eat}(e, x, y)]$
b. $\lambda z \lambda y \lambda x \lambda e[\text{give}(e, x, y, z)]$

In this manner, Davidson is able to capture the appropriate entailments between propositions involving action and event expressions through the conventional mechanisms of logical entailment. For example, to capture the entailments between (49b–d) and (49a) below,

(49) a. Mary ate the soup.
b. Mary ate the soup with a spoon.
c. Mary ate the soup with a spoon in the kitchen.
d. Mary ate the soup with a spoon in the kitchen at 3:00 pm.

In this example, each more specifically described event entails the one above it by virtue of *and*-elimination (conjunctive generalization) on the expression.

(50) a. $\exists e[\text{eat}(e, m, \text{the\_soup})]$
b. $\exists e[\text{eat}(e, m, \text{the\_soup}) \wedge \text{with}(e, \text{a\_spoon})]$
c. $\exists e[\text{eat}(e, m, \text{the\_soup}) \wedge \text{with}(e, \text{a\_spoon}) \wedge \text{in}(e, \text{the\_kitchen})]$
d. $\exists e[\text{eat}(e, m, \text{the\_soup}) \wedge \text{with}(e, \text{a\_spoon}) \wedge \text{in}(e, \text{the\_kitchen}) \wedge \text{at}(e, \text{3:00 pm})]$

There are of course many variants of the introduction of events into predicative forms, including the identification of arguments with specific named roles (or partial functions, see Chierchia, 1989; Dowty, 1989).

In lexical semantic analysis, it is standard practice to create component-based classifications using linguistic data that demonstrate pairwise distinctions for grammatical or semantic well-formedness judgments. One such approach is the determination of aspectual class or *Aktionsart* (see also Rothstein, Chapter 12). This is essentially a characterization of the different kinds of eventualities that predicative expressions denote. There have been several influential distinctions proposed in the literature, but the best known are those introduced by Kenny (1963) and Vendler (1967). Kenny assumed that there are three basic aspectual types: *states*, *activities*, and *performances*. Vendler proposes a similar distinction for states and processes, but splits the last class (his *events*) into two categories, *accomplishments* and *achievements*. His classification as well as his terminology have been the starting point for much of the work in aspect and event semantics in the field. These event classes are summarized briefly below.

State: An unchanging situation that holds at a time or over an interval, with no endpoints.
Activity: A dynamic event with no endpoints (an *atelic* event).
Accomplishment: An incrementally changing event with a culminating endpoint (a *telic* event).
Achievement: An instantaneous change of state.

Examples of states are seen in simple attributive predications, such as (51a–b), as well as with non-dynamic relations, such as (51c–d).

(51) a. Mary is *happy*.
b. Marc is *Dutch*.
c. Jan *loves* Bill.
d. Mary *believes* Jan is happy.

States can be distinguished from activities by virtue of certain grammatical diagnostics, many of which Vendler introduced into the literature. Consider a verb such as *swim* in sentence (52a). This denotes an activity of unspecified duration, and the sentence does not convey information regarding a culmination of this activity. With the addition of a goal *to*-PP, however, as in sentence (52b), the swimming activity is bounded, and the resulting event denotes an accomplishment.

(52) a. Jan *swam* yesterday.
b. Jan *swam* to the dock yesterday.
c. Jan *is swimming*.

Hence, we can analyze the verb *swim* as lexically denoting an activity, which can be interpreted contextually as an accomplishment, through the appropriate compositional modification. Finally, notice that sentence (52c) denotes a "snapshot" of the swimming process. Both of these aspectual *coercions* are known to distinguish processes from states.

In a similar fashion, there are verbs which lexically denote accomplishments, such as *build* and *destroy*. These verbs encode the logical culmination to the activity performed during the event, as illustrated in (53) below.

(53) a. The children *built* a fort.
b. John *destroyed* the anthill.

Finally, an achievement is an event that results in a change of state, just as an accomplishment does, but where the change is thought of as occurring instantaneously. For example, in sentences (54a–c) the change is not a gradual one, but something that has a point-like quality to it. Hence, modification by *point adverbials* such as *at 3 pm* is suggestive that a sentence denotes an achievement (see Dowty, 1979).

(54) a. The plane *crashed* at noon.
b. John *found* his wallet at 3 pm.
c. The train *arrived* at midnight.

Pustejovsky (1988, 1991b) extends the decompositional approach presented in Dowty (1979) by explicitly reifying the events and subevents in the predicative expressions. Unlike Dowty's treatment of lexical semantics, where the decompositional calculus builds on propositional or predicative units (as discussed above), a "syntax of event structure" makes explicit reference to quantified events as part of the word meaning. Pustejovsky further introduces a tree structure to represent the temporal ordering and dominance constraints on an event and its subevents (see also Moens and Steedman, 1988).

(55) a. EVENT $\rightarrow$ STATE | PROCESS | TRANSITION
b. STATE: $\rightarrow$ e
c. PROCESS: $\rightarrow$ $e_1 \ldots e_n$
d. TRANSITION$_{ach}$: $\rightarrow$ STATE STATE
e. TRANSITION$_{acc}$: $\rightarrow$ PROCESS STATE

For example, the accomplishment denoted by "building a house" consists of the building process, followed by the state representing the result of the object being built. Grimshaw (1990) adopts this theory in her work on argument structure, where complex events such as *break* are given a similar representation. In such structures, the process consists of what an agent, x, does to cause the breaking of y, and the following state represents the resulting broken item. The process corresponds to the outer causing event as discussed above, and the state corresponds in part to the inner change-of-state event. Both Pustejovsky and Grimshaw differ from the authors above in assuming a specific level of representation for event structure, distinct from the representation of other lexical properties. Furthermore, they follow Davidson (1967a), Higginbotham (1985), and particularly Parsons (1990), in adopting an explicit reference to (at least) one event variable in the parameter structure of the verbal semantics.

Recently, Rappaport-Hovav and Levin (2001) and Levin and Rappaport-Hovav (2005) have adopted a large component of the event structure model for their analysis of the resultative construction in English; event decomposition has also been employed for properties of adjectival selection, the interpretation of compounds, and stage and individual-level predication (Carlson, 1977a; Diesing, 1992a; Jäger, 2001).

Research done by Tenny (1989), Dowty (1991), Krifka (1992, 1998), and others enriches this typology by developing a theory of how an event is shaped by the incremental participation of the theme in that event. The central aspect of this view is that an accomplishment is defined as involving a homomorphism from parts of the event to parts of the incremental theme. The problem of incrementality can be illustrated with the following examples.

(56) a. John ate a hamburger.
b. Mary wrote a novel.

The process of eating something is an incremental activity and results in an accomplishment, described by reference to the quantized unit appearing in the direct object (theme) position, only when the entire hamburger has been eaten or the entire novel has been written.

Recent work on scalar change (see Hay et al., 1999; Beavers, 2008; Kennedy and Levin, 2008) and dynamic event semantics (Naumann, 2001) suggests a new understanding of the interplay between verb meaning, event semantics, and argument structure with these predicates, by focusing on the measurement of the change in value over the properties of the participants in each intermediate state during the event.

Starting from a quite different perspective, Krifka (1989a, 1992) presents an interpretation of Aktionsart using a lattice-theoretic interpretation of event structure. Using the sum operation from lattice theory, where a complex event $e_1 \sqcup e_2$ can be formed from any two events, e_1 and e_2, Krifka introduces a part/whole relation, $e_1 \sqsubset e_2$, iff $e_2 = e_1 \sqcup e_2$. This allows for a distinction to be made between *quantized* and *cumulative* predicates. Processes of undifferentiated activity, such as *walking* or *singing*, are cumulative and are closed under the sum operator, while an accomplishment, such as *build a house*, is not.

(57) a. $\forall P[\mathrm{CUM}(P) \leftrightarrow \forall x \forall y[[P(x) \wedge P(y)] \rightarrow P(x \sqcup y)]]$
b. $\forall P[\mathrm{QUA}(P) \leftrightarrow \forall x \forall y[[P(x) \wedge P(y)] \rightarrow x \not\sqsubset y]]$

These two classes map fairly closely to the well-known categories of atelic and telic predicates, mentioned above. For example, no part of building a house is a complete house-building; the event is quantized by the relationship to the result, i.e., the house (see Krifka, 1992). The activity of walking, on the other hand, is cumulative, and any event of walking is composed of subevents of walking. See Champollion and Krifka, Chapter 13 for further discussion.

2.5 Lexical decomposition

Lexical decomposition is concerned with the internal semantic structure of lexical items within a lexicon. The focus of lexical decomposition is on how the lexical items are semantically similar and distinct by virtue of shared knowledge structures or semantic primitives. While numerous structures and primitives (e.g., semantic features and semantic markers) have been proposed, we limit our discussion here to the most currently relevant theories, all of them *structural decomposition* models, as introduced above.

The goal of lexical decomposition has traditionally been to provide the necessary and sufficient conditions for the meaning of every lexical item in a subject domain or language. In many ways, this goal is similar to that of the syntactic analysis of sentences in a language. If primitives and structures are taken as an exhaustive set on top of which all expressions in the language are expressed, then the meaning of any lexical item in the language will have to be derived from these terms.

Perhaps the first significant framework of structural decomposition was generative semantics (see Lakoff, 1965/1970). It emerged just as Katz and Fodor's feature-based decomposition model was shown to be both incomplete and inadequate (see Weinreich, 1972) as a model for language semantics. Generative semanticists argued that deep structure was the appropriate level for semantic structure and that transformational rules operate only on that structure, without subsequent semantic consequences. Lexical items are decomposed into a set of abstract components and transformations are done on those components (see Lakoff, 1965/1970; Ross, 1970). For example, the lexical item *kill* is decomposed into the predicate DEAD and two higher-level predicates CAUSE and BECOME. The deep semantic structure associated with this verb consists of these semantic components organized into a labeled bracketing.

While the framework of generative semantics is no longer generally adopted, many aspects of the theory can be seen in contemporary lexical theories, owing to some significant generalizations the theory made about semantic structure in language. For example, the sentences in (58) form a sort of paradigm for the concept *dead*, related by the application of abstract predicates, which systematically change the meaning of the words associated with it (see Lakoff, 1965/1970; McCawley, 1968b; Carter et al., 1988).

(58) a. John killed Bill.
b. Bill died.
c. Bill is dead.

Assuming that the underlying form for a verb like *kill* encodes the stative predicate in (58c) and the relation of causation, generative semanticists posited representations such as (59) below.

(59) (CAUSE(x, (BECOME(NOT(ALIVE y)))))

Here the predicate CAUSE is represented as a relation between an individual causer x and an expression involving a change of state in the argument y. Although there is an intuition that the cause relation involves a causer and an event, neither Lakoff nor Carter makes this commitment explicitly (a point we return to below).

In a very influential work, Dowty (1979) presents a model-theoretic interpretation of the ideas from generative semantics, but with one important difference: Dowty associates complex decompositional expressions such as the one in (59) with the lexical items directly, without the syntactic machinery of predicate reduction that was required in a generative semantics derivation from deep to surface structure. Hence, the lexicon in Dowty's theory is far richer than normally envisioned.

Another significant contribution made by Dowty's study of word meaning is his reinterpretation of Vendler's classification of the Aktionsarten, mentioned in Section 2.4, in model-theoretic terms. Thus, states, activities, accomplishments, and achievements are given a formal treatment within an intensional logic.

Pursuing a similar line of reasoning to the generative semanticists concerning lexical decomposition, Jackendoff (1972) built on the Gruber (1976) thesis to argue that predicates such as [+cause] and [+inchoative] are encoded in the meaning of the word itself.[3] In Jackendoff's later work (1983, 1990, 2002), the approach to lexical decomposition makes claims for cognitive relevance that are not important motivations for many researchers. However, Jackendoff believes in the cognitive primacy of the primitives used within his system, and the role of these primitives in performing inferences. We examine Jackendoff's semantic representation briefly here, as it pertains to lexical decomposition.

At the core of Jackendoff's conceptual semantics is an inventory of primitive categories from which lexical meanings are constructed. These include concepts such as event, state, action, place, path, property, and amount. Along with these are the formation rules used to combine these categories into concepts associated with lexemes. To illustrate, consider sentence (60) below, along with its lexical representation in Jackendoff's system.

(60) a. John flew the plane from New York to Boston.
b. CAUSE(John, GO(plane, $[_{[\text{path}]}$ FROM (IN [Boston]), TO(IN [New York])])))

Interestingly, many of these predicates are spatial in origin. Jackendoff, like many others interested in the nature of semantic extension, explores the idea that the predicates within the spatial domain may be used to analyze concepts within other semantic domains. The basic idea here is that for different semantic fields such as possession, identification, circumstantial, and temporal, a verb from the spatial field can acquire a new meaning using the same primitives because it is being evaluated relative to a new field. Examples of this include:

(61) a. *Possessional*: John will take the house and Mary the kids.
b. *Identificational*: John turned into a great father.
c. *Circumstantial*: Mary led me to believe she was younger than I.
d. *Temporal*: The seminar has been moved to Wednesdays.

[3] Jackendoff (1972), following Chomsky (1970), was philosophically at odds with the claims made by generative semantics. The interpretive semantics they defended took semantics to be a process of interpretation over the derived surface form of the sentence, rather than the deep structure.

Regardless of the decompositional approach adopted, there are many questions that remain: do its primitives provide a complete and exhaustive description of the concepts of natural language? How open-ended is the system? What is the additional information which distinguishes the meaning of one lexical item from another? That is, the primitives do allow for generalizations, but what allows for the discrimination of concepts (the function filled by distinguishers in Katz and Fodor's theory), and how many features are necessary to that end?

In the approaches described here, the general approach is to use decomposition as "annotations" that reflect components of the meanings of lexical items, rather than exhaustively decompose the meanings of words, as was the goal in the earlier days of generative grammar.

More recent versions of lexical representations inspired by generative semantics and Jackendoff's decomposition model can be seen in the Lexical Relational Structures of Hale and Keyser (1993), where syntactic tree structures are employed to capture the same elements of causation and change of state as in the representations of Carter, Jackendoff, and Dowty. The work of Levin and Rappaport, building on Jackendoff's Lexical Conceptual Structures, has likewise been influential in further articulating the internal structure of verb meanings (see Levin and Rappaport-Hovav, 1995).

Generative Lexicon can be seen as a hybrid theory, incorporating aspects of Jackendoff's and Dowty's work with the event semantics of Davidson and Parsons. It has taken several decades for Davidson's observations regarding the role of events in the determination of verb meaning to find their way convincingly into the major linguistic frameworks. Over the past two decades, a synthesis has emerged which attempts to model verb meanings as complex predicative structures with richer event structures (see Parsons, 1990; Pustejovsky, 1991b, 1995; Levin and Rappaport-Hovav, 1995). This research has developed the idea that the meaning of a verb can be analyzed into a structured representation of the event that the verb designates, and has furthermore contributed to the realization that verbs may have complex, internal event structures.

2.6 Semantic roles

While decomposition aims to define lexical meaning in terms of a word's internal features, theories of semantic roles can be seen as *partial decomposition* models, focusing on articulating the function or role that the arguments of a predicate play in the determination of sentence meaning. Hence, as mentioned above in Section 2.2, we can view semantic roles as enhanced argument structure specifications.

Argument structure is the syntactic encoding of the functional behavior of an expression in the object language. In linguistically motivated models of lexical semantics, one of the basic semantic distinctions between nouns and verbs is stated in terms of their selectional behavior in syntax (the valence properties discussed in Section 2.2). The argument structure for a word can be seen as the simplest specification of its semantics, indicating the number and type of parameters associated with the lexical item as a predicate. For example, the verb *sleep* can be represented as a predicate taking one argument, *love* as taking two arguments, while the verb *buy* takes two, three, or four arguments, depending on the context.

(62) a. **sleep**(x)
b. **love**(x,y)
c. **build**(x,y,z)

The first theory of semantic roles within a generative model was *Case Grammar*, a semantically oriented grammar developed by Fillmore (1968b) and others, e.g., Anderson (1977) and Starosta (1988). Case was first used for the morphological analysis of noun endings in, e.g., German and Russian. Fillmore showed that these noun endings serve the same purpose as the positioning of nouns and prepositions in lexical surface structures. Fillmore (1968b) introduced the notion of case grammar and a case frame, a predicate containing arguments that are a set of obligatory and optional cases. Implicit in the theory is that each NP in a sentence can be assigned only one case and that the cases assigned by a verb can be realized only once in a sentence. He defined a number of cases including:

1. Agentive (A): an animate perceived instigator of the action identified by the verb.
2. Instrumental (I): an inanimate force or object causally involved in the action or state identified by the verb.
3. Dative (D): an animate being affected by the action identified by the verb.
4. Objective (O): the semantically most neutral case.

For example, the verb *open* requires that its objective role be filled: something must open or be opened. In (63a), only the objective role is filled. In (63b) and (63c), both agentive and objective roles are filled. In (63d), the instrumental and objective roles are filled. In (63e), the agentive, objective, and instrumental roles are filled.

(63) a. The door opened.
b. Mary opened the door.
c. The door was opened by Mary.
d. The key opened the door.
e. Mary opened the door with the key.

Fillmore noted that different case roles can occupy the same grammatical function, e.g., the grammatical subject is *door* in (63a) and (63c) which occupies the objective role, *Mary* in (63b) and (63c) which has the agentive role, and *key* in (63d) and (63e) which has an instrumental role.

Fillmore's theory attempts to explain how the arguments of a predicate are assigned to particular syntactic structures and is not concerned with establishing an independent level of semantic representation. To handle assignment, Fillmore assumed a principle of a case hierarchy, which allowed the selection of grammatical subject and object in default configurations. As an example of case assignment, consider the verb *break* which assigns both obligatory and optional cases. Obligatory cases include the objective, while optional cases include both the agentive and the instrumental cases.

(64) John broke the window with a rock.

In sentence (64), by default assignment, agentive is assigned to the subject, objective to the object, and instrumental to the phrase within the prepositional phrase. This is a type of default selection which can be violated if the verbal morphology indicates a structure such as a passive as in (63c).

Fillmore (1977a) notes some deficiencies and limitations of case grammar. Although case grammar is useful as a guide to decomposition of verb meaning, the theory does nothing to clarify the nature of sense relations like antonymy and hyponymy. Case grammar allows the recognition of sentences as partially synonymous by matching case structures. Because it does not claim to be a complete model for meaning, case grammar avoids the pitfalls of the decomposition model of Katz–Fodor; on the other hand, because of its incompleteness, it is unclear what role such a system of cases might play in a comprehensive semantic theory.

Part of Jackendoff's early work on the theory of lexical decomposition (as discussed above) included a formalization of Gruber (1976)'s more limited notion of thematic role. In this view, which is quite similar to Fillmore's conception of cases, Jackendoff (1972) classifies verbs according to which thematic (*theta*) roles they assign to their arguments. Thus, *theta theory*, as this view has come to be known, is a minimal decomposition of verb meaning, where features and abstract predicates have been replaced by named functional roles, as in case grammar. The success of theta theory has come not from how well it characterizes verb denotations, but in how "functional" roles interact with other principles of syntax to determine the well-formedness of a sentence.

Thematic relations are now generally defined as partial semantic functions of the event being denoted by the verb or noun, and behave according to a predefined calculus of roles relations (e.g., Carlson, 1984; Chierchia, 1989; Dowty, 1989). For example, semantic roles such as agent, theme, and goal can be used to partially determine the meaning of a predicate when they are associated with the grammatical arguments to a verb.

(65) a. **put**⟨AGENT,THEME,LOCATION⟩
b. **borrow**⟨RECIPIENT,THEME,SOURCE⟩

Thematic roles can be ordered relative to each other in terms of an implicational hierarchy. For example, there is considerable use of a universal subject hierarchy such as shown below (see Fillmore, 1968b; Comrie, 1981).

(66) AGENT > RECIPIENT/BENEFACTIVE> THEME/PATIENT > INSTRUMENT > LOCATION

Many linguists have questioned the general explanatory coverage of thematic roles, however, and have chosen alternative methods for capturing the generalizations they promised. Dowty (1991) suggests that theta-role generalizations are best captured by entailments associated with the predicate itself. A theta-role can then be seen as the set of predicate entailments that are properties of a particular argument to the verb. Characteristic entailments might be thought of as prototype roles, or *proto-roles*; this allows for degrees or shades of meaning associated with the arguments to a predicate. Others have opted for a more semantically neutral set of labels to assign to the parameters of a relation, whether it is realized as a verb, noun, or adjective (see Hobbs et al., 1988).

In the late 1970s, Fillmore began to rethink his views of semantics and developed a "scenes-and-frames" semantics to overcome the deficiencies and limitations he had noted with case grammar. The basic ideas of the new semantics, influenced in part by Minsky (1975), were that "people associate certain scenes with certain linguistic frames" and that "meanings are relativized to scenes," i.e., lexical items or expressions are understood by placing them within scenes or images in which they have some linguistic functions, e.g., naming.

In the theory, frames are linguistic entities that represent the meanings of lexical items. Scenes can not only be visual but also refer to "interpersonal transactions, standard scenarios, familiar layouts" (Fillmore, 1977b) and "body image" (the way we orient and classify linguistic frames such as UP-DOWN and LEFT-RIGHT).

Fillmore's account views scenes-and-frames as offering an alternative to traditional accounts of lexical decomposition issues like lexical ambiguity, synonymy, semantic fields and selection restrictions (Fillmore, 1975). Synonymy can be understood as "indistinguishable scenes for which the frame offers lexical options". A selection restriction is viewed as the relation between a frame and a scene. "The selection restriction information about the use of a word can be stated as a specification of the nature of the appropriate scene" (Fillmore, 1975, p. 71).

Fillmore furthermore argues that the denotations of lexical items can better be characterized by a sort of prototype theory; that is, "instead of the meaning of a linguistic form being represented in terms of a checklist of conditions that have to be satisfied in order for the form to be appropriately or truthfully used, it is held that the understanding of meaning requires, at least for a great many cases, an appeal to an exemplar or prototype" (Fillmore, 1975). A prototype is an ideal example of some concept to which other instances of the same concept bear a strong (but not necessarily total) resemblance. For example, a prototypical bird might have a beak, wings, feathers, and be able to fly, but an ostrich would still be recognized as a bird. The prototype idea can be seen in Berlin and Kay (1969)'s study of color terms, in Labov's work on the boundary criteria between cups and bowls (Labov, 1972b), and in the work of the psychologist Rosch and Mervis (1975).

2.7 Qualia structure

Thus far, we have focused on the lexical information associated with verb entries. All of the major categories, however, are encoded with syntactic and semantic feature structures that determine their constructional behavior and subsequent meaning at logical form. In Generative Lexicon Theory (Pustejovsky, 1991a, 1995), it is assumed that word meaning is structured on the basis of four generative factors, or *qualia roles*, that capture how humans understand objects and relations in the world and provide the minimal explanation for the linguistic behavior of lexical items (these are inspired in large part by the Moravcsik (1975, 1981) interpretation of Aristotelian *aitia*). These are: the FORMAL role: the basic category that distinguishes the object within a larger domain; the CONSTITUTIVE role: the relation between an object and its constituent parts; the TELIC role: its purpose and function; and the AGENTIVE role: factors involved in the object's origin or "coming into being". Qualia structure is at the core of the generative properties of the lexicon, since it provides a general strategy for creating new types. For example, consider the properties of nouns such as *rock* and *chair*. These nouns can be distinguished on the basis of semantic criteria which classify them in terms of general categories such as `natural_kind`, `artifact_object`. Although very useful, this is not sufficient to discriminate semantic types in a way that also accounts for their grammatical behavior. A crucial distinction between *rock* and *chair* concerns the properties which differentiate *natural kinds* from *artifacts*: functionality plays a crucial role in the process of individuation of artifacts, but not of natural kinds. This is reflected in grammatical behavior, whereby *a good chair*, or *enjoy the chair* are well-formed expressions reflecting the specific purpose for which an artifact is designed, but *good rock* or *enjoy a rock* are odd out of context, since for *rock* the functionality (i.e., TELIC) is undefined. Exceptions exist when new concepts are referred to, such as when the object is construed relative to a specific activity, such as in *The climber enjoyed that rock*; *rock* itself takes on a new meaning, by virtue of having telicity associated with it, and this is accomplished by integration with the semantics of the subject NP. Although *chair* and *rock* are both `physical_object`, they differ in their mode of coming into being (i.e., AGENTIVE): artifacts are manufactured, *rocks* develop in nature. Similarly, a concept such as *food* or *cookie* has a physical manifestation or denotation, but also a functional grounding, pertaining to the activity of "eating". These distinct aspects of a category are represented by the qualia structure for that concept, which provides a coherent structuring for different dimensions of meaning.

By analyzing the semantics of objects in terms of qualia, the classic domain of entities from Montague Grammar can be organized as a hierarchical system of subtypes (sorts), structured into three broadly defined types:

(67) *Natural types*: Natural kind concepts grounded in the Formal and Constitutive qualia roles.
Artifactual types: Concepts grounded in the Telic (purpose or function), or Agentive (origin) qualia roles.
Complex types: Concepts integrating reference to the relation between at least two types from the other levels.

Qualia structure has proved to be an expressive representational device and has been adopted by adherents of many other grammatical frameworks. For example, Jensen and Vikner (1994) and Partee and Borschev (1998) as well as Borschev and Partee (2001) appeal to qualia structure in the interpretation of the genitive relation in NPs, while many working on the interpretation of noun compounds have developed qualia-based strategies for interpretation of noun–noun relations (Busa and Johnston, 1996; Johnston and Busa, 1999; Jackendoff, 2010). Van Valin Jr. and La Polla (1997) and Van Valin Jr. (2005) have also adopted qualia roles within several aspects of analyses in Role and Reference Grammar (RRG), where nominal semantics have required finer-grained representations.

2.8 Type theory and the lexicon

How can lexical semantic information be exploited in the compositional operations responsible for building larger semantic expressions in language? In this section we discuss how the representational strategies and approaches outlined above can be integrated into a uniform framework, one that can interface with the mechanisms we are familiar with within compositional semantics. Specifically, we present a type-theoretic treatment of lexical semantic information, as developed in Pustejovsky (2006), Asher and Pustejovsky (2006), and subsequently in Asher (2011).

The basic semantic knowledge associated with a lexical item can be split into two categories: its *semantic type* and its *selectional type*. While the former identifies the semantic class that a lexical item belongs to (such as *entities*, *events*, and *attributes*), the latter class specifies the semantic characteristics associated with the arguments to a lexical item. From a type-theoretic position, such as that adopted within formal semantics since Montague, these are in fact identical, as the type of a functional expression is determined by the nature of the typing of its arguments (see Partee, 1975, 1978; Bach, 1984).

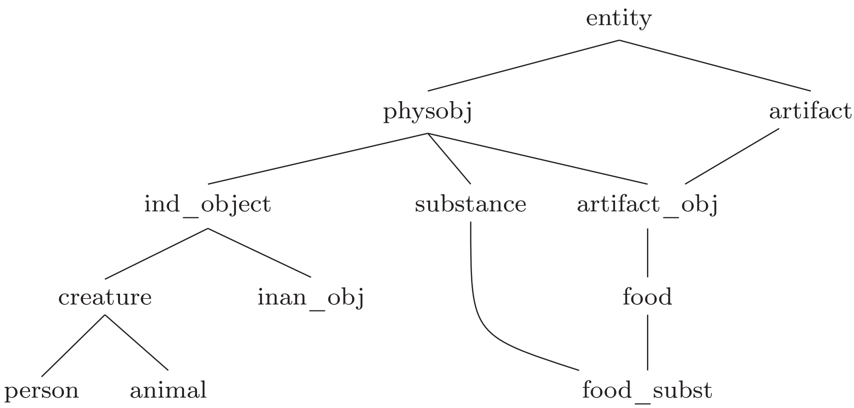

Figure 2.1 *Fragment of a type hierarchy*

Following standard assumptions within type-theoretic semantics (see Chierchia and McConnell-Ginet, 2000), we assume a vocabulary of atomic and derived types. For the present discussion, we let the atomic types be: e the general type of entities; and t the type of truth values. Derived types consist of all *functional types*, formed with the functional infix, $\rightarrow$; hence, for any types σ and τ, then $\sigma \rightarrow \tau$ is a type.

As in Montague Grammar and other standard frameworks, we will take a lexical entry to consist of a lambda term and a type assignment to the variables in the term. This will then determine via the standard interpretation for the lambda term a functional type for the whole expression. Unlike Montague Grammar, however, *Type Composition Logic* (TCL) (see Asher and Pustejovsky, 2006; Asher, 2011) has a much richer system of types reflecting the information conventionally associated with a word in the Generative Lexicon approach (its qualia structure), and correspondingly more complex rules for manipulating these types. Such typing knowledge is typically structured by means of some sort of inheritance mechanism (Evans and Gazdar, 1989, 1996; Copestake, 1993; Pollard and Sag, 1994; Copestake and Briscoe, 1997), and modeled as a lattice or semi-lattice (Carpenter, 1992). Briscoe et al. (1993) describe a rich system of types for allowing default mechanisms into lexical type descriptions. An example of such an inheritance structure is shown in Figure 2.1.

As presented in the previous section, the qualia structure is a system of relations that characterizes the semantics of a lexical item, and TCL provides a way to encode this directly in the type associated with a lexeme. Following Asher and Pustejovsky (2006), we adopt two additional type constructors, $\otimes$ and $\bullet$. The constructor $\otimes$ introduces a qualia relation, Q, such that if σ and τ are types, then so is $\sigma \otimes_Q \tau$, for Q. The constructor $\bullet$ introduces a *complex type*, such that if σ and τ are types, then so is $\sigma \bullet \tau$.

To illustrate how a richer lexical semantics is reflected directly in the type structure, notice that a feature structure denoting the qualia structure for an expression, α, reduces to the type $\alpha : (\beta \otimes_A \sigma) \otimes_T \tau$ in TCL (where A and T stand for Agentive and Telic qualia, respectively).

(68)
$$\begin{bmatrix} \alpha & \\ \text{QS} = & \begin{bmatrix} \text{FORMAL} & = \beta \\ \text{TELIC} & = \tau \\ \text{AGENTIVE} & = \sigma \end{bmatrix} \end{bmatrix}$$

We can define all three basic types from (67) using the qualia and these constructors. The first two classes in (67) are defined in terms of qualia; a natural physical object is a subtype formed from predication with the atomic type, e. The natural types, $\mathcal{N}$, are those subtypes that are formally structured as a join semi-lattice, $\langle \mathcal{N}, \sqsubseteq \rangle$, in this domain (Pustejovsky, 2001). We say that this type occupies the value of the FORMAL quale in the type structure. The creation of a predicate that, in turn, selects for a natural type follows conventional functional typing assumptions: for any type τ in the subdomain of natural types, $\tau \in \mathcal{N}$, $\tau \to t$ will be considered a *natural* functional type.

Once we have defined natural type entities, their corresponding functional types are defined. The creation of predicates over the subdomain of natural types follows conventional functional typing assumptions: for any type τ in the subdomain of natural types, $\tau \in \mathcal{N}$, $\tau \to t$ is a *natural* functional type. This allows us to define natural predicates such as *die* or *touch*, as: $\lambda x{:}e_N[die(x)]$, $\lambda y{:}e_N \lambda x : e_N[touch(x, y)]$.

The second class of types, *artifactual types*, are defined as any type with an associated TELIC type. For example, the concept of a potable liquid would have the typing, $liquid \otimes_T drink$. Similarly, an artifactual entity such as *bread* would be typed as, $(phys \otimes_A bake) \otimes_T eat$. The creation of functional types over the domain of artifactual types is defined as follows: for any type τ in the domain of artifactual entity types, $\tau \in \mathcal{A}$, $\tau \to t$ is an *artifactual* functional type. For example, $\lambda x{:}e_A[break(x)]$; $\lambda y{:}e_A \lambda x{:}e_N[fix(x, y)]$.

Finally, *complex types* are constructed through a type-construction operation (the dot, $\bullet$) over the domain of Naturals, Artifactuals, and Complex Types. Consider the noun *book*, a complex type denoting both the informational content and the physical manifestation of that content: $phys \bullet info$. Other examples include the nouns *lunch*, *school*, and *promise*. Constructing functional types over the subdomain of complex types is straightforward: for any type τ in the domain of complex entity types, $\tau \in \mathcal{C}$, $\tau \to t$ is a *complex* functional type. Examples include verbs such as *read*: $\lambda y{:}phys \bullet info\ \lambda x{:}e_N[read(x, y)]$.

One of the advantages of introducing a finer-grained system of types is the ability to explain the selectional constraints associated with the arguments to a predicate; that is, *die* selects for an animate entity; *assemble* selects for a semantically plural individual, and so on.

Another advantage of a richer type system, however, is the way that it facilitates new solutions to semantic analyses that were not previously available. For example, consider the problem of verbal polysemy, mentioned in Section 2.3.1 above, where a verb is able to appear in multiple syntactic contexts, with complementary or additional arguments. The examples below illustrate this phenomenon with the verb *enjoy*, an aspectual verb *begin*, and an experiencer causative, *wake up*.

(69) a. Mary enjoyed *the movie*.
b. Mary enjoyed *watching the movie*.

(70) a. Mary began *a book*.
b. Mary began *to read a book*.

(71) a. *The coffee* woke John up.
b. *John's drinking the coffee* woke him up.

What these sentence pairs illustrate is the process of *type coercion*, a semantic operation that converts an argument to the type which is expected by a predicate, where it would otherwise not be accepted (see Pustejovsky, 1995). This is an operation in the grammar ensuring that the selectional requirements on an argument to a predicate are satisfied by the argument in the compositional process. The rules of coercion presuppose a typed language such as that outlined above. By allowing lexical items to coerce their arguments, we obviate the enumeration of multiple entries for different senses of a word.

The notion that a predicate can specify a particular target type for its argument is a very useful one and intuitively explains the different syntactic argument forms for the verbs above. In sentences (69) and (70), noun phrases and verb phrases appear in the same argument position, somehow satisfying the type required by the verbs *enjoy* and *begin*. Similarly, in sentences (71), noun phrases of very different semantic classes appear as subject of the verb *wake*.

If we analyze the different syntactic occurrences of the above verbs as separate lexical entries, following the sense enumeration theory outlined in previous sections, we are unable to capture the underlying relatedness between these entries; namely, that no matter what the syntactic form of their arguments, the verbs seem to be interpreting all the phrases as events of some sort. It is exactly this type of complement selection which type coercion allows in the compositional process.

2.9 Open issues in lexical semantics

Contemporary views on what constitutes lexical knowledge still vary significantly in formal semantics, artificial intelligence, and computational linguistics. To a large extent, the nature of grammar itself is determined by what information the lexicon supplies to other linguistic components. Even with this accepted view, the lexicon has been viewed as a mostly passive module of grammar. What has changed over the past twenty years is the amount of semantic information that is associated with lexical items, as well as what is taken to be a lexical item in the first place. What started as a static repository of pure stems, with active word formation rules generating everything from inflected forms to derivational compounds, has developed into a rich library of lexically based syntactic encodings, generative operations, and type-theoretic processes.

One of the most challenging questions confronting lexical semantics researchers is perhaps how to integrate to and interface with discourse semantics and contextual information. If lexical meaning is context-sensitive at the sentence level, as suggested in previous sections, then perhaps lexical semantics should directly encode how words are ambiguous or underspecified at the level of discourse as well. It has been proposed (Lascarides and Copestake, 1999; Asher and Lascarides, 2003b; Bos, 2004) that context-sensitive approaches to both sentence composition and discourse interpretation should have a common view about meaning, some of the same formal tools, and some of the same problems. There is not only context sensitivity in both lexical and discourse meaning but also interdependence.

It has alternatively been suggested that this issue reduces to the question of how "pragmatic enrichment" is formally handled in the interpretation of a contextually situated utterance. Some researchers argue that pragmatic or situational frames encode "unarticulated constituents" that fill in the gaps in the interpretation of an utterance left by a syntactically impoverished sentence (Travis, 1981; Bach, 1994; Sperber and Wilson, 1995; Carston, 2002; Recanati, 2004). Countering this view, Stanley (2002a,b), Stanley and Szabó (2000), and others claim that any truth-conditional effect of extra-linguistic context to a sentence can be traced to the logical form of the lexical items involved. Both theories have data to support their arguments and there are merits to both positions. Some resolution to this question may in fact come from computational models of discourse and how lexical knowledge is exploited in context.

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3

Sentential semantics

Peter Pagin

3.1 Sentences and sentence meaning

There are three basic conceptions of a *sentence*: syntactic, semantic and pragmatic (Stainton, 2000). According to the syntactic conception, a sentence is an expression with certain grammatical properties, as specified in a grammar. According to the semantic conception, a sentence is an expression with a certain type of meaning, for instance a sentence expressing a *proposition*, something that is true or false (with respect to the actual world). According to the pragmatic conception, a sentence is an expression with a certain kind of use, typically that of making a *speech act*.

These three conceptions are naturally enough pretty well correlated. Speakers of natural languages typically use sentences in the grammatical sense for making speech acts and expressing propositional thoughts by means of the sentence meaning. Nevertheless, in many cases they come apart. On the one hand, speakers often use sub-sentential expressions, such as 'Reserved for tonight', pointing to a chair (Stainton, 2000, p. 446), for making a speech act.

On the other hand, very often, what is a grammatical sentence does not have a meaning that is simply a propositional content in an ordinary sense. This can happen for a variety of reasons, such as indexicality, presupposition, conventional implicature, discourse phenomena, interrogative mood.

In this chapter, we shall be concerned with sentences in the syntactic sense, and we shall look at how semantic theories of various types model sentence meaning. In some cases we will also consider their philosophical motivations. The topic will be delimited in certain ways. We shall only discuss *declarative* sentences (see Dekker et al., Chapter 19, and Portner, Chapter 20 for chapters on non-declaratives). We shall also not cover dynamic phenomena in discourse semantics (see Asher, Chapter 4). We are also not going to discuss presupposition and similar phenomena in the semantic/pragmatics interface (see Schlenker, Chapter 22). We *shall* be concerned with semantic context dependence and related phenomena.

One of the key features of the syntactic conception of a sentence is that sentences are syntactically (or morphosyntactically) *complex*. Since they result from combining linguistic elements, there is a question of how the meaning of the sentence is related to the meanings of its *parts* and the way they are combined. This will be the topic of Section 3.3. The rest of the chapter is organized as follows: Section 3.2 gives a conceptual background for talk about meanings and semantic values. Section 3.3 presents the idea of semantic compositionality, informally and formally. Section 3.4 presents Frege's views on sentence meaning, and Section 3.5 does the same for Davidson's. Section 3.6 gives a presentation of possible-worlds semantics and is followed by sections on Montague semantics (3.7), Kaplan style semantics (Section 3.8), centred-worlds propositions (Section 3.9), relativism (Section 3.10), two-dimensionalism (Section 3.11), and situation semantics (Section 3.12). Section 3.13 is concerned with structured meanings, Section 3.14 with verificationism, and Section 3.15 with procedural semantics. Section 3.16 contains some concluding words.

3.2 Semantic values and meta-semantics

There are two main formats that a semantic theory takes with respect to sentences. First it can ascribe one or more *properties* to sentences and specify the *conditions* under which a sentence has this property or properties. Typically the property is that of *being true*, or some property similar to or related to that. Truth definitions are of this kind. Let us call this the *axiomatic* style.

The alternative is to assign explicit *semantic values* to sentences. The semantic theory then takes the format of specifying one or more *semantic functions* that map expressions on semantic values. Let us call this the *algebraic* style.

These two formats are typically inter-translatable. For instance, in a *truth-theoretic* (axiomatic) format, the meaning specification for sentences takes the form of material biconditionals of the form 's is true iff p' (see Section 3.5). Whether the sentence s is true, then, depends on whether p is the case, which is determined by the (actual) world. In a corresponding algebraic framework, we have a function μ that assigns values 1 (for truth) or 0 (for falsity) to sentences, and we can equally ask for the conditions under which the value is 1.

By contrast, whether we include possible worlds, and therefore have an *intensional* semantics, or leave possible worlds and similar entities out of the semantics makes a crucial difference. This difference, in turn, is related to the distinction between semantics and meta-semantics. In an *extensional* semantics, the standard semantic value of a one-place predicate is a set of objects – informally, the set of objects of which the predicate is true.

The conditions for being in the extension of the one and for being in the extension of the other, however, are intuitively distinct. You can take account of this in two different ways. The first is semantic. You add intensions to your semantic theory, typically as functions from possible worlds to extensions. Then you have a theory with two levels: on one (upper) level intensions, and on the other (lower) level extensions with respect to worlds.

The second way is meta-semantic. Semantics proper only deals with extensions, but there are certain facts in the world which combine to determine what the semantic value is. These facts, how they combine and how they select the semantic value, on this view fall strictly outside semantics. The debate concerning the meaning of proper names, between Fregeans and Millians, exhibits this conflict over meaning determination. For Fregeans it belongs to semantics (*sense*), while for Millians it does not.

Many semantic frameworks include more than one type of semantic value or property, often but not always at different levels. Whether the framework has certain formal properties, such as compositionality, can then be asked for each of the types of value separately (is *extension* compositional; is *intension* compositional?). In some cases the different kinds of value interact in such a way that it is rather the system as a whole that must be characterized, as we shall see.

3.3 Compositionality

There is a remarkable fact about human linguistic communication: language users manage to successfully communicate new thought contents (contents not thought before) by means of new sentences (not used or considered before). Since mind-reading is out of the question, and *chance* would deliver a microscopic rate of communicative success (given how many sentences and contents there are), there must be something about language itself that makes this possible, as was also noted by Frege (1914, 1923):

> It is astonishing what language can do. With a few syllables it can express an incalculable number of thoughts, so that even a thought grasped by a terrestrial being for the very first time can be put into a form of words which will be understood by somebody to whom the thought is entirely new. This would be impossible, were we not able to distinguish parts in the thought corresponding to the parts of a sentence, so that the structure of the sentence serves as an image of the structure of the thought. (Frege, 1923, opening paragraph)

The hearer's task in communication is that of finding an appropriate *interpretation* of an utterance. On a widely accepted view, the ability to discharge this task for *new* sentences is made possible by a systematic correlation between the syntactic build-up of sentences and their meanings. It is common to spell out this correlation by means of the principle of *compositionality* (PC):

(PC) The meaning of a complex expression is a function of the meanings of its parts and its mode of composition.

(First stated in this format by Partee, 1984a, p. 281)

We shall say that the *semantics* of language is compositional or not, intending the assignment of meaning by some particular semantic function or semantic theory. In a derivative sense, we can say that the *meaning property* of a particular language is compositional if the *correct* semantics for it is compositional in the first sense.

In interpreting (1a), given the syntactic structure of (1b),

(1) a. John saw the dog
 b. $[_{S}\ \text{John}_{NP}\ [_{VP}\ \text{saw}_{VT}\ [_{NP}\ \text{the}_{Det}\ \text{dog}_{N}]]]$

the hearer knows the meaning of *the*, *dog*, *John*, and *saw*, and the semantic significance of (a) the Determiner + Noun (Det+N) combination, (b) the Verb (transitive) + Noun Phrase combination (VT+NP), and (c) the Noun Phrase + Verb Phrase combination (NP+VP). He starts with working out the meaning of *the dog*, using (a), goes on working out the meaning of *saw the dog*, using (b), and finishes by working out the meaning of (1a) from there, using (c).

Although (PC) is a standard formulation, what is meant by 'part', as the principle is normally understood, is *immediate part* (immediate constituent). The principle is often incorrectly stated as saying that the meaning of the complex expression is a function of the meanings of the *simple parts* and the way they are combined. But this principle is degenerate. The mode of combination of the *simple* parts in (1) is in itself a combination of Det+N, VT+NP, and NP+VP constructions, and the speaker would have to know the semantic significance of that complex mode. In fact, there are denumerably many ways of combining simple parts, and so if the hearer needs to know the semantic significance of each, the explanation of how he can understand new sentences cannot any more appeal to a working out strategy based on *finite* knowledge.

A principle closely related to (PC) is the principle of *substitutivity* (PS) (where '$A[e'/e]$' designates the expression that results from substituting e' for e in one or more occurrences).

(PS) If in a complex expression A a constituent e is replaced by a constituent e' that has *the same* meaning as e, then the meaning of the new expression $A' = A[e'/e]$ has the same meaning as A.

The intersubstituted constituents need not be immediate. In fact, if the semantics is *total*, so that each grammatical expression is meaningful, then (PC) and (PS) are *equivalent*.

If, by contrast, the semantics is *partial*, the two principles can come apart. On the one hand, if not all parts of a complex expression are meaningful, then the meaning of the complex is trivially not a function of the meanings of the parts ((PC) does not hold), but it can still hold that when two parts with the same meaning (i.e. meaningful parts) are intersubstituted, the meaning of the complex is preserved ((PS) holds). On the other hand, it may also be that A is meaningful, and that e and e' mean the same, yet $A[e'/e]$ is *not* meaningful ((PS) does not hold), while it is still true that the meaning of every complex expression that *has* meaning is a function of the meaning of its parts and their mode of combination ((PC) holds).

These observations are due to Wilfrid Hodges (2001). He calls the principle that the parts of every meaningful expression are meaningful *the domain principle*. The principle that if two expressions mean the same, then substituting the one for the other does not lead to loss of meaningfulness in the complex is called *the Husserl principle* (and the semantics *husserlian*) by Hodges. He also proved that given that the domain principle and the Husserl principle hold, (PC) and (PS) are again equivalent, even if the semantics is partial.

Using the equivalence, we can see that (PC) in several respects is quite weak. To get a counterexample to (PS), and thereby to (PC), we need two expressions e and e' with the *same* meaning, and two complex expressions, A and $A[e'/e]$ with *different* meanings. If there is no counterexample, (PS) and hence also (PC) hold. Now, if no two different expressions in the language in question have the same meaning (meaning is *hyperdistinct*), then no counterexample is possible, and hence the semantics is vacuously compositional. Similarly, if no two expressions in the language differ in meaning, again the semantics is trivially compositional.

The first of these two observations, that hyperdistinctness entails compositionality, is somewhat damaging for the explanatory power of compositionality. It may be that the meaning of complex expressions of a language obeys no regularity whatsoever, so that it is impossible to *work out* the meaning of a new complex expression, and yet because of hyperdistinctness, meaning is compositional. So compositionality alone does not explain how speakers can work out the meaning of new complex expressions. Some further property related to processing is required (see Pagin, 2012).

So far we have been talking as if semantic values or properties are assigned to *expressions*, where expressions are understood as *surface* forms, that is, types of spoken utterance, types of written inscriptions, or types of other concrete marks or events. Surface forms are, however, often syntactically ambiguous. Two different words may have the same surface form (homonymy), and complex expressions may on top be structurally ambiguous. Since different disambiguations often yield different meanings, we must define the semantic function for *disambiguated expressions*, such as analysis trees, or *grammatical terms*.

For setting out compositionality formally, we therefore need a syntactic framework, which specifies disambiguated expressions of the language, together with a domain of possible semantic values. Then the semantics is defined as a function from disambiguated expressions to semantic values. In the modern tradition, there are two approaches to this. Both are algebraic, in the sense that the syntax is conceived of as an *algebra* with syntactic operations defined over a basic set of expressions. In the tradition from Montague (1970b, 1973b), Janssen (1986, 1997) and Hendriks (2001), the syntax is built up from *categories* of expressions and corresponding sets of expressions of these categories. There are also rules that specify the categories of the arguments and values of syntactic operations. We shall look more closely at this idea in Section 3.7 on Montague semantics.

In the more recent tradition from Hodges (2001), there is no appeal to categories and types. Instead, syntactic operations are taken to be *partial*; they are defined only for certain arguments (combinations of arguments). We shall here follow Hodges, with some modifications. The syntax for a language L is a triple (G_L, E_L, V_L), where G_L is a *grammatical term algebra*, E_L is the set of *expressions* of L, and V_L is a mapping from grammatical terms to expressions (for convenience we shall henceforth drop the subscript). G itself is a triple (T, Σ, A), where T is the set of *grammatical terms*, Σ the (finite) set of *operations* that map n-tuples of grammatical terms on grammatical terms, and A is a (finite) set of *atomic* grammatical terms. T is the *closure* of A under Σ, that is the set of terms that are generated from A by means of (possibly repeated) applications of the operations in Σ.

To exemplify, let A be the set {'John', 'saw', 'the', 'dog'} and Σ the set $\{\alpha, \beta, \gamma\}$, corresponding to the rules for forming Det+NP, VT+NP, and NP+VP, respectively, of Example (1). Then the grammatical term that corresponds to the phrase structure analysis (1b) is as follows:

(2) γ('John', β('saw', α('the', 'dog')))

The V function maps the grammatical terms on the expressions of L. For each operation σ on terms, there is a corresponding operation $\overline{\sigma}$ on expressions such that

(V) $V(\sigma(t_1, \ldots, t_m)) = \overline{\sigma}(V(t_1), \ldots, V(t_n))$

In the very simple case of our example, we just have the equation in (3) where σ is α or β or γ, and '␣' marks a word boundary (space).

(3) $V(\sigma(t_1, t_2)) = V(t_1)␣V(t_2)$

After three applications of (V), we therefore get the following in (4):

(4) $V(\gamma($'John', $\beta($'saw', $\alpha($'the', 'dog'$))))$ = 'John'␣'saw'␣'the'␣'dog'

This is a structural-descriptive name of *John saw the dog*.

No abstract limitations are imposed on V (such as that the value of the first argument should appear in the expression (surface string) to the left of the value of the second argument), although a number of restrictions will be empirically motivated, in order that the hearer be able to parse the string. The algebraic framework as such is very general; it can be adapted to phrase structure rules as well as to transformations or movements.

A *semantic* function μ is also defined on the grammatical terms, mapping terms on a domain M of semantic values. Given the algebraic framework, we can now state a more formal version of (PC):

(PC′) For every n-ary syntactic operation $\sigma \in \Sigma$, there is a function $r_\sigma : M^n \longrightarrow M$ such that for all grammatical terms $t_1, \ldots, t_n$ such that $\alpha(t_1, \ldots, t_n)$ is defined and μ-meaningful, it holds that $\mu(\alpha(t_1, \ldots, t_n)) = r_\sigma(\mu(t_1), \ldots, \mu(t_n))$.

We call the function r_σ a *meaning operation*. If (PC′) holds for a semantic function μ, we say that μ is compositional. Compositionality is a general formal property that any particular semantic function, *given* a syntax, either has or lacks.

Historically, the first precise statement of (PS) was given by Frege (1892b, p. 32), for *Bedeutung*. Clarity about (PC) developed slowly after that and did not reach maturity until the mid-to-late 1970s. In the following sections we shall see how this definition applies to various types of semantic theory. In some cases, we will find reason to go beyond the standard compositionality expressed in PC′. For more on compositionality, see Janssen (1997), Szabó (2008), Pagin and Westerståhl (2010a,b, 2011).

3.4 Frege

During the seventeenth, eighteenth, and nineteenth centuries, the idea of *judging* something to be the case and *what* one judges to be the case were not sharply distinguished. On the contrary, it was assumed that a judgment has at least two components (a *subject idea* and a *predicate idea*), and it is precisely through the *judging*, and in particular the *affirming*, that the two ideas are combined into a complex whole.

Anticipated by Bolzano, Frege insisted that the judging activity and content must be separated. He argued in the late essay 'Negation' (Frege, 1918b) that logically complex sentences, such as negations and conditionals, when affirmed, contain subsentences with contents that may be denied (in the case of negation) or not judged at all (in the case of the conditional). Since the content of the complex sentence contains parts that correspond to the subsentences, the subsentences too must have contents, even though they are not affirmed. Having content must therefore be distinct from being affirmed.

The view itself was already in place in Frege's middle period (especially Frege, 1892b), when he developed his mature ideas of linguistic meaning. Frege employed two semantic values, *reference* (*Bedeutung*) and *sense* (*Sinn*). These notions are introduced at the beginning of Frege (1892b), applied to the case of proper names, in order to solve the problem of the difference between informative and uninformative true identity statements. The concept of the sense of an expression is explained to be that which contains the *mode of presentation* of the referent.

In the case of a proper name, the reference is the bearer of the name. To exemplify different modes of presentation of the bearer, Frege uses definite descriptions. For instance, for the name *Aristotle*, Frege suggests 'the student of Plato and teacher of Alexander the Great' (Frege, 1892b, note 2) as articulating the sense/mode of presentation. However, Frege does not say that it is invariably the case that the name is synonymous with some (non-trivially formed) definite description.

For Frege, truth values, The True and The False, are objects. The sense of a sentence, then, what Frege called a *Thought* (ein *Gedanke*), is then (what contains) a mode of presentation of either The True or The False. So as in most theories of sentence meaning, the non-extensional semantic value is defined in relation to truth and falsity. However, Frege's theory is not truth-conditional in any ordinary sense. *Sense* is not meant to encode the conditions under which the sentence refers to The True.

Frege does not specify the relation between sense and reference in purely semantic or metaphysical terms, but rather in *cognitive* terms. For instance, as spelled out by Perry (1977), Frege appears to accept the following as a *criterion of difference of sense*:

(Dif) If A understands S and S', and accepts S as true while not accepting S', then S and S' have different senses.

So, sense is as fine-grained as the discriminations that subjects make in their attitudes. This combines well with his semantic view about difference of sense. As mentioned above, Frege stated the substitution principle for Bedeutung (see (PS), p. 69), but did not state it separately for Sinn. He did, however, seem to believe in the substitution version of *inverse compositionality* for sense:

(PIC) For any complex expressions A and A', if A and A' have the same meaning, then A' results from A through replacing some sub-expressions $e_1, \ldots, e_n$ by some expressions $e'_1, \ldots, e'_n$, respectively, where e'_i has the same meaning as e_i, for $1 \leq i \leq 1$.

(PIC) is a sufficient condition for difference of meaning. Given two complex expressions A and A', if their top structure, i.e., the mode of composition of their immediate constituents, are different, then they differ in meaning, and if any of their corresponding immediate constituents differ in meaning, then A and A' differ in meaning as well. As pointed out by Heck and May (2011), Frege seems to have believed in the inverse compositionality for *sense*. For Frege it was important that mathematical expressions differing as much as e.g. '4×4' and '2^4' also differ in sense (discussed especially in Frege, 1891). Compositionality does not force the expressions to differ in sense, only allows them to.

The (Dif) principle is closely related to Frege's semantics for attitude contexts, or more generally, what he called *indirect contexts*. Indirect contexts include *oratio obliqua* contexts and attitude contexts. It is part of Frege's doctrines about sense (1892b) that expressions occurring in indirect contexts have an *indirect reference* and that the indirect reference is the same as the ordinary sense. Thus, in (5) the embedded sentence *Hesperus is a planet* does not have its ordinary reference (The True), but its indirect reference, which is the Thought *that* Hesperus is a planet.

(5) John believes that Hesperus is a planet.

This doctrine of indirect reference avoids violations of the (PS) principle for reference. For it may be that (5) is true, while (6) is false, despite the coreference of *Hesperus* and *Phosphorus*:

(6) John believes that Phosphorus is a planet.

This would violate the (PS) principle for reference, since we get (6) from (5) by substituting *Phosphorus* for *Hesperus*. By the doctrine of indirect reference, the two names differ in reference in this context, given that they already differ in sense.

Nonetheless, the standard principles (PC) and (PS) of compositionality are not satisfied for reference in Frege's semantics, since they do not make provision for the idea that the semantic value of an occurrence of an expression may depend on the *linguistic context* of that occurrence. In fact, Frege's semantics makes the reference of belief sentences depend on the *senses* of some of its part. Letting μ_r be the reference function and μ_s the sense function, we can state the general clause for belief sentences as follows:

(7) $\mu_r(B(N, p)) = r_b(\mu_r(N), \mu_s(p))$

Here '$B(N, p)$' is short for 'N believes p', and r_b is a function such that $r_b(x, y) =$ True iff x is belief-related to y (where y is a Thought).

This clause is clearly not compositional, since there is a *switch* from μ_r to μ_s for the second argument to B. There is, however, a generalization of standard compositionality that accepts such switches. *General compositionality* holds for a set $S = \{\mu_1, \ldots, \mu_n\}$ of semantic functions, where one element, say μ_1, is *designated* as applying to *unembedded* occurrences of expression. So semantic evaluation starts with μ_1. The semantics makes use of a *selection function* $\Psi : S \times \Sigma \times N \longrightarrow S$ that maps a semantic function, a syntactic operation, and an argument place on a semantic function. The principle of general compositionality can then be stated as follows:

(GPC) A system $S = \{\mu_1, \ldots, \mu_n\}$ of semantic functions is *general compositional* iff there is a selection function Ψ such that for every k-ary operation α and every member $\mu_i \in S$ there is a meaning operation r_{α,μ_i} such that for any terms $t_1, \ldots, t_k$, if $\alpha(t_1, \ldots, t_k)$ is μ_i-meaningful, then

$$\mu_i(\alpha(t_1, \ldots, t_k)) = r_{(\alpha,\mu_i)}(\mu_{j_1}(t_1), \ldots, \mu_{j_k}(t_k))$$

where $\mu_{j_m} = \Psi(\mu_i, \alpha, m)$, $1 \leq m \leq k$.

Standard compositionality is the special case where S has just one element (cf. Pagin and Westerståhl, 2010c).

As stated in (GPC), a general compositional system S has finitely many members. There is a question whether Frege's semantics meets this condition. In the equation (7), the semantics only makes use of the fact that the reference of the belief sentence depends on the sense of the embedded sentence, not on the additional idea that the sense of the embedded sentence also is the reference, *in that context*. Given Frege's idea that the sense of an expression *presents the referent*, and hence *determines the referent*, it may seem that the sense of the *embedded* occurrence of the embedded sentence in (5), *Hesperus is a planet*, must have a sense different from its ordinary sense, an *indirect sense*. It is therefore a common interpretation of Frege that there is an infinite *hierarchy* of indirect senses. In a simply iterated belief sentence like (8), the sentence (5) occurs in an indirect context, and so has indirect reference.

(8) Bill believes that John believes that Hesperus is a planet.

The sentence *Hesperus is a planet* occurs *doubly embedded* and so occurs in an indirect indirect context. On some interpretations of Frege, the sentence then has a doubly indirect reference. The doubly indirect reference, in turn, is the *simply indirect sense* it has as embedded in (5). Doubly embedded in (8), it has a doubly indirect sense. And so on. Using superscript indices for level, where $\mu^0 = \mu_r$ and $\mu^1 = \mu_s$, and a corresponding index on the meaning operations r_b^i, we would have the equation in (9):

(9) $\mu^i(B(N, p)) = r_b^i(\mu^i(N), \mu^{i+1}(p))$

There is some textual evidence that Frege actually believed in indirect senses (see Frege, 1902). With infinitely many senses μ^j, $j = 0, 1, 2, \ldots$, the condition of general compositionality that S is a finite set is not met. Frege has also been criticized in the literature (e.g. in Davidson, 1965) for providing an *unlearnable semantics*. Note that it is not the semantic switching in itself that motivates the hierarchy, but the ideas that the sense plays the double roles of reference in the indirect context *and* reference determination.

One last consequence of this idea deserves to be mentioned. In Frege's semantics, syntactic combination invariably has the form of letting one expression fill an *argument place* in another expression. A one-place predicate is an *unsaturated expression*, that is, it has an argument place, and in this case for a singular term. When the argument is given, we get a sentence. Correspondingly, the semantic significance of such a combination is *function application*: the reference of the unsaturated expression is a function, which applies to the reference of the argument expression. Thus, we have in general the following (AP = application):

(AP) $\mu_r(\alpha(t)) = \mu_r(\alpha)(\mu_r(t))$

Now, although Frege did not claim that sense is compositional, the idea that reference is compositional (modulo context) and that ordinary sense is a kind of reference naturally leads to the claim that sense is compositional (modulo context) as well. That is, we should, at least in all cases that do not involve context shift, apply (AP) to sense as well (just substitute 's' for 'r').

However, this idea is problematic. It cannot plausibly be combined with the idea, which Frege also had (e.g. in Frege, 1923), that the sense of a *part* of an expression is a *part* of the sense of the whole. For if the sense of α is a function that applied to the sense of t gives as value the sense of $\alpha(t)$, which in turn contains the sense of α as a proper part, then the sense of α is a non-well-founded entity: it is a function defined partly in terms of itself (see Dummett, 1981a, p. 293).

All in all, Frege's conception of the sense of a sentence contains several strands that are in conflict with each other. This comes out even more in his account of indexical expressions (Frege, 1918a).

3.5 Davidsonian truth-theoretic semantics

On the face of it, Davidson-style truth-theoretic semantics is a straightforward truth-conditional semantics, where sentence meaning is specified in the following format:

s is true in L iff p.

However, things are more complicated. On one level, there is a semantic theory of an axiomatic kind, which uses only extensional concepts. On a second level, there are meta-semantic ideas about the *modal force* of the theorems of such a theory. On a third level, again also meta-semantic, there is an idea that meaning is captured by *sets* of such theories. On top, there is an elaborate meta-semantic theory, of *radical interpretation*, for selecting the right set of theories. This presentation will be based on the papers collected in Davidson (1984).

A truth-theory T is intended to have the form of a Tarskian truth definition but is meant to be an empirical theory about a natural language *L*. The language is identified as the language spoken by a particular speaker, (call her S). Davidson (1965, 1967b) argues that a meaning theory must show how it is possible for a speaker with finite knowledge to have infinite capacity, that is, the capacity to understand in principle each of the infinitely many meaningful sentences of a natural language. Although he does not use the term, his general requirements are, nearly enough, that such a theory should be compositional. More specifically, it should be an *axiomatic* theory with the following components:

(i) Axioms for simple singular terms
(ii) Axioms for simple predicates
(iii) Recursive semantic clauses for constructions
(iv) Theorems for sentences

For each sentence *s* of the object language, the theory must contain a theorem that specifies the relevant semantic property of *s*. The theorems are to be derivable from the axioms, by means of the recursive clauses, and a suitable set of rules of inference.

He also argues (Davidson, 1967b, pp. 20–22) that such a theory should use only extensional semantic vocabulary. The reason is that intensional vocabulary, such as 'means that', creates non-extensional contexts that create problems for the derivations, rendering some needed rules of inference invalid. He suggests that the proper way of satisfying these requirements is to use the Tarskian format of a truth definition. The semantic ingredients are, then, as follows:

(i) a *reference* function *R* that assigns referents to simple closed terms;
(ii) a *satisfaction* relation SAT relating infinite sequences of objects and open sentences (possibly containing free variables);
(iii) a truth property.

All of these are relativized to an object language. Davidson's official position here is to assume a prior understanding of *truth*, while *reference* and *satisfaction* are *instrumental* notions, used only for deriving the theorems. The set of theorems, specifying sentence meanings, makes up the entire empirical content of such a semantic theory, called a *T-theory*. For the simple case of the language of predicate logic, we set out a version of the format of the clauses below. The symbol s with subscripts ranges over open and closed sentences; σ with subscripts ranges over infinite sequences of objects, and $\sigma_i(j)$ is the object in the j:th position of sequence σ_i. We use $\sigma[a/b]$ to denote the sequence that results from σ by replacing object b, wherever it occurs in σ, by object a. We use x with subscripts for object language variables, and t with subscripts for object language closed singular terms. F_i is used for an object language predicate, and G_i for the corresponding meta-language predicate. $A(t_1, \ldots, t_n)$ is an object language (open or closed) sentence that contains the terms $t_1, \ldots, t_n$. We use $\vdash_T$ to indicate that the sentence that follows is derivable in the T-theory. Then we have the following:

(TT) Clauses in a T-theory for a first-order language:

(i) $\vdash_T R(t) = a$

(ii) $\vdash_T \textsc{sat}(\sigma, F_i(x_1, \ldots, x_n))$ iff $G_i(\sigma(1), \ldots, \sigma(n))$

(iii) $\vdash_T \textsc{sat}(\sigma, At_1, \ldots, t_n)$ iff $\textsc{sat}(\sigma[R(t_i)/\sigma_i], Ax_1, \ldots, x_n)$, $1 \leq i \leq n$

(iv) $\vdash_T \textsc{sat}(\sigma, s_1 \,\&\, s_2)$ iff $\textsc{sat}(\sigma, s_1)$ and $\textsc{sat}(\sigma, s_2)$

(v) $\vdash_T \textsc{sat}(\sigma, \neg s)$ iff it is not the case that $\textsc{sat}(\sigma, s)$

(vi) $\vdash_T \textsc{sat}(\sigma, \exists x_i A)$ iff there is an object a such that $\textsc{sat}(\sigma[a/\sigma(i)], A)$

(vii) $\vdash_T \mathrm{T}(s)$ iff for all sequences σ, $\textsc{sat}(\sigma, s)$.

(i) gives the general form of reference axioms for simple terms, and (ii) gives the form of satisfaction axioms for simple predicates. (iii) provides the semantics for predication, that is, atomic sentences. (iv) and (v) give the recursive clauses for conjunction and negation, while (vi) gives the clause for the existential quantifier. Finally, (vii) equates truth with satisfaction by all sequences, just as in Tarski. We derive a theorem, a so-called T-sentence, by starting with (vii), and then applying rules according to the form of the object language sentence, substituting on the right-hand-side, until the right-hand side no longer contains any occurrence of ‘SAT’ or ‘R’.

Together with these clauses, we need to specify the inference rules that apply. It cannot be the case that the T-theory is closed under all *logically valid* rules, because that would generate many theorems that would not be of the right kind. Davidson (1973, p. 138) suggested what he called ‘canonical proofs’. He did not spell out the details, but suggested that a canonical proof ‘moves through a string of biconditionals’. In particular, a rule of substitution must be added: if it holds that $\vdash_T p$ iff q, then ‘p’ and ‘q’ may be inter-substituted in $\vdash_T$ contexts. By these means, we will be able to derive T-sentences of the form below:

$$\vdash_T \mathrm{T}(s) \text{ iff } p$$

Davidson and others set out a program to develop the truth-theoretic framework to handle other features of natural language. Davidson himself adapted it to simple context dependence, quotation, and indirect discourse. Others have extended it much further, applying it to other natural language constructions, and spelling out proof procedures (see Larson and Segal, 1995; Lepore and Ludwig, 2005).

From the point of view of capturing natural language meaning, there is a strong suspicion that T-theories, being extensional, are much too weak. Davidson himself pointed out that a sentence like (10) below is true, since both the left-hand-side and the right-hand-side of the biconditional are true, and since the biconditional is material, nothing more than that is needed.

(10) 'Grass is green' is true in English iff snow is white.

Part of the answer is to point out that it is not enough for a biconditional of the theorem form to be true in order to qualify as being a true T-*theorem*. In order to be a true theorem the T-sentence must be derivable, in the canonical way, in a T-theory *all of whose* theorems are true. That will weed out all individual T-sentences that just happen to be true. But it is not enough to weed out systematic error (see Foster's objection below on p. 79).

Another part of the answer by Davidson (1967b, 1973, 1974) consisted in the appeal to meta-semantic theory of *radical interpretation*, which selects T-theories. Radical interpretation relates T-theories to belief ascriptions (in the first place), by means of inferences of the following kind.

(11) (1) Speaker S holds sentence *s* true.
(2) $\vdash_T$ *s* is true iff *p*
(3) Hence, S believes that *p*.

For the radical interpreter, who tries to find an appropriate T-theory for the speaker S, premise (1) specifies part of the *data*; without knowing what *s* means the interpreter can notice, on the basis of the speaker's behaviour (like overt assent), that she or he holds a sentence true. Premise (2) is provided by the current semantic *hypothesis* of the interpreter. The conclusion is a belief attribution to S. If that attribution is reasonable, this confirms the semantic hypothesis. If it is *un*-reasonable, the hypothesis is *disconfirmed*.

What are reasonable belief attributions? The basic observation is that too much attribution of false beliefs and inconsistent beliefs undermines an interpretation that leads to them via inferences of type (11). *The principle of charity* says that *correct* interpretations *maximize* or *optimize* attributions of true and consistent beliefs. Charity is applied to the theory as a whole: only the best theories (those that are not inferior to others) are acceptable. The principle of charity is a criterion of acceptability, not primarily a heuristic for finding the best theories.

The fact that a language contains context-dependent sentences helps select theories by appeal to charity: sentences held true in some contexts but not in others help confirm theories that correlate them with true beliefs about the current context.

Those theories that are acceptable by appeal to charity are sometimes called *interpretive*. So, it is part of the Davidsonian concept of sentence meaning that sentence meaning is specified by a T-sentence provided it is a theorem of an interpretive T-theory.

This still leaves some loopholes, however. One was suggested by Foster (1976). Suppose we have an interpretive T-theory T_1. Then, we devise another theory T_2, so that they are related for any *s* and *p* as follows:

(12) a. $\vdash_{T_1} T(s)$ iff p
b. $\vdash_{T_2} T(s)$ iff the Earth moves and p

Given that the Earth *does* move, the two theories are equally well supported by charity, and should both be correct if one of them is. According to Davidson's reply (Davidson, 1976), acceptable T-theorems have a kind of modal force: they are *lawlike*. That they are lawlike means that they are *counterfactual supporting*: if the speaker *were to hold s* true, she or he *would* believe that *p*. The upshot is that although T_2 is true if T_1 is true, its theorems can fail to be lawlike. Thus, it is part of Davidson's conception of sentence meaning that it creates a nomic connection between holding true and belief.

Finally, since there is no guarantee that there is a unique best theory, by the charity criterion, how do we make a selection among the best? We do not. According to Davidson, they are *all* correct. They may appear on the surface to be mutually incompatible, but according to Davidson the true empirical content of interpretive T-theories is precisely what is *common* to them. The underlying facts about the speakers' attitudes are captured differently by different theories, but they are equivalent in capturing the same underlying facts. Davidson (1979) compares the situation to measuring temperature with different scales, Centigrade and Fahrenheit; different numerical values are offset by the difference in scales and so capture the same physical states. This is Davidson's *indeterminacy* of interpretation. The meaning of a sentence is precisely what is shared between what all correct (interpretive) T-theories say about it.

3.6 General possible-worlds semantics

Possible-worlds semantics is a purely semantic framework. It is not associated with any particular meta-semantic theory or any particular foundational view. The idea of possible worlds was first suggested by Leibniz. In the twentieth century it was reintroduced by Wittgenstein (1922; the space of logical possibilities) and Carnap (1956, first edition, 1947). For Carnap, a possible world was a total consistent state-description, hence a linguistic item. The possible-worlds framework was developed in the late 1950s by the addition of a so-called accessibility relation, due to Hintikka (1962), Kanger (1957c), and Kripke (1963).

The possible-worlds framework is used both descriptively and model-theoretically. In model theory, the main purpose is to give a semantics for modal operators and characterize logical properties of sentences containing them. Descriptive semantics assumes that a domain of possible worlds is given. The nature of possible worlds is largely a metaphysical question.

The basic semantic framework associates each non-logical expression *e* with semantic properties on two levels: *e* has an extension with respect to every possible world, and it has an intension, which is a *function* from possible worlds to extensions. If the semantics is partial, the intension may be undefined for some worlds; for instance, the intension of a proper name might be undefined with respect to worlds where the actual world referent of the name does not exist. Note that the intension is the *value* of the semantic function (μ), not the semantic function itself; the intension takes worlds as arguments, not expressions. Since we get extensions by application of the intension, one semantic function is sufficient.

Sentence meaning is then modelled as a function from possible worlds to truth values (sometimes as sets of possible worlds – those worlds where the sentence is true). This is the basic notion of a *possible-worlds proposition*. In a truth definition format, the clause for the necessity operator $\Box$ is that $\Box p$ is true at a world $\boldsymbol{w}$ iff p is true at all worlds $\boldsymbol{w}'$ accessible from $\boldsymbol{w}$, where R is the accessibility relation:

(Nec) $\models_{\boldsymbol{w}} \Box p \quad \text{iff} \quad \models_{\boldsymbol{w}'} p \quad \text{for all worlds } \boldsymbol{w}' \text{ such that } \boldsymbol{w}R\boldsymbol{w}'$

Where $\mu(p)$ is an *intension* I, the corresponding intension for $\Box p$ is a function I′ such that for a world $\boldsymbol{w}$, $\mathrm{I}'(\boldsymbol{w}) = 1$ iff $\mathrm{I}(\boldsymbol{w}') = 1$ for all worlds $\boldsymbol{w}'$ accessible from $\boldsymbol{w}$. To render this in the algebraic format we define a function r_N as in (13), where I is an intension.

(13) $r_{\mathrm{N}}(\mathrm{I})(\boldsymbol{w}) = 1$ iff $\mathrm{I}(\boldsymbol{w}') = 1$, for all worlds $\boldsymbol{w}'$ accessible from $\boldsymbol{w}$.

And then the necessity clause is simply as in (Nec′).

(Nec′) (i) $\mu(\Box p)(\boldsymbol{w}) = r_{\mathrm{N}}(\mu(p))(\boldsymbol{w})$
(ii) $\mu(\Box p) = r_{\mathrm{N}}(\mu(p))$

Here the first sub-clause gives the application of the intension to a world $\boldsymbol{w}$, and the second sub-clause gives the equivalent non-applied form. It clearly conforms to the compositional format.

One question here is whether possible-worlds semantics satisfies the condition of giving the content of attitudes by means of the truth conditions of sentences. If Bill holds true (14a), is the content of his belief really specified by (14b)?

(14) a. John may be a secret agent.
b. There is a world $\boldsymbol{w}$ accessible from the actual world $\boldsymbol{a}$ such that John is a secret agent in $\boldsymbol{w}$,

Is it a belief about the existence of some possible world? From the point of view of possible-worlds semantics as a descriptive semantics, the answer must be *yes*. Bill represents a proposition to himself by means of (14a), and that same proposition is more explicitly expressed by means of (14b). In order to systematically describe the semantic properties of the object language, the meta-language has to be more explicit. Indeed, this is a theme in much of what follows: the object language, e.g. with indexicals, offers a particular cognitive perspective on a proposition that is not shared by other ways of specifying the same proposition. There is intuitively a difference in meaning between (14a) and (14b), but in order to characterize it, more abstract resources are needed than those offered in possible-worlds semantics itself.

A related crucial issue concerns the individuation of propositions. It is commonly held that logical truths, such as $p \rightarrow p$, and mathematical truths, such as $1 + 1 = 2$, are true in *all* possible worlds. Because of this, all these truths have the *same* intension: the constant function I that gives the value 1 for every world as argument. Again, that means they express the *same* possible-worlds proposition. Moreover, since a conjunction $p\,\&\,q$ is true at a world just in case both conjuncts are true at that world, we have the result that for any true mathematical sentence ϕ, $p\,\&\,\phi$ expresses the same proposition as p itself. Since this goes against our intuitive meaning discriminations, we must either reject these intuitions or reject standard possible-worlds semantics as providing an adequate model of sentence meaning. The first alternative is seldom considered an option.

One possibility that has been used in the literature for several reasons (including modelling para-consistent logic, counterpossible conditionals, and inconsistent belief) is to add *impossible* worlds. Another reason is to get more fine-grained propositions. We can distinguish between p and $p\,\&\,\phi$ because there is a world where ϕ, although a mathematical truth, is false (see Priest, 1997). However, since accepting impossible worlds includes rejecting established parts of standard semantics (such as the interpretation of negation, or the recursive clause for conjunction), the topic cannot be pursued here.

In the following subsections, various enrichments of the basic possible-worlds framework will be considered. Some motivations for these theories come from the need for more fine-grained meanings, and some from attempting to handle more complex linguistic phenomena.

3.7 Montague semantics

Richard Montague pioneered the application of formal semantics in general, and possible-worlds semantics in particular, to natural language, and did so in many respects. A first step was to generalize the possible-worlds framework to handle various kinds of *context dependence*. An ordinary possible world is a point where a sentence is true or false if there are no other sources of truth value variation in the sentence. A sentence like (15) is true at some *times* and false at others.

(15) John is sitting.

Montague suggested treating times on a par with possible worlds as points of evaluation. A sentence like (15) will be true or false with respect to *pairs* $\langle w, t\rangle$ of a world w and a time t. Such a pair is an *index*, or *point of reference*, a notion that generalizes that of a possible world. Instead of just a domain W of possible worlds, the domain of indices is the full set of pairs $W \times T$ of worlds and times. In Montague (1973b), intensions are functions from world–time pairs to extensions. Together with a designated time t_0 (the now-point) of a model, and a temporal order $\leq$, this allows giving a semantics for tenses. The present tense corresponds to being true at t_0, the present perfect to being true at some time before t_0 and the future tense to being true at some time later than t_0.

Montague (1968, 1970b), considers indices more generally, including contextual factors like the *speaker* of a context. Instead of a set of times, there is a more general set J of *contexts of use*. Context-of-use indices allow a treatment of demonstratives and first- and second-person pronouns because there is, for example, a *speaker parameter* in the formal representation of a context of use. Montague (1970b, p. 228) defines *meanings* as functions from $W \times J$, while *senses* are functions of just possible worlds, that is, when the context-of-use parameter has been fixed. A sense is therefore an ordinary possible-worlds proposition, and this is the value of a meaning applied *to* a context of use.

A second big feature in Montague's work is the precise formulation and formal implementation of compositionality. Compositionality is not stated as a *principle*, that is, a general statement about natural language, but as a requirement on the formal semantics. In Montague (1970a, p. 201), this takes the form of requiring that the *semantic operations* on so-called possible denotations correspond to syntactic operations so that the compositional equation (cf. the identity in (PC′), p. 71) is satisfied.

In Montague (1970b, 1973b), the implementation of compositionality is further technically developed. There, the semantic function is a mapping between *algebras*, a *syntactic* algebra and a *meaning* algebra. An algebra, as Montague presents it (1970b, p. 224) is a pair $\langle A, F_\gamma\rangle_{\gamma\in\Gamma}$, where A is a non-empty set, Γ an index set, and F a family of operations on A, of various arities; for $\gamma \in \Gamma$, F_γ is an operation in F. A compositional function will then be a homomorphism (MCP = Montague compositionality principle):

(MCP) A *homomorphism* is a function from an algebra $\langle A, F_\gamma\rangle_{\gamma\in\Gamma}$ to a *similar* algebra $\langle B, G_\gamma\rangle_{\gamma\in\Delta}$ iff $\Gamma = \Delta$ and for any $\gamma \in \Gamma$ and any n-tuple $a_1, \ldots, a_n$, where $a_i \in A$ $(1 \leq i \leq n)$, for which F_γ is defined, it holds that

$$h(F_\gamma(a_1, \ldots, a_n)) = G_\gamma(h(a_1), \ldots, h(a_n)).$$

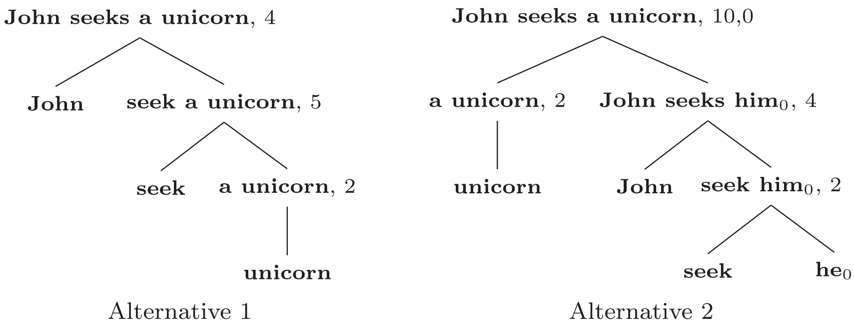

Figure 3.1 *Analysis trees for example (16). A number indicates the relevant operation.*

When A is a set of linguistic expressions and B a set of meanings, h is a compositional semantic function. In his formal semantics, Montague introduces both a syntactic algebra and a meaning algebra and requires the semantic function to be a homomorphism.

In Montague's framework, we also need to add syntactic *categories* and assign those to expressions. Each argument place i of an n-ary operation F_γ is associated with a syntactic category C, such that proper arguments at place i belong to C. When these conditions are met for each i, the *value* of F_γ belongs to a particular category. These categories of arguments and values are specified in *rules*. In Montague (1970b) this is done in a formal, set-theoretic way, while in Montague (1973b) the syntactic operations and their category requirements are presented together in a more informal manner.

Structurally ambiguous sentences, like (16) can be generated from the basic expressions and the syntactic operations in more than one way.

(16) John seeks a unicorn.

On the first alternative, the quantifier *a unicorn* is directly embedded under *seeks*, and corresponds to the reading of *unicorn* saying that John is trying to make it the case that he finds some unicorn or other. On the second alternative, the quantifier rule for indefinite phrases like *a unicorn* is applied last, and this corresponds to the reading according to which there is a particular unicorn that John tries to find. These two alternatives are represented by two different *analysis trees* (Montague, 1973b, p. 255), see Figure 3.1.

Semantic interpretation applies to analysis trees, which are unambiguous, not directly to the meaningful expression, like (16), which are not. Part of Montague's achievement was to actually provide grammars in this algebraic format for interesting fragments of English.

A third major feature in Montague's framework is his *type theory* of meanings. In Montague (1973b, p. 258), an *interpretation*, or *intensional model* is a structure $\langle A, I, J, \leq, F\rangle$, where A is a set of individuals, I a set of possible worlds, J a set of times, $\leq$ linear order in J, and F an interpretation function for constants. There are two basic types: the type e of (possible) individuals (entities) and the type t of truth values, which are taken as the elements of $\{0, 1\}$. Derived types are function types: where a and b are types, $\langle a, b\rangle$ is the type of functions from the type a domain to the type b domain.

For each type a there is a set $D_{a,A,I,J}$ of possible *denotations* of type a, and a set $S_{a,A,I,J}$ of *senses* of type a, where the notation X^Y denotes the set of functions from Y to X:

$$\begin{aligned} D_{e,A,I,J} &= A \\ D_{t,A,I,J} &= \{0, 1\} \\ D_{\langle a,b\rangle,A,I,J} &= {D_{b,A,I,J}}^{D_{a,A,I,J}} \\ S_{a,A,I,J} &= D_{\langle s,a\rangle,A,I,J} = {D_{a,A,I,J}}^{I\times J} \end{aligned}$$

Each syntactic category corresponds to a denotation type and a sense type. A sentence has a denotation of type t, either 0, if false at the designated world-time pair, or 1, if true. Its sense is a (temporal) proposition, that is a function from world–time pairs to truth values. An intransitive verb (category IV) has its denotation in $D_{\langle e,t\rangle,A,I,J}$, a function from individuals to truth values, that is an extension, and its sense in $D_{\langle s,\langle e,t\rangle\rangle,A,I,J}$, that is a function from world–time pairs to extensions.

Montague (1970b, 1973b) does not give the semantics for the defined fragment of English directly, but indirectly via translation from the fragment into a formal language, for which the semantics is given directly. The formal language is IL, intensional logic. IL has a very simple *categorial grammar* that corresponds directly to the type theory for meanings. Each meaning type is also a type of expressions of IL, for instance t the type of sentences. Combining an expression of type a with an expression of type $\langle a, b\rangle$ results in a complex expression of type b. Montague provides a homomorphic translation from the analysis trees of the fragment of English into IL, and a homomorphic, and thereby compositional, interpretation of IL to the meaning algebra. By composing the translation and the interpretation, we get a homomorphic semantic function from the (analysis trees) of the English fragment into the meaning algebra. Montague found the indirect procedure to be more perspicuous.

Montague's semantics is at bottom intensional. This comes out clearly in the translation from the English fragment into IL. IL has two operators, '$\hat{}$' and '$\check{}$', that perform type shifts by *abstraction* and *application* respectively. If expression α is of of type a, and therefore denotes a meaning of type a, then expression $\ulcorner\hat{\alpha}\urcorner$ is of type $\langle s, a\rangle$, and denotes the *sense* of α, a function from world–time pairs to denotations of α at those pairs. If α denotes a sense, then $\ulcorner\check{\alpha}\urcorner$ denotes the extension of α at the designated world–time pair.

Several operations in the English grammar that result in a combination of two expressions correspond to function application in IL and its interpretation. For instance, by rule S4, the operation F_4 takes two arguments. The second is to be of category IV, that is of intransitive verbs, like *talk*, and the first of category t/IV, which yields a sentence when combined with an intransitive verb. $F_4(\alpha, \delta) = \alpha\delta'$, that is the concatenation of α with the expression δ'. The symbol δ' is the third person singular present of δ. As an example, we have F_4(**John**, **talk**) = **John talks**.

Let the translation of α be α' and the translation of β be β'. Then the translation of $F_4(\alpha, \beta)$ is $\alpha'(\hat{}\beta')$. This means that the denotation of α' applies to the *sense* of β', not to the denotation of β'. This holds in general for the rules that correspond to function application IL (Montague, 1973b, pp. 261–262). Generally, then, in Montague semantics, linguistic contexts are treated as *intensional*. In an argument position, an expression will denote its sense, not its actual denotation.

This feature allows capturing the intensional character of, for example, the context that is the object position of the transitive verb *seek*. The translation of (16) into IL according to the Alternative 1 reading (Montague, 1973b, p. 266) becomes the following (where $\hat{P}$ is function abstraction over properties P):

(17) $\mathbf{seek}'(\hat{}j, \hat{P}(\exists u([\mathbf{unicorn}'_{*}(u) \wedge P(\hat{}u)])))$.

The denotation of this is 1 (true) in case the *seek* relation holds between the individual concept of John and a certain property Q of properties of individual concepts. A property P of individual concepts has this property Q just in case there is an object u such that the individual concept of u has both P and the *unicorn* property. Roughly, Q is the property of being a property that a unicorn concept has. Clearly, the property Q doesn't require the existence of unicorns. So, neither does the Alternative 1 reading of (16) in Montague's framework.

As can be seen from (17), however, the subject position of **seek**′ also takes the individual concept of John as argument, not the individual John himself. In this case we ultimately do want the individual. To ensure this, Montague uses a number of *postulates* to guarantee that certain contexts, like the subject position of *seek*, are extensional. These have the form of axioms (Montague, 1973b, pp. 263–264) to be satisfied by a restricted range of ('logically possible') interpretations.

Let's finally reconsider the question of compositionality. The fact that the denotation of a complex expression depends on the *sense* of one of its parts, in argument position, means that a semantic *switch* takes place, in the sense of general compositionality (see (GPC), p. 74). *Denotation* in Montague's (1973b) is therefore not (standard) compositional.

Is *sense* compositional? The denotation of a belief sentence depends on the sense of the embedded sentence (translation rule T7 in Montague, 1973b, p. 262). If the embedded sentence is itself a belief sentence, as in (8), repeated below, we have a doubly embedded sentence ('Hesperus is a planet'):

(8) Bill believes that John believes that Hesperus is a planet.

Thus, it will be the 'sense of the sense', or indirect sense, that the sentence contributes to determining the denotation of (8).

This does in fact generate an infinite hierarchy of senses, just as in Frege, but in Montague's case it is harmless. The reason is that the indirect sense is determined by the sense itself. More precisely (Montague, 1973b, p. 259), since $[\hat{}\hat{}\alpha]^{\mathfrak{A},i,j,g}$ is that function h that applied to a pair $\langle i', j'\rangle$ gives $[\hat{}\alpha]^{\mathfrak{A},i',j',g}$ as value, and since this value does not depend on the pair $\langle i', j'\rangle$, the sense of the sense of α is a constant function from indices that gives the sense of α as value at each index. Although the sense of the sense of α is distinct from the sense of α, it is determined by the sense of α. Hence, no new interpretation function is required, and *sense* in Montague (1973b) is indeed compositional.

3.8 Kaplan-style semantics

David Kaplan's 'Demonstratives' (1989b) was well known for years before it was eventually published, together with the addition 'Afterthoughts' (1989a). Its project is to develop a version of possible-worlds semantics that takes semantic context-dependence into account. In particular, the semantics takes account of parameters such as the time of a context, the speaker and hearer of a context, the place of a context, the selection of what is demonstrated in a context. Because of this, Kaplan distinguishes between three levels of meaning: *character*, *content*, and *extension*. The content of an expression at a context of use may depend on features of that context. The character of the expression encodes the context-dependence and does not itself depend on context. As we saw above, this idea was to some extent anticipated by Montague (1970b).

The character of an expression is a function from context of utterance to *content* (Kaplan, 1989b, pp. 505–507). The content, in turn, is a function from *circumstances of evaluation* to extensions. A circumstance of evaluation includes a possible world, but according to Kaplan it must also contain a time (we return to this below).

For an expression that is not context sensitive, the character is a constant function from context to content. Pure indexicals like *I*, *here*, and *now*, and demonstrative indexicals, like *you* and *that*, have non-constant character. Consider the sentences below:

(18) a. I am here now.
b. David Kaplan is in Portland on 26 March 1977.

(18a), as uttered by David Kaplan on 26 March 1977, provided he was then in Portland, has the same content as (18b), uttered by anyone at any time and any place.

A central part of Kaplan's project is to capture the *logical* properties of certain sentences, characterized in his *logic of demonstratives*. There, a sentence like (18a) is a logical truth, in the sense that, because of its *character*, it is true in every context, for it holds in every context that the speaker of the context is at the place of the context at the time of the context. It was important that this logical property of sentences like (18a) can be combined with their modal *contingency*. For (19) is false at every context.

(19) $\Box$ I am here now.

This very combination of features depends precisely on the fact that the modal operator takes the *content* of the embedded sentence as argument and only shifts a parameter of the circumstances of evaluation, the possible world. Kaplan thereby manages to separate these two features: that in *every context*, the content of (18a) is a content that is true *in the circumstances of that context*, while it still is false in *other* circumstances of evaluation.

Kaplan (1989b, p. 530) further attaches a direct cognitive significance to the concepts of character and content. Contents are 'Fregean Thoughts', or the objects of thought. Contents are what one *believes*. Characters correspond to the *cognitive significance* of Thoughts. The *Thought* expressed by David Kaplan in Portland on 26 March 1977 by uttering (18a) would be the same as the *Thought* expressed by anyone at any time and any place by uttering (18b). Their perspectives would necessarily be different, and so the *cognitive significance*, or the presentation, of the Thoughts, would be different. This view of the psychological relevance of the semantic distinction is intuitively plausible and serves as a strong motivation for the distinction. As we shall see soon, it also leads to trouble.

Kaplan requires a sharp distinction between contexts of use and circumstances of evaluation. This distinction is forced by some semantic facts about indexicals (Kaplan, 1989b, p. 500):

(T2) When what was said in using a pure indexical in a context c is to be evaluated, with respect to an arbitrary circumstance, the relevant object is always the referent of the indexical with respect to the context c.

Now consider the following:

(20) At some time it snows where John is now.

Let us assume that we have a semantic clause for *at some time* that says that 'at some time, p' is true at a context c just in case, for some time t, the context c' that is like c except that the time of c' is t, p is true at c'. Let $\tau(c)$ be the time of c, and use 'c[x/y]' for the context that is like c except that x replaces y.

(21) $\models_c$ at some time p iff for some time t, $\models_{c'}$ p

where $c' = c[t/\tau(c)]$. The clause (21) will have the effect that (20) is true at a context c just in case (22) is true with respect to some time t in the context $c' = c[t/\tau(c)]$.

(22) It snows where John is now.

But then the value of 'now' with respect to c' is precisely t. So, (20) comes out, incorrectly, as true just in case there is some time t such that it snows where John is *at t* (not where he is at the time of utterance of (20)). This gives the intuitively wrong result, a result that would be right for (23):

(23) At some time it snows where John is.

Correspondingly, it violates the principle (T2) that, according to Kaplan, holds of all pure indexicals, including 'now'.

The conclusion is that when the *time parameter* has to be shifted, because of the occurrence of a temporal operator like 'at some time', what is shifted can*not* be a parameter in the context of use. Some other point of evaluation is needed, and that is precisely the circumstance of evaluation. There is therefore a division of labour between the context of use and the circumstances of evaluation: the former fixes the value of the indexicals and therefore determines content, while the latter contains all the *shiftable parameters*, corresponding to modal operators (which shift the world), and temporal operators (which shift the time).

If *at some time* were to have the semantics of (21), it would shift the time of the context. It would then be an operator on character, which is what Kaplan calls a 'monster' (Kaplan, 1989b, p. 510). He claims that English does not contain any.

Since temporal indexicals like *now* require their semantic values to be fixed by context, both the context of use and the circumstances of evaluation must contain a time parameter ('double indexing', cf. Subsection 3.11). For a sentence that does not contain any temporal indexical, the time parameter of the context does no work. The content of a sentence like (24) at a context *c* is not a classical (eternal) proposition, true or false at possible worlds, but a *temporal* proposition, true or false at world-time pairs.

(24) It snows where John is.

Kaplan gives an argument for this (the so-called operator argument):

> If we built the time of evaluation into the contents (thus removing time from the circumstances leaving only, say, a possible world history, and making contents specific as to time), it would make no sense to have temporal operators. (Kaplan, 1989b, pp. 502–503)

Whatever the value of this argument, the idea that we actually *believe* temporally neutral contents has met with a fair bit of philosophical opposition (starting with Richard, 1981).

The double temporal indexing has further consequences in connection with compositionality. Kaplan requires both that character is compositional and that content with respect to a context is compositional (Kaplan, 1989b, p. 507, with slightly compressed wording):

(F1) The character of the whole is a function of the characters of the parts (and the mode of composition).

(F2) The content of the whole in a context *c* is a function of content of the parts in *c* (and the mode of composition).

Now, compare (24) with (22). There is an intuition that we would *say* the same thing in a particular context, whether we use (24) or (22). But the assumption that the utterances would have the same content leads to a violation of (F2), compositionality for content. For the results of embedding (24) and (22) under *at some time* are (20) and (23), respectively. Since (20) and (23) have different contents, compositionality for content is violated if they are formed with the same syntactic operation from sentences with the same content. Hence, (22) and (24) must differ in content (see Westerståhl, 2012).

This conclusion differs from that of David Lewis (1980) and Michael Dummett (1981a, pp. 446–447; 1981b, pp. 572–574). Both argued that we must distinguish between the content of an utterance made by a sentence on its own (what Lewis called 'what is said' and Dummett 'assertoric content') and what it contributes when embedded in larger linguistic contexts (Lewis's 'compositional value', Dummett's 'ingredient sense'). Both suggestions would involve giving up standard compositionality for content (the content of (22) and (24) are the same, but they embed differently).

3.9 Centred-worlds propositions

An alternative approach to indexical sentences was proposed by David Lewis (1979a). Following a suggestion in Quine, Lewis proposed that the meaning of a sentence is a set of *centred worlds*. A centred world is a pair $(\boldsymbol{w}, c)$ of an ordinary possible world $\boldsymbol{w}$ and a *centre*. As Lewis proposed it, a centre is a pair of a *time* and a *location*. Others have proposed that a centre is a pair (S, t) of a *speaker* S and a time t. Using the latter, we would say that the meaning of (25) below is the set of centred worlds $(\boldsymbol{w}, (S, t))$ such that S is hungry at t in $\boldsymbol{w}$:

(25) I am hungry.

This set of centred worlds is supposed to be the meaning of the sentence, as well as *what is said* by means of it in a context, and the *content* of belief. The proposal to use centred worlds is therefore in a sense an idea of collapsing Kaplan's levels of character and content into one single level, where the propositional content and the cognitive significance are merged.

One thing has to be added on the attitude level, however. For believing a classical proposition, a certain belief or *holding-true* attitude must be taken towards that proposition. That attitude can be characterized by saying that the speaker or believer takes the actual world to be a world where that proposition is true. Usually we say that the proposition just is the content of that belief. This doesn't work for centred propositions, for we would lose the ingredient that it is the speaker or thinker *him-* or *herself* that is hungry at the very time of speaking or thinking. The simple attitude of holding-true must therefore be replaced by something else, and Lewis proposes to take the idea of *self-attribution* as basic.

The idea therefore is that the speaker *self-attributes* the centred-world proposition. More precisely, the speaker attributes the centred-world proposition to the triple of the *actual world*, *him-* or *herself* and the *current time*. That is, with $\boldsymbol{a}$ as the actual world, self-attributing the centred-worlds proposition amounts to taking the pair $(\boldsymbol{a}, (S', t'))$ of the actual world, the current speaker and the current time to be in the set of centred worlds $\{(\boldsymbol{w}, (S, t)) : S \text{ is hungry at } t \text{ in } \boldsymbol{w}\}$.

To see the connection with Kaplan's theory even more clearly, note that given a world, the pair of a speaker and a time uniquely determines a context in that world (and vice versa). We can therefore replace talk of centres with talk of contexts. And we can replace talk of the set of pairs of worlds and contexts with talk of the characteristic function from pairs of worlds and contexts to truth value. But then, with μ_{K} for character and μ_{L} for Lewis's corresponding semantic function, we have the following equation:

$$\mu_{\mathrm{L}}(\boldsymbol{w}, c) = \mu_{\mathrm{K}}(c)(\boldsymbol{w})$$

We conclude that the theories are in a sense equivalent (not taking issues of double indexing into account). The main difference lies, of course, in what is attributed as the contents of utterances and beliefs. For instance, as noted, e.g. in Egan (2007), the hearer cannot simply *take over* the same content as expressed by the speaker, for if the hearer self-attributes the content of (25), she or he will think that *she* or *he*, the hearer, is hungry. So the reduction of levels of meaning results in a complication of the theories of assertion, belief, and communication.

3.10 Relativism

Relativism is the general philosophical idea that the truth or falsity of a proposition may depend not just on 'the facts' in an ordinary sense, that is, on a possible world, but on additional factors as well, and in particular on properties of *persons*. On this definition, already the temporalism of Kaplan, according to which content is a function from pairs of worlds *and times* to truth values, is a species of relativism. Lewis's theory of centred-worlds propositions, as functions from worlds and centres to truth values, is another.

Relativism has become a topic of interest in philosophy in recent years, for two reasons: firstly, because of claims that certain phenomena are best treated by means of a relativist account, and secondly, because more precise semantic theories have been given to accommodate relativism (see García-Carpintero and Kölbel, 2008).

Three areas in particular have been in focus for relativist treatment: *predicates of personal taste* (see, e.g., Lasersohn, 2005), *epistemic modals* (see, e.g., Egan, 2007), and *future contingents*. Here we take a brief look at the latter.

In Aristotle's classical puzzle about future contingents we are asked to evaluate the sentence in (26):

(26) Tomorrow there will be a sea battle.

There are two conflicting intuitions about it. On the one hand, assuming that the future is open and the facts at the time of utterance of (26) do not determine whether a sea battle will take place, it seems that (26), at the time of utterance, is neither true nor false. On the other hand, if on the following day a sea battle does take place, it seems right to say that the utterance, or the sentence as uttered, *turned out* to have been true after all. Hence, it seems that it was in one respect neither true nor false, and in another respect true.

MacFarlane (2003, 2008) has proposed to account for both intuitions by means of a relativist semantics. On MacFarlane's proposal, (26) must be evaluated with respect to both a context of use and a context of *assessment*. By the context of assessment that is identical to the context of use, (26) is neither true nor false, and by the context of assessment the following day, after observing the battle, it is true. In a picture of branching time where worlds are world histories which can overlap in contexts (pass through the same context), MacFarlane (2008, p. 13) gives the following definition:

(27) An occurrence of a sentence S at C_U is true as assessed from C_A iff for every world $w \in W(C_U|C_A)$, S is true at $\langle C_U, w, a\rangle$.

Here $W(C)$ is the set of worlds that overlap at C. a is an assignment of values to variables. $W(C_U|C_A) = W(C_U) \cap W(C_A)$, provided $W(C_U) \cap W(C_A) \neq \varnothing$, and equals $W(C_U)$ otherwise.

On this relativist view, what is expressed by a sentence, given a context of use, is a function from pairs of a world and context of assessment. The context of assessment is not determined by the context of use. As a matter of terminology, a semantics that does take the context of assessment to be determined by the context of use is called *non-indexical contextualism* by MacFarlane (2009).

3.11 Two-dimensionalism

The basic idea of two-dimensionalism is that *pairs* of indices, rather than single indices, are used for semantic evaluation. Thus, we have two-dimensional possible-worlds semantics in case sentences are evaluated with respect to pairs of worlds, and a two-dimensional semantics for time dependence if pairs of times are used. In this sense, Kaplan's semantics is two-dimensional, since (possibly different) times are both in the context of use and in the circumstances of evaluation. The first to observe that a two-dimensionalist semantics of time might be needed because of the semantics of 'now' was Hans Kamp (1971). Kamp noted that the model theory can use two different methods of handling the 'rigid' (in Kripke's sense) character of *now*. One option is that the model includes a designated time t_0, a *now* point, such that all sentences are considered as uttered at t_0, and *now* has a constant meaning:

(28) $\ulcorner$Now $p\urcorner$ is true with respect to a time t iff p is true with respect to t_0.

The alternative is to allow that sentences can be uttered at different times, and then *now* is an indexical. The time of utterance is then the *now*-point from the perspective of the utterance, and evaluable with respect to any arbitrary time. This is two-dimensionalism.

Correspondingly, in two-dimensional possible-worlds semantics, one world is considered to be the *world of utterance*, and what is uttered in that world can be evaluated at an arbitrary world. In that case, *actually* is treated as an indexical. For evaluation of a sentence, we then need two worlds, the first to determine the content of the utterance, the second for evaluating the content as so determined. The first world then plays the role of *context of use*, in Kaplan's sense, and the second as the *circumstances of evaluation*. The meaning of a sentence is then a function from pairs $(\boldsymbol{w}_1, \boldsymbol{w}_2)$ of worlds to truth values.

Robert Stalnaker (1978) used this idea to propose that in some cases, the standard possible-worlds *proposition* that is expressed by means of a sentence s is the so-called *diagonal*. If we think of the set of pairs of worlds as given by a two-dimensional matrix, with a pair of worlds in each cell, the diagonal is the subset of the matrix where the pair members are identical, i.e., $\{(\boldsymbol{w}_1, \boldsymbol{w}_1), (\boldsymbol{w}_2, \boldsymbol{w}_2), \ldots\}$. The *diagonal intension* of a sentence p, $\mu_d(p)$, is an ordinary possible-worlds proposition. It gives the value True for any world $\boldsymbol{w}$ such that the *pair* $(\boldsymbol{w}, \boldsymbol{w})$ on the diagonal is given the value True by the two-dimensionalist intension $\mu(p)$. Stalnaker's idea was that the content of an assertion that p in some cases is best taken to be $\mu_d(p)$, rather than a proposition fixed by the world of utterance.

The rationale for this proposal comes partly from the semantics proposed for proper names by Saul Kripke (1972). According to Kripke, the intension of a proper name like *Hesperus* is a constant function: its value for any world as argument is the planet Venus (provided Venus exists in that world); proper names are in this sense *rigid designators*. Since *Phosphorus* is another name for Venus, *Hesperus* and *Phosphorus* have the same intension. There will be no semantic difference between (29a) and (29b):

(29) a. Hesperus = Hesperus
 b. Hesperus = Phosphorus

However, we can associate different reference-determining conditions with the two names, so that in some worlds of utterance, *Hesperus* and *Phosphorus* corefer, while in others they do not. Therefore, in a two-dimensional matrix, (29a) will be true with respect to all pairs of worlds, while (29b) will be true at some and false at others. On a straight interpretation of (29b), it expresses the necessary true proposition (or at least a necessarily non-false proposition), but it is plausible to interpret the speaker as asserting the diagonal proposition p which is such that p is true in $\boldsymbol{w}$ just in case the referents of *Hesperus* and *Phosphorus*, as determined in $\boldsymbol{w}$, are identical in $\boldsymbol{w}$. This is a non-trivial proposition, true in some worlds, false in others. So here, what is meta-semantic for the rigidity theorist is semantic for the two-dimensionalist.

Formally, with $\mu(e)$ as a binary function from pairs of worlds $(\boldsymbol{w}_i, \boldsymbol{w}_j)$ to extensions, and with $\mu^1(e)$ as the primary intension of expression e and $\mu^2_{\boldsymbol{w}}(e)$ as the secondary intension of e at world $\boldsymbol{w}$, we have the following equations:

(30) a. $\mu^1(e) = \lambda\boldsymbol{w}((\mu(e))(\boldsymbol{w}, \boldsymbol{w}))$
b. $\mu^2_{\boldsymbol{w}_i}(e) = \lambda\boldsymbol{w}((\mu(e))(\boldsymbol{w}_i, \boldsymbol{w}))$

Sometimes (as suggested, e.g., in Chalmers, 2006; Michels, 2011), the first element in each pair is to be a *centred world* in the sense of Subsection 3.9, so as to bring in a context of use *within* the world of utterance. A central part of this appeal to two-dimensionalism is that different intensional operators depend on different intensions:

(2D) a. A sentence $\Box\phi$ is true at $(\boldsymbol{w}_i, \boldsymbol{w}_j)$ iff ϕ is true at all pairs $(\boldsymbol{w}_i, \boldsymbol{w}_k)$ such that $\boldsymbol{w}_k$ is accessible from $\boldsymbol{w}_j$.
b. Where B is a *belief* operator, $B\phi$ is true at $(\boldsymbol{w}_i, \boldsymbol{w}_j)$ iff $\mu^1(\phi)$ is true in all the worlds that are belief-alternatives to $\boldsymbol{w}_i$.

The truth of $\Box\phi$ depends just on the so-called *secondary intension* of ϕ at $\boldsymbol{w}_i$, while the truth of $B\phi$ depends on the so-called *primary intension*, as the content of a belief entertained in $\boldsymbol{w}_i$.

3.12 Situation semantics

In situation semantics (see Barwise and Perry, 1983; Barwise, 1989), *situations* play several roles, some of them analogous to worlds in possible-worlds semantics, and some of them to contexts. Analogous to two-dimensionalism, the meaning of a sentence ϕ is a *relation* between an *utterance* situation u and a *described* situation s (which is equivalent to a function from pairs (u, s) to truth values).

$u\ |\phi|\ s$

This is again similar to Kaplan's concept of character, which can be viewed as a relation between contexts of use and circumstances of evaluation. The interpretation of a sentence ϕ as used in a real situation u is then $\mu_u = \{s : u\ |\phi|\ s\}$, the set of situations at which ϕ, as uttered in u, is true.

There are two basic kinds of situations, *real* and *abstract*. Real situations are particulars, concrete parts of reality that stand in causal relations to each other. They are therefore much like *events*. The utterance situation u is a *real situation*, and it fixes the *time* relevant for evaluation.

By contrast, s is an *abstract situation*, something that obtains or not, therefore much like *a state of affairs*, and again is thought of as a *partial possible world*. Abstract situations are set-theoretic constructions from basic real entities of three kinds:

(a) Space–time locations
(b) Relations
(c) Individuals

Abstract situations are *sets* of *basic states*. A basic state is a *triple* (as shown below) where l is a space–time location, r an n-ary relation, $x_1, \ldots, x_n$ objects (basic or constructed), and i is a *polarity*, either 1, for obtaining (truth), or 0 for non-obtaining (falsity).

$$\langle l, \langle r, x_1, \ldots, x_n\rangle, i\rangle$$

With polarity value 1, the basic state is that state where the objects $x_1, \ldots, x_n$ stand in the relation r at space–time location l, and with value 0 that state where they do not. Two such states are *incompatible* iff they differ just in polarity. Two abstract situations are incompatible if they contain, respectively, incompatible states, otherwise compatible.

Abstract situations are related to real situations. An abstract situation is said to be *actual* iff it correctly and exhaustively represents some real situation, and it is said to be *factual* if it is part of an actual situation. *Types* of situations are abstract situations with an *indeterminate* (a parameter) instead of an object. A situation s is of a type T iff s results from T by substituting entities of the appropriate sorts (e.g. locations, individuals) for the indeterminates.

There is also an *ordering relation* between situations. One situation s is said to be a part of a situation s' iff every basic state that is an element in s is also an element in s'. All real situations are mutually compatible. For any two real situations s, s', there is a larger real situation s'' that contain both s and s' as parts. The real world has all real situations as parts, but it is not itself a situation, since the collection of all real basic states is to be regarded, from a set-theoretic point of view, as a *proper class*, while abstract situations are all sets. Similarly, maximal internally compatible collections of basic states are analogous to possible worlds.

Statements of these features and others of situations belong to *situation theory*, which concerns the formal and ontological properties of situations per se, irrespective of the appeal to situations within semantics. Another ingredient of situation theory that should be mentioned is the central feature that situations may be *constituents* of other situations, since they are like real events, or representations of real events. This feature, like the others, is of course designed with the semantics in view.

What are the semantic motivations? One basic motivation is that of achieving more fine-grained meanings than classical possible-worlds semantics. In the classical theory, all sentences that are necessarily true express the same proposition and therefore have the same meaning within the semantics. This can be avoided in situation semantics because situations are partial and therefore do not all contain everything that exists in maximal collections of basic sets. The first two sentences of (31) are true in the same possible worlds and so have the same possible-worlds intension.

(31) a. Albert is a man.
b. Albert is a man and $1 + 1 = 2$.
c. Albert is a man, and if Albert is a man, then Albert is a man.

They are not, however, true in exactly the same situations, for some simple situations do not contain numbers. Hence, the interpretations of (31a) and (31b) are different.

The outcome is desirable, but this ontological move in situation theory is not sufficient to distinguish the interpretation of (31a) from the interpretation of (31c), since every situation that makes (31a) true also makes (31c) true, unless we countenance impossible situations or non-standard interpretations of the conditional. Hence, the desired fineness of grain is not really achieved.

A second motivation was that of making context-dependence, in a wide sense, an integral part of the semantic framework. In at least one respect, situation semantics goes beyond Kaplan-style semantics when it comes to the context-dependence, in a wide sense, of semantic evaluation. In Kaplan-style semantics, contents are evaluated at world–time pairs. In situation semantics, they (i.e. interpretations) are evaluated at situations. Since situations are partial, an interpretation may be false at one situation even though it is true at a *larger* situation. An example is an utterance (32) by a speaker watching a card game (Barwise and Etchemendy, 1987, p. 122 and Kratzer, 2011a):

(32) Claire has three of clubs.

That card game is the *intended* real situation described. If the speaker is mistaken about the identity of the player, and Claire, unbeknown to him or her, is actually taking part in *another* card game, and at that very time *does* have three of clubs, then the utterance is nonetheless *false*, according to this theory, since it is false of the situation described. This context-dependence in evaluation goes beyond standard context-dependence associated with indexicals and other context-sensitive expressions. Whether it is the intuitively right result is perhaps not completely clear.

A third motivation derives from the possibility of making situations constituents of other situations. This has been used to model reports such as in (33):

(33) John saw Bill kiss Mary.

In the interpretation of (33), a situation *type*, the type

$\langle y, \langle \text{kiss, Bill, Mary} \rangle, 1 \rangle$

with y an indeterminate, is a constituent of the situation of John's seeing something; it is what he sees. If (33) is true, then there is a real situation of this type, and this situation is a particular that John stands in a causal relation to. (33) is an example of *naked infinitive* constructions that situation semantics was designed to give a semantics for.

A fourth motivation, finally, is the possibility of exploiting so-called *resource* situations. A resource situation is different from the described situation but can be used, for instance, to offer an alternative domain of objects in order to restrict quantification or fix the reference of a definite description. Relative to a resource situation $r(u)$ of an utterance situation u, the description 'the butler' may pick out a unique butler, which may be the entity relevant in the interpretation of (34) below, for example.

(34) The butler is at a butlers' conference.

That the referent is not the unique butler at the described situation does not then cause trouble.

3.13 Structured meanings

A radical move to make meanings more fine-grained than sets of possible worlds is to take meanings as *structured*. Instead of having an entity like a function as a semantic value, semantic values are seen as having *parts*, some of them with parts in their turn. This typically provides a *constituent* structure that mirrors the structure of syntax.

We need to distinguish between a weaker thesis that there are semantic values that have structure, and the stronger thesis that some particular values are in fact structured. Especially, if the meaning of a sentence is a proposition, can it be that the proposition itself is a structured entity? This may of course be a terminological issue, but if it assumed (as part of what characterizes the concept of a proposition) that propositions are the contents of beliefs, and what is said in assertions, then there is also a substantial question whether what is said, or believed, may be something structured.

The term *proposition* was in fact used to stand for a structured entity before it was used as a term for possible-worlds intensions. Russell writes:

> Consider, for example, the proposition '*A* differs from *B*'. The constituents of this proposition, if we analyse it, appears to be only *A*, difference, *B*. (Russell, 1903, p. 47)

It has become common to render the propositions, analysed in this way, by means of an ordered *n*-tuple notation, such as the following

⟨difference, *A*, *B*⟩

Ordered tuples of this kind are commonly known as *Russellian propositions*.

Russellian propositions are naturally generalized to more complex meanings by allowing ordered tuples to have ordered tuples as constituents. This will generate *tree structures*, where the top node is the meaning of the whole expression, which is an *n*-tuple. Each element in the *n*-tuple is a simple meaning or itself a tuple of the same kind, which is subordinate to the topmost tuple. And so on.

One version of this was proposed in Cresswell (1985), where trees are built up from ordered pairs, and each pair consists of a function and an argument. The function is the semantic value of an incomplete expression (in Frege's sense), and its argument is the semantic value of the *syntactic* argument to the incomplete expression. In Lewis (1970, p. 33) meanings simply *are* trees. The simple nodes of the trees are pairs of a category and a possible-worlds intension of that category. The meaning tree mirrors the syntactic tree of the expression whose meaning it is. King (2007) also takes structured meanings to be trees that mirror syntactic trees, but he takes the further step of actually characterizing the meaning tree by reference to the syntax: a meaning is part of a structured meaning because it is the meaning of an expression that occupies a certain position in a syntactic tree. In Bealer (1993) we find a slightly more abstract conception. Bealer does not explicitly speak about tuples or trees, but rather of an *algebra* with an ordering relation. The restrictions on that ordering relation nevertheless effectively entail that structured meanings have a tree structure.

We get an even more abstract characterization by imposing a structure on the *synonymy relation* rather than directly on the meanings themselves. The classical proposal is Carnap's idea of *intensional isomorphism* (1956, pp. 56–57)

(ISO) a. Two simple expressions e and e' are synonymous iff they are co-intensional.

b. Two complex expressions A and A' are synonymous iff they have the same (top) mode of composition and their corresponding immediate parts are synonymous.

It can be shown that with synonymy, that is, sameness of meaning, defined this way, meanings must be individuated as structured meanings are; they can therefore be represented as structured (see Pagin, 2003, and cf. (PIC), p. 73).

A main motivation for postulating structured meanings is that they provide the more fine-grained meanings that are needed both for intuitions about difference of meaning and for belief reports. It clearly helps to distinguish (31a) both from (31b) and (31c), and the last two from each other. A main problem with using structured meanings as contents of belief, and as *what is said*, that is, as *propositions*, is that it is unclear how anything at all is *said*, or *represented*, by means of a structured meaning.

The quote from Russell above continues as follows:

> Consider, for example, the proposition '*A* differs from *B*'. The constituents of this proposition, if we analyse it, appears to be only *A*, difference, *B*. Yet these constituents, thus placed side by side, do not reconstitute the proposition. The difference which occurs in the proposition actually relates *A* and *B*, whereas the difference after analysis is a notion which has no connection with *A* and *B* . . . A proposition, in fact, is essentially a unity, and when analysis has destroyed the unity, no enumeration will restore the proposition. (Russell, 1903, pp. 47–48)

The problem Russell points to has come to be known as the *unity of the proposition problem*, even though there is nothing generally agreed on to be *the* problem. One question is how there can be anything at all that has an essential unity and represents possible states of affairs.

Another question is how anything can have parts and structure and still intrinsically represent states of affairs. Propositions as meanings are what makes sentences into representations. So propositions should not *themselves* be in need of interpretation. However, trees or ordered tuples do not intrinsically represent states of affairs; we need to add a method of projecting, for instance ⟨taller, Plato, Socrates⟩, on the proposition *that Plato is taller than Socrates*. With another method than the intended one, the triple could be mapped on the proposition *that Socrates is taller than Plato*. Indeed, it could be mapped on any proposition that in some sense or other contains or is about Plato and Socrates and the *taller than* relation. It is an open question whether the required fineness of grain can be combined with intrinsic representational content.

3.14 Verificationism

In the narrow sense, *verificationism* is the view that the meaning of a sentence is its *method of verification*. In a wider sense, it covers theories of meaning that in some way or other relate sentence meaning to evidence.

The idea that the meaning of a sentence is its method of verification seems to have been first proposed by Wittgenstein in the late 1920s. He writes for instance:

> The verification is not *one* token of the truth. It is *the* sense of the proposition. (Wittgenstein, 1975, p. 200)

The idea was taken up by the logical positivists, in particular Moritz Schlick (1936, p. 341), Rudolf Carnap (1936), and Alfred Ayer (1936) (for an overview of the position and its development, see Hempel, 1950). Carnap's statement is particularly explicit:

> If we knew what it would be for a given sentence to be found true, then we would know what its meaning is. And if for two sentences the conditions under which we would have to take them as true are the same, then they have the same meaning. Thus the meaning of a sentence is in a certain sense identical with the way we determine its truth or falsehood; and a sentence has meaning only if such a determination is possible. (Carnap, 1936, p. 420)

According to Carnap, *synonymy* amounts to sameness of method of verification (or falsification), which provides a clear sense of saying that the meaning *is* the method of verification. Carnap also states the so-called *criterion of meaningfulness*, that only sentences that can be verified or falsified are meaningful. This demarcation criterion should be distinguished from verificationism itself, but they go very naturally together.

Especially in Carnap, there is a historical background in his own *Aufbau* (1928) and Russell's *External World* (1914), which were (sketches of) attempts at *reducing* sentences that appear to describe an external world to sentences that describe what is immediately given in experience. In the verificationism of the 1930s, by contrast, the most basic sentences themselves do describe the external world. They are, however, *observation sentences* (or even so-called *protocol sentences*, such as *Red here now*), sentences whose truth value can be settled by means of direct observation. One problem with this approach is that it is hard to understand the semantic difference between a sentence that describes experience and a sentence that can be directly established as true or false on the basis of that same experience but in fact describes an external state of affairs instead.

There was an attempt to reduce theoretical sentences of scientific theory to observation sentences by means of so-called *operative definitions* (e.g. to define *temperature* in terms of the use of thermometers), but this had the effect of restricting the scope of scientific theories to what is in fact measured. Similarly there are problems with *universal* sentences, such as (35):

(35) All ravens are black.

This cannot be conclusively verified even assuming that its instances can. Ayer also tried to exclude cognitively meaningless sentences from scientific theories by appeal to having, together with *other sentences*, observational consequences, but that turned out to be very difficult (see Hempel, 1950). Carnap's reaction to these problems was to turn from conclusive verification to degree of *confirmation* (Carnap, 1936). However, the relation between evidence, degree of confirmation, and linguistic meaning then becomes much more complex and less direct.

A more recent form of verificationism was developed in the 1970s and 1980s from a background in intuitionism in logic and mathematics, and in proof theory. Verificationism in the 1930s had kept classical logic, and thereby the principle of *bivalence*, that every (cognitively meaningful, non-indexical, declarative) sentence is either true or false. But if there is no general guarantee that every apparently meaningful sentence can be either verified or falsified, either bivalence should be given up, or many apparently meaningful sentences must be deemed meaningless after all.

The new verificationism does not accept the principle of bivalence, or classical logic. It has been primarily concerned with logic and mathematics, rather than with empirical sentences. It takes two closely related forms. In one form, the concept of a *proof* is basic. According to this conception, which is close to classical verificationism, the meaning of a sentence is characterized by what counts as a proof of it. That is, what characterizes meaning is not a one-place property but a relation: *x is a proof of y*.

For any given provable sentence A, there are infinitely many proofs, some of them differing only marginally, some very much. It seems hard to characterize the conditions of being a proof of A in an informative way, and especially in a compositional way. This problem was addressed in the early seventies by Michael Dummett and Dag Prawitz, who made the distinction between *canonical* and *non-canonical* (or *direct* and *indirect*) proofs (Prawitz, 1974, pp. 63–77; Dummett, 1975a, pp. 240–247). Although a proof in general of a sentence A can have any form, a canonical proof of A reflects the form of A itself:

(36) $\wedge$ A canonical proof of $A \wedge B$ is a pair $\langle a, b\rangle$ where a is a proof of A and b is a proof of B.

$\vee$ A canonical proof of $A \vee B$ is a pair $\langle a, b\rangle$ where either a is l and b is a proof of A or a is r and b is a proof of B.

$\rightarrow$ A canonical proof of $A \rightarrow B$ is a function f that for any proof of A as argument gives a proof of B as value.

$\forall$ A canonical proof of $\forall x A x$ is a function f that for any term t in the language as argument gives as value a proof of $A(t/x)$.

$\exists$ A canonical proof of $\exists x A x$ is a pair $\langle t, b\rangle$ where t is a term in the language and b is a proof of $A(t/x)$.

$\neg A$ is defined as $A \rightarrow \perp$ (where $\perp$ is Falsum, the emblematic falsity constant).

This is the modern version of the Brouwer–Heyting–Kolmogorov explanation of the meanings of the logical constants. A proof in general of a sentence A is then seen as a method which, when applied, yields a canonical proof of A. Hence, when there is a proof, there is a canonical proof. The law of excluded middle is not validated by this semantics (although $\neg\neg(A \vee \neg A)$ is valid).

A speaker is assumed to understand a sentence A *compositionally*, from understanding its parts and the way they are put together, and this idea of understanding is realized with the recursive specification of canonical proofs. Specifications of the conditions for being proofs of atomic sentences, e.g. arithmetic equations, can be added. The concept of a proof here is general and informal, not restricted to proofs in any particular formal system. If it were, any expansion of the system would automatically change the meaning of the logical constants.

The other form of the new verificationism focuses on conditions for correctly asserting a sentence (utter it with assertoric force). That the meaning of a sentence should be characterized in terms of assertibility is especially stressed in Dummett (1976).

The specifications of what counts as canonical proofs correspond to *introduction rules* for the logical constants. For instance, the introduction rule for $\wedge$ says that $A \wedge B$ may be inferred from the set of premises $\{A, B\}$. Unlike the canonical proofs form, this alternative explanation appeals to a particular kind of deduction, exemplified by Natural Deduction systems.

The appeal to canonical proofs does offer a very fine-grained conception of linguistic meaning. For instance, a canonical proof of a sentence $A \wedge B$ will always be different from a proof of A, even if B is a simple logical truth made from the same linguistic material as A itself (compare (31a) and (31c)).

This feature holds in particular of the intuitionistic type theory by Martin-Löf (1984); the theory has evolved since, but there is no later canonical book-length presentation. Here the relation between proofs and propositions are built into the formal system. Proofs are proof objects, and propositions are *types* of proof objects. They are not mere collections, but intensional in nature. That a proposition is true consists in the circumstance that it has at least one element. The basic sentences of type theory are so-called *judgments*, and among the forms of judgment we have $a : A$, which says that a is of type A (is a proof of the proposition A). By means of operations on proof objects, we can form more complex proof objects that belong to correspondingly more complex propositions.

Martin-Löf's type theory has been applied in formal semantics, by Aarne Ranta (1995) in particular. The general idea is that sentences of type theory provide the underlying logical form of sentences of natural language. Proof objects are rich in information (in this respect similar to *events* in event semantics). They can contain other objects as parts, which can be exploited in tracking anaphoric relations in sentences.

3.15 Procedural semantics

Rather different semantic ideas have been called 'procedural'. The unifying idea is rather loose, but in all cases there is an idea that some level of linguistic meaning is associated with some sorts of procedures or transitions. We can, I believe, distinguish between two main kinds:

(a) Meaning is associated with updates of information, i.e. transitions between propositions.
(b) Meaning is associated with fine-grained methods of deriving ordinary intensions.

Procedural semantics in the (a) sense is usually called 'dynamic'. In semantics of the (b) variety, the procedure in question is an abstract interpretation process, the process of interpreting a linguistic expression and arriving at an intension. This is meant to apply generally, irrespective of whether the content represents information updates in the sense of (a). The procedure of getting to the intension of the sentence is taken to be encoded in a separate layer of meaning, the procedural level. I am aware of two abstract semantic systems where this basic idea has been technically developed. One, TIL (Transparent Intensional Logic) was originated by Pavel Tichý and carried on by Pavel Materna, Mari Duži, and Bjørn Jespersen. The other is developed by Yiannis Moschovakis.

Technically, both are type-theoretic systems with some similarity to Montague semantics. Philosophically, both stress the affinity to Frege and to verificationism. Frege thought of sense as (containing) a mode of presentation of the referent and has often been interpreted as taking sense to be (or contain) a *method of identifying the referent*, in particular in the case of proper names (see Dummett, 1981a, pp. 95–96). Analogously, in verificationism, the *method of verification* or *method of falsification* is a method for determining the truth value of a sentence. These are ideas that can range from a condition (necessary and/or sufficient) for being the referent to a step-by-step series of instructions for determining or constructing the referent.

The latter, algorithmic, conception was suggested by Tichý (1969), taking the intension of an expression to be a Turing machine. Conceptions similar to this became popular in cognitive science. Johnson-Laird (1978, p. 249) said that 'compiling and executing a program correspond rather naturally to stages in a person's comprehension of an utterance' and (quoting himself, p. 151) 'we might speak of the intension of a program as the procedure that is executed when the program is run, and of the extension of a program as the result the program returns when it has been executed'. This suggests that the procedural meaning is not itself what the hearer understands, but rather the meaning of instructions that lead to understanding when executed. In general, the two levels must be kept apart: the semantic value the language user comes to know by means of applying or instantiating a certain abstract procedure, and the abstract procedure itself as a separate semantic value.

In Moschovakis (2006) meanings are said to be algorithms in the literal sense. More precisely, they are so-called *referential intensions* and the referential intension in (A) of an expression A is said to be an algorithm for computing the *denotation* of A relative to an assignment g, $\mathrm{den}(A)(g)$ (Moschovakis, 2006, p. 51).

Denotations are type-theoretic entities over some basic types: a type of individuals, a type of truth values, and a type of *states*. A state is quintuple of a world, a time, a spatial location, a speaker, and a function δ that assigns values to proper names and demonstratives. Functions that takes states as arguments are called *Carnap intensions*.

The computational element comes in with the so-called *recursion variables*: free variables of various types that may depend on other recursion variables of *lower rank*. This is exemplified in (37):

(37) a. John likes Mary and he dislikes her husband.
b. $p \,\&\, q$ **where**
$\{p := \textbf{likes}(j, m)$,
$q := \textbf{dislikes}(j, h)$,
$h := \textbf{husband}(m)$,
$j := \textbf{John}$,
$m := \textbf{Mary}\}$

Example (37b) is a *rendering* of (37a) in the formal language $\mathbf{L}^{\lambda}_{\mathrm{ar}}$. It denotes the Carnap intension of (37a), which is a function from states to truth values. The recursion variables p, q, h depend on the values of the recursion variables j, m, and their values are computed compositionally, and in some cases also capture anaphoric relations.

Proper terms (complex terms or constants) are said to be *referentially synonymous* iff their referential intensions are *naturally isomorphic*, where natural isomorphism between terms is similar to Carnap's intensional isomorphism (see 3.13, page 97). Thereby the referential intensions of Moschovakis are similar to Carnap's *meanings* (1956), that is, what is identical between synonymous expressions according to 3.13, with the added element of recursion variables whose values correspond to the Carnap meanings of syntactic constituents. The procedural element is seen in the perspective of computing the values of the recursion variables step by step, in the order of dependence, but does not seem crucial to the individuation of referential intensions.

In TIL, the algorithmic perspective was given up in favour of a *constructional* (see Materna, 2009; Duží et al., 2010). It is still meant to be procedural, but semantic values are not always computable. Like Moschovakis's system, TIL is based on a type theory, with basic types those of individuals, truth values, times/real numbers, and possible worlds, together with the non-basic types of partial functions between already constructed types.

To these basic types are added so-called *constructions*. Moreover, with the construction comes a hierarchy of *orders*: The types of the basic function hierarchy belong to order 1. Constructions of order n are those that construct members of types of order n. The *collection* of all constructions of order n is itself a type of order $n + 1$. Orders are cumulative.

The peculiar features of TIL are its various *construction operators*, including $^0(\cdot)$ and $[\cdot, \ldots, \cdot]$. ^0X is the *trivialization* of X, or *mention* of X. The expression '$3 + 7$' simply denotes the number 10, but it corresponds to a particular way constructing or computing the number 10, distinct from, for example, that of '$4 + 6$'. The construction operators provide a way of denoting the constructions themselves, without executing/evaluating the constructions, reflecting the syntactic build-up rather than simply denoting the result.

Thus, ^{03} is the trivial construction of 3, an entity distinct from the number 3 itself. Analogously ^{07}. $^0+$ is the trivial construction of the addition function. These constructions can be combined by means of the *composition operator* $[\cdot, \ldots, \cdot]$: given a construction of a function, and constructions of arguments to that function, the composition operator constructs the value of the function (which is a construction of 10):

$$[^0{+}\,^03\ ^07].$$

In some cases, what is wanted is not denoting the construction of the value, which we get by composition, but rather the construction of the composition itself. This is achieved by another trivialization:

$$^0[^0{+}\,^03\ ^07].$$

This is then taken to denote an abstract procedure which, when executed, delivers as a result a construction of the number 10. This is again a procedure which, when executed, delivers the number 10 itself.

In case the composition operator contains a free variable, as in $^0[^0{+}x\ ^07]$, what results is a so-called concept of a construction type. By contrast, $\lambda x[^0{+}x\ ^07]$ is a *function* that for a given value of x gives a construction of the sum as value.

^0X entities are hyperintensional meanings and clearly are very much like structured meanings, with a structure that reflects the syntactic structure of the expressions they provide a meaning for. In what sense are they of a procedural nature? As far as I understand, they are procedural only in so far as they are viewed from a procedural perspective, that is, as offering a method of reaching, step by step (starting from the construction itself), what is ultimately constructed (e.g. the number 10). The same perspective can be applied to structured meanings of other kinds.

3.16 Conclusions

The modern tradition of formal semantics evolved out of an effort to place mathematics on a firm logical basis. It has remained close to logic in employing formal methods and keeping the concept of *truth* as one of its core concepts. Connected with the concept of truth is the general notion of *truth conditions*, a notion made use of in trying to capture the non-extensional character of linguistic meaning. As we have seen, this theme has been developed in many different ways. Furthermore, there are yet further approaches, such as *dynamic semantics* (see, e.g., Asher, Chapter 4 and Dekker (2012) for a recent overview) and *event semantics* (see, e.g., Rothstein, Chapter 12). A common feature in all the various types of semantics is the attempt to model in a precise way how the meanings of linguistically complex expressions are determined by the meanings of their parts and the way these are combined. This is indeed one of the defining features of formal semantics.

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4

Discourse semantics

Nicholas Asher

4.1 Introduction

Most people would take it as self-evident that individual words in natural languages have a meaning that is organized according to the syntactic structure of a sentence so as to combine together to make a unit of meaning, the proposition, corresponding to a sentence. Moreover, most linguists who have attempted to model this phenomenon have adhered to some form of *compositionality*, according to which the meaning of the whole is a function of the meaning of the parts (see Partee, Section 1.3.1). Sentences, however, do not occur in isolation, and they are not interpreted in isolation either. The past thirty years have witnessed an impressive list of findings, according to which many words and semantic constructions of a higher order depend for a specification of their meaning on the discourse context. Several theories of discourse interpretation have emerged to do justice to these observations.

The sensitivity of an expression's or construction's meaning to discourse context is different in kind from the well-known context sensitivity attributed to indexical and demonstrative expressions by Kaplan (1989b) and his followers. In standard Montague semantics, an expression is evaluated semantically at an index or point of evaluation that consists of a world, a time, and perhaps other components as well. Various meaningful expressions or morphological markings like the tense morphemes in many languages can manipulate or shift these elements of evaluation; for instance, a sentence in the past tense, whose logical form for our purposes here we can fix as PAST(φ) when evaluated at a world w and time t will be true if and only if φ is true at w and some t' in the past of t. According to Kaplan, the evaluation of indexical expressions involves a different sort of parameter, a context, which cannot be shifted by elements in the language. The fixity of such contexts is used to derive the *rigidity* of indexicals and demonstratives – that is, the observation that an indexical or demonstrative in a language like English has the same semantic value relative to every world (and time) of evaluation.

Discourse contexts, unlike Kaplanian contexts, shift or *evolve* as the discourse proceeds; as the discourse proceeds new elements become part of the discourse context and can serve to determine the meanings of discourse-sensitive elements in future continuations of the discourse. Let us consider the case of anaphoric pronouns and their interaction with the use of indefinite noun phrases in prior discourse.

(1) a. A man walked in. He drank an orange juice.
    b. A man walked in. Then a boy walked in. He drank an orange juice.

In (1a) the indefinite noun phrase *a man* furnishes an antecedent for the pronoun in the second sentence; choosing this antecedent as the value of the pronoun provides it with a determinate semantic interpretation. In (1b) the use of a second indefinite noun phrase *a boy* in the discourse context provided by the first sentence (1a) introduces another antecedent and a second possible interpretation of the pronoun *he*, which is not available to the interpretation of the pronoun in (1a). Thus, the second sentence of (1b) has in some sense transformed the discourse context provided by the first sentence of (1a).

Another feature of discourse contexts is that elements for semantic interpretation may be available at one stage in the evolution of the discourse context and may fail to be available at later stages of the context. Let us consider once more the case of anaphoric pronouns.

(2) a. Suppose a man walked in. Suppose he drank an orange juice.
    b. Suppose a man walked in. Suppose he drank an orange juice. # Then he left.

In (2a) the two sentences of (1a) are embedded within the scope of the verb *suppose*. Nevertheless the pronoun *he* can still be interpreted as referring to the man who (supposedly) walks in. However, in (2b) the second occurrence of the pronoun *he*, the one in the sentence *Then he left* cannot be. The way the discourse has continued in (2b) makes the semantic value of the indefinite noun phrase unavailable for the interpretation of the pronoun in the third sentence.

This last phenomenon is tied to a third observation as to how logical and other operators structure discourse contexts. The so-called *donkey sentences*, rediscovered by Geach (1962), show that pronouns have access to the semantic value of an indefinite within the consequent of a conditional.

(3) If a man owns a donkey, he beats it.

This poses problems for a compositional treatment of indefinites. (3) has the truth conditions of a universally quantified statement in which the universal quantifiers ranging over men and donkeys bind variables introduced by *he* and *it* respectively. That is, the logical form of such a sentence is as follows:

(3)′ $\forall x(\text{man}(x) \rightarrow \forall y(\text{donkey}(x) \rightarrow (\text{owns}(x, y) \rightarrow \text{beats}(x, y))))$

However, if indefinite noun phrases are to be translated as existential quantifiers, then providing a narrow nuclear scope for such quantifiers, which does not contain the consequent of the conditional, would not provide the right bound variable treatment of the pronouns and giving these quantifiers wide scope would yield the wrong truth conditions for (3).

These three observations point to a complex interaction between discourse contexts and semantic interpretation. While I have illustrated the observations with individual anaphoric pronouns and indefinites, the same moral holds for tense morphemes and temporal adverbs that are also sensitive to discourse structure and were an original motivation for dynamic semantics (Kamp, 1979). And similar observations hold concerning presupposition (Heim, 1983a; van der Sandt, 1992; Frank and Kamp, 1997; Geurts, 1999; Beaver, 2001), and other forms of anaphora or ellipsis. On the other hand, there has been considerable debate about what factors affect semantic interpretation and what expressions are sensitive to discourse context for their interpretation. Dynamic semantic theories like Discourse Representation Theory (DRT), Dynamic Predicate Logic (DPL), Update Semantics, and versions of Continuation Semantics (de Groote, 2006) have developed accounts of discourse contexts based on a close study of the interactions of the logical operators and quantifiers familiar from first-order logic with discourse contexts and semantic interpretation. Other theories of discourse interpretation, principally the work on Segmented Discourse Representation Theory (SDRT) inspired by work in artificial intelligence like that of Hobbs (1979, 1985a), Polanyi and Scha (1984), Grosz and Sidner (1986), Mann and Thompson (1987), accord discourse contexts a much richer, relational structure that includes *discourse relations* linking basic discourse units to other discourse units. Discourse relations are distinct from standard logical operators; they specify thematic, causal, structural and temporal relations between the semantic contents conveyed by the basic discourse units, typically associated with clauses. Lascarides and Asher (1993) argue that the interpretation of discourse context sensitive expressions or morphemes like tense are sensitive to such structure as well as to logical structure; Asher (1993) makes a similar argument concerning anaphors referring to propositions and ellipsis, following earlier work of Hobbs (1979) concerning individual anaphors and definite descriptions. Yet other work on discourse contexts concentrates on the *salience* of various discourse entities as antecedents for anaphoric expressions – that is, which discourse entities are the ones that are most likely to be antecedents for the anaphoric expressions (Gundel et al., 1993; Grosz et al., 1995).

Despite these differences concerning the nature of discourse structure, all of these theories share a basic idea about semantics made clear already in the dynamic semantics of Kamp (1981b), Heim (1982), Groenendijk and Stokhof (1991), Kamp and Reyle (1993), and Veltman (1996). The idea is that the text and its context constitute the unit of meaning. Each sentence is interpreted relative to a context and in turn contributes or updates the context of interpretation. The meaning of a sentence is thus naturally thought of as a relation between contexts. In the last thirty years, computer scientists and linguists have developed sophisticated ways for modeling the effects of context on interpretation. These ways include various kinds of dynamic logics for programs and dynamic semantics, and there is often a close correspondence between them. Various versions of dynamic semantics, DRT, DPL, Update Semantics, and even some versions of Situation Semantics (Heim, 1990a; Elbourne, 2005) treat the meaning of a natural language sentence as a relation between information states, an input information state and the output information state. Thus, each sentence corresponds to an *action* on the input information state, just as elements in a program are actions on the input computational state. The input information state represents the content of the discourse context to date, while the output information state represents the content of the previous discourse context integrated with the content of the formula.

Let us investigate this relational conception more closely. An interpretation for a discourse depends not only on a compositional semantics for sentences but also on what one might call a "binder" rule.[1] Let the structure of a text be the sequence of its constituent sentences. Given a category of sentences S and a "combinator", '.', we define the category of texts T inductively:

$S \longrightarrow T$

$T.S \longrightarrow T$

Thus, a sentence is a text and a text combined with a sentence is also a text. Where $\|T\|$ is the meaning (or meaning representation) of T and $\|S\|$ is the meaning of a sentence whose meaning is to be added to $\|T\|$, a binder rule is an operation b that takes a text meaning, combines it with a sentence meaning, and returns a new text meaning that can be integrated with further text meanings:

(4) $b\colon \|T\| \times \|S\| \longrightarrow \|T\|$

[1] The modeling of continuation style semantics for programs using the notion of a monad in category theory is due to Moggi (1991). Barker and Shan (2006); and de Groote (2006) show the applicability of continuation style methods for the semantics of natural language discourse.

All theories of discourse semantics have some form of binder rule. A Stalnakerian semantics for discourse (Stalnaker, 1978) is perhaps the simplest model of discourse semantics. According to Stalnaker each sentence denotes a set of possible worlds, and a discourse context is also a set of possible worlds. The operation b is set-theoretic intersection. While this picture is attractive because of its simplicity and because of its direct connection with standard model-theoretic semantics and classical logic, it cannot begin to do justice to the problems of interpreting intersentential anaphora or tense. Consider, for instance, the phenomena of intersentential anaphoric dependence observed in (1). On a Stalnakerian view, the discourse context provides no recoverable semantic value for the indefinite noun phrase that can serve to interpret the anaphoric pronoun; the natural idea that the pronoun in the second sentence of (1a) introduces a variable that is bound by the existential quantifier introduced by the indefinite noun phrase in the first sentence cannot coherently combine with a Stalnakerian semantics for discourse. Accordingly, linguists interested in discourse semantics have largely adopted some version of dynamic semantics in which discourse contexts make available values for variables that anaphoric expressions can exploit. Below I consider three ways of understanding discourse contexts that develop this idea.

4.2 Discourse Representation Theory

In the early 1980s Hans Kamp and Irene Heim published the first accounts of discourse semantics that investigated in depth the behavior of anaphoric pronouns and discourse contexts (Kamp, 1981b; Heim, 1982). I concentrate on Kamp's theory here. In Kamp's dynamic semantics, *Discourse Representation Theory* (DRT), a discourse context is a mental representation of what has been said, a Discourse Representation Structure (DRS). Updating a discourse context C with an assertion that p is the merge of the contextually given DRS with the DRS for p. The operation b is an operation of merge over DRSs, DRT's meaning representations. DRSs are pairs of sets, the first element of which is a set of discourse referents which represent entities that the discourse talks about and the second element of which is a set of formulas over those discourse referents. The formulas in the DRS language correspond to first-order formulas in a sense that we will make quite precise in a minute, but they often look quite different from first-order formulas, for example, they may contain DRSs within them. Where K and K_1 are DRSs, then a DRS condition is either an atomic formula (in the usual sense) or of the form $\neg K$, $K \Rightarrow K_1$ or $K \vee K_1$. The merge of two DRSs $\langle U_1, C_1\rangle$ and $\langle U_2, C_2\rangle$ is: $\langle U_1 \cup U_2,\ C_1 \cup C_2\rangle$.

Let's look at how DRT treats anaphoric pronouns.

(5) John bought a book on semantics. He is reading it now.

(6) Every book John buys is about semantics. He is reading it* now.

We pretend that (5) is said "out of the blue" and thus the discourse context is just the empty DRS. We update this empty DRS with the contents of the first sentence of (5), which yields the following structure:

(5)′

$$\begin{array}{|c|}\hline j, x \\ \hline \text{bought}(j, x) \\ \text{book-on-semantics}(x) \\ \hline \end{array}$$

The processing of sentence 2 of (5) yields the following DRS. Note the peculiarity of the conditions $z =?$ and $u =?$; these are *underspecified* conditions introduced by the anaphoric pronouns *he* and *it*. The meaning of ? in $z =?$ is an instruction to select a "suitable" discourse referent from the discourse context to identify with z. Only then will the pronoun have a complete interpretation.

(5)″

$$\begin{array}{|c|}\hline z, u \\ \hline \text{read}(z, u) \\ z = ? \\ u = ? \\ \hline \end{array}$$

We now use DRS merge to get the DRS for the whole discourse:

(5)‴

$$\begin{array}{|c|}\hline j, x, z, u \\ \hline \text{bought}(j, x) \\ \text{book-on-semantics}(x) \\ \text{read}(z, u) \\ z = ? \\ u = ? \\ \hline \end{array}$$

Of course the DRS in (5)‴ isn't completely specified because it still contains underspecified conditions. Substituting the discourse referents introduced by the preferred antecedents for the pronouns we get:

$(5)^{+}$

$$\begin{array}{|c|}\hline j, x, z, u \\ \hline \text{bought}(j, x) \\ \text{book-on-semantics}(x) \\ \text{read}(z, u) \\ z = j \\ u = x \\ \hline \end{array}$$

DRT's treatment of anaphoric expressions calls for some remarks about the semantics/pragmatics interface. First, lexical and compositional semantics by themselves typically cannot specify completely the content of anaphoric elements. In order to get a complete interpretation (on at least the view of many discourse theorists), pragmatics must complete underspecified conditions (replacing ? with the appropriate discourse referents). Underspecification allows us to view anaphora resolution as an inferential process, formalizable within logic eventually. An alternative view is to let the semantics freely generate all possible anaphoric bindings, some to be discarded on pragmatic grounds. A second remark is that the semantics of pronouns and other anaphoric expressions is subject to certain semantic constraints, which DRT has made an important focus in the literature. One such constraint is called *accessibility*: it is a constraint defined on the structure of the DRS representations and states that only discourse referents in a DRS universe to the left linked to the current DRS with the operator $\Rightarrow$ or a universe of a DRS that includes a condition of the form $Z =?$ are accessible to that condition.

In (5) all the discourse referents are accessible to the underspecified conditions. This is not the case for the discourse referents j and x in the DRS for (6):

(6)′

$$\begin{array}{|c|} \hline \\ \hline \begin{array}{|c|} \hline j, x \\ \hline buys(j, x) \\ book(x) \\ \hline \end{array} \Rightarrow \boxed{\text{on\_semantics}(x)} \\ \text{read}(z, u) \\ z = ? \\ u = ? \\ \hline \end{array}$$

The same principles are at work in the specification of tense morphology (Kamp and Reyle, 1993). Here I give just an outline of how the semantics goes for a mini discourse in the simple past in French.

(7) Un homme entra. Il fuma une cigarette. Il partit.
(A man entered. He smoked a cigarette. He left.)

The semantic representation for the first sentence now includes more detailed information than before because we explicitly take account of the temporal information included in the past tense. The past tense introduces a discourse referent for an eventuality that is located prior to the "now" of the discourse (symbolized by the discourse referent n). In addition, it introduces certain local variables, Rpt, $TPpt$, and Ept (reference time, temporal perspective time, and event time), that are updated as discourse proceeds.

$$
\begin{array}{|c|}
\hline
x, e, n \\
\hline
man(x) \\
\text{enter}(e, x) \\
e < n \\
Rpt := TPpt = Ept := e \\
\hline
\end{array}
$$

After the second sentence, we exploit these local variables to establish the temporal structure of the text (for details on the algorithm for computing the values of these variables, see Kamp and Reyle, 1993).

$$
\begin{array}{|c|}
\hline
x, e, e_1, y, n \\
\hline
\text{man}(x) \\
\text{enter}(e, x) \\
e < n \\
\text{cigarette}(y)\ \text{smoke}(e_1, x, y) \\
e < e_1 \\
e_1 < n \\
Rpt := TPpt = Ept := e_1 \\
\hline
\end{array}
$$

After the third sentence, we get yet another update:

$$
\begin{array}{|c|}
\hline
x, e, e_1, e_2, y, n \\
\hline
\text{man}(x) \\
\text{enter}(e, x) \\
e < n \\
\text{cigarette}(y)\ \text{smoke}(e_1, x, y) \\
e < e_1 \\
e_1 < n \\
\text{leave}(e_2, x) \\
e_1 < e_2 \\
e_2 < n \\
Rpt := TPpt = Ept := e_2 \\
\hline
\end{array}
$$

At this point it is useful to bring up two key points about all dynamic theories:

- They exploit the syntax of the sentence currently being processed in defining how the input context gets updated to the output context via the binder function.
- Constructing the logical form for the output context is independent of the *interpretations* of the input context and the new information. Only the structure or "form" of the information influences this. The logical form doesn't need to be interpreted incrementally; the DRS which represents *all* of the discourse can be constructed before it's evaluated against a model.

This allows dynamic semantics to be more or less compositional, and more or less dynamic. For instance, Kamp (1981b) and Kamp and Reyle (1993) do not have dynamic formulations for their semantics. The following embedding definition for DRSs takes place against the background of a fixed first-order model $M = (D, \mathcal{I})$, consisting of a domain of discourse D and an interpretation function $\mathcal{I}$. g, h, k below are partial assignment functions that take discourse referents into elements of D.

Definition 4.2.1

$$
\begin{aligned}
\langle g, h\rangle \models \langle U, C\rangle \;&\text{ iff }\; g \subset_U h \text{ and for all } \gamma \in C,\; h \models \gamma \\
g \models x_i = x_j \;&\text{ iff }\; g(x_i) = g(x_j) \\
g \models \text{Name}(x) \;&\text{ iff }\; \mathcal{I}(\text{Name}) = g(x) \\
g \models P(x_1, \ldots, x_n) \;&\text{ iff }\; \langle g(x_1), \ldots, g(x_n)\rangle \in \mathcal{I}(P) \\
g \models \neg K \;&\text{ iff }\; \text{there does not exist an } h \text{ such that} \\
&\qquad\qquad \langle g, h\rangle \models K \\
g \models K \vee K' \;&\text{ iff }\; \text{there is some } h \text{ such that} \\
&\qquad\qquad \langle g, h\rangle \models K \text{ or } \langle g, h\rangle \models K' \\
g \models K \Rightarrow K' \;&\text{ iff }\; \text{for all } h \text{ such that } \langle g, h\rangle \models K, \\
&\qquad\qquad \text{there is a } k \text{ such } \langle h, k\rangle \models K'
\end{aligned}
$$

A DRS K is *true* in a model M iff $\langle \Lambda, g\rangle \models K$ in M (Λ is the empty function).

In effect the construction rules for DRT in Kamp (1981b) and Kamp and Reyle (1993) are not compositional in the usual sense because they do not start from a fixed lexicon with each expression having an independent model-theoretic content as in classical formal semantics. Nevertheless, compositional versions of DRT have been given by Asher (1993) and Muskens (1996) that bring dynamic semantics into line with standard formulations of compositional semantics. We can rewrite the syntax of DRSs in line with this compositional approach using a standard Tarskian model and provide a relational semantics for it, explicitly showing the effect of the binder function and permitting a precise relation between DRT style semantics and classical logic. To this end, I define simultaneously the model-theoretic transition P_M and the satisfaction of conditions V_M relative to a model M. f, g, h are once again partial assignment functions from discourse referents to elements in the domain of the model.

Definition 4.2.2

$$
\begin{aligned}
fP_M(U, \emptyset)g \ &\text{iff} \ f \subseteq g \wedge \mathrm{Dom}(g) = \mathrm{Dom}(f) \cup U \\
f \in V_M(R(x_1, \ldots, x_n)) \ &\text{iff} \ R_M(f(x_1), \ldots, f(x_n)) \\
fP_M(K^\frown \gamma)g \ &\text{iff} \ fP_M(K)g \wedge g \in V_M(\gamma) \\
f \in V_M(\neg K) \ &\text{iff} \ \neg\exists g fP_M(K)g \\
f \in V_M(K \Rightarrow K') \ &\text{iff} \ \forall g(fP_M(K)g \rightarrow \exists hgP_M(K')h) \\
f \in V_M(K \vee K') \ &\text{iff} \ \exists g fP_M(K)g \vee \exists h fP_M(K')h
\end{aligned}
$$

We can reformulate this to make it look even closer to the model theory for other versions of dynamic semantics, in particular Dynamic Predicate Logic, or DPL, which we will meet in the next section. In particular we don't need the distinction between condition satisfaction V_M and transition P_M. Every DRS formula according to the syntax laid out above becomes an action and its semantic value is a transition. It's just that some of the transitions are tests, in the sense of dynamic logic, as they do not change the input.

Definition 4.2.3

$$
\begin{aligned}
fP_M(U, \emptyset)g \ &\text{iff} \ f \subseteq g \wedge dom(g) = dom(f) \cup U \\
fP_M(R(x_1, \ldots, x_n))f \ &\text{iff} \ R_M(f(x_1), \ldots, f(x_n)) \\
fP_M(K^\frown \gamma)g \ &\text{iff} \ fP_M(K)g \wedge gP_M(\gamma)g \\
fP_M(\neg K)f \ &\text{iff} \ \neg\exists g fP_M(K)g \\
fP_M(K \Rightarrow K')f \ &\text{iff} \ \forall g(fP_M(K)g \rightarrow \exists hgP_M(K')h) \\
fP_M(K \vee K')f \ &\text{iff} \ \exists g fP_M(K)g \vee \exists h fP_M(K')h
\end{aligned}
$$

We can now lift the relational semantics for DRT to a functional semantics over sets of input assignments. I assume a sufficiently large set *MOD* of models, namely, those formed from maximal consistent saturated sets of first-order formulas.

It is useful to define not only P but also its *lifted* counterpart $\mathcal{P}$ on sets of model sequence pairs (MSP)'s for a DRS K. $\mathcal{P}(K) : \mathrm{Pow(MSP)} \rightarrow \mathrm{Pow(MSP)}$ is defined distributively or pointwise over the set of model sequence pairs, exploiting K's effect on an input MSP(M, g) to produce a certain output MSP(M', g'). That is for a context X and a given DRS K:

$$[\mathcal{P}(K)](X) = \{(M, g') : \exists g(M, g) \in X \wedge gP_M(K)g'\}$$

One can associate with each DRS K a set of pairs $\langle M, f\rangle$ where f is a proper embedding of K in a Tarskian model M. Such sets are called information states and they correspond to a first-order formula. This connection is made precise in the following lemma (proved by induction). I use here the formulation of Fernando (1994). Let $\{\langle M, 0\rangle : M \in MOD\} = \sigma_0$.

Lemma 4.2.1 (Characterization Lemma (A))

- *For every first-order formula χ with a set of free variables U, there is a DRS (U, C) such that $\mathcal{P}(U, C)[\sigma_0] = \{(M, f) : \mathrm{Dom}(f) = U$ and $M \models \chi[f]\}$*
- *Every DRS (U, C) has a characteristic formula χ where U is the set of free variables in χ and $\mathcal{P}(U, C)[\sigma_0] = \{(M, f) : \mathrm{Dom}(f) = U$ and $M \models \chi[f]\}$*

The interpretation of a discourse in such versions of dynamic semantics involves the relational composition of constituent sentences' relational meanings. In dynamic semantics for natural languages, as well as in the dynamic semantics for programming languages, the interpretation of a formula can either function as a test on the input context or can transform the context. For example, *John is sleeping* in dynamic semantics yields a formula that functions as a test on the input context, which we can think of as a set of elements of evaluation. If an element of evaluation verifies the proposition that John is sleeping, then it is passed on to the output context; if it does not verify the proposition, it does not become part of the output context. Operators like conditionals form complex tests on an input context C: an element of evaluation e will pass the test defined by *If A then B* just in case any output o from A given e will yield an output from B (given o as an input). Some sentences, for instance those containing indefinite noun phrases, output a context that is distinct from the input one. They transform elements of the input context; in particular they *reset* or *extend* the assignment functions that are parts of elements of the context to reflect the information they convey. On a view that treats assignments as total functions over the set of variables, an indefinite has the action of resetting an assignment that is part of the point of evaluation for formulas, as in Tarskian semantics. On a view where assignments are treated as partial functions, the interpretation of an indefinite extends the assignment with a value to the variable introduced by the indefinite in logical form. This reset or extended assignment becomes part of the output context.

DRT is a dynamic theory of discourse interpretation. The idea is that each sentence has a *context change potential* (CCP) that changes a discourse context when the information contained within the sentence is added to the context. The background context is represented as a DRS; the contribution of the individual sentence is the context DRS extended with the conditions and discourse referents contributed by the processing of the sentence. Thus, the CCP of a sentence is a relation between DRSs. More precisely, let C_φ be the set of conditions of the DRS φ, χ_φ be the characteristic formula of φ, and let $\varphi^\frown\psi = ((U_\psi \cup U_\varphi), (C_\psi \cup C_\varphi))$, if $(\chi_\varphi \wedge \chi_\psi)$ is first-order consistent.

The CCP of an unambiguous sentence S, which by a procedure known as the DRS construction procedure yields a DRS K_S,[2] can now be represented as the DRS transition predicate T_{drs}, between consistent DRSs. We define T_{drs} as

[2] For details see Kamp and Reyle (1993).

the set below:

$\{(K, K_S, K^{\star}) : K$ is a DRS, $K_S, K^{\star}$ are consistent DRSs and $K^{\star} = K^{\frown}K_S\}$

As shown in Groenendijk and Stokhof's DPL (for a discussion see, e.g., van Eijck and Kamp, 1997), the CCP of a sentence may also be represented as a relation between information states (assuming once again the presence of the DRS construction procedure). A model-theoretic context is a set of model sequence pairs (MSPs), and so a natural candidate for the model-theoretic notion of the CCP of a sentence S is just the lifted function P applied to the DRS derived from S.

Using the Characterization Lemma, Fernando (1994) has shown a precise equivalence between the representational and model-theoretic conceptions of CCP for the simple core fragment of DRT and he has also shown that the notion of equivalent CCP is recursively enumerable (r.e.). The representational level and the model-theoretic level yield bisimulation-equivalent notions of context and CCP.[3] Let $\varphi_{\perp}$ be the set of absurd formulas, and let *MOD* be defined as above. Define Acc as the smallest set of states such that, where $[\mathcal{P}(\varphi)](\sigma)$ represents the application of the function $\mathcal{P}$ to σ:

$\sigma_0 \in \text{Acc} \wedge (\sigma \in \text{Acc} \Rightarrow [\mathcal{P}(\varphi)](\sigma) \in \text{Acc})$

Thus, we can define within Acc for any consistent $\varphi, \sigma_{\varphi} = [\mathcal{P}(\varphi)](\sigma_0)$. Suppose that $\mathcal{P}(\varphi^{\frown}\psi) = \mathcal{P}(\varphi) \circ \mathcal{P}(\psi)$ and define $\varphi \underline{\leftrightarrow} \psi$ iff $\forall \varphi'(\varphi^{\frown}\varphi' \in \varphi_{\perp} \leftrightarrow \psi^{\frown}\varphi' \in \varphi_{\perp})$.

Theorem 4.2.1 (Fernando, 1994): *$\varphi \underline{\leftrightarrow} \psi$ iff $\sigma_{\varphi} = \sigma_{\psi}$; and further, $\underline{\leftrightarrow}$ and $\varphi_{\perp}$ are r.e.*

$\underline{\leftrightarrow}$ defines a bisimulation relative to the function $^{\frown}$, and $\mathcal{P}(K)[\sigma_0]$, in effect, exploits $\underline{\leftrightarrow}$ to induce a bisimulation relative to state transitions, the model-theoretic interpretation of a DRS on a set of MSPs. Further, bisimilarity on state transitions is strongly extensional; bisimilar transitions on states have identical outputs when applied to the empty information state, which explains the first part of the theorem. For the second part of the theorem, note that $\underline{\leftrightarrow}$ is defined proof-theoretically, by an operation on DRSs. Given the Characterization Lemma, every DRS is equivalent to a first-order formula. Hence, the notions $\underline{\leftrightarrow}$ and $\varphi_{\perp}$ are first-order definable and so r.e.

4.3 Dynamic Predicate Logic

Various versions of dynamic semantics differ as to what are the input and output states of the basic discourse equation in (4). DRT, for example, incorporates the relational conception of meaning at a representational level. The

[3] A similar representation theorem for a slightly different conception of model-theoretic context is sketched in Asher (1993). For more on the notion of bisimulation, see Aczel and Mendler (1989).

input and output states are representations known as *Discourse Representation Structures*, or DRSs. DRT proposes to build the update and dynamics into the construction of logical form but not of its interpretation. This makes the semantics of DRT static and provably equivalent to a Tarskian semantics, but it means that the construction of the logical form is a relatively complicated affair.

In presenting the relational version of DRT, we actually presented key ideas of the dynamic semantics known as Dynamic Predicate Logic (DPL) (Groenendijk and Stokhof, 1991), where the meaning of a sentence is a relation between an input assignment and an output assignment (relative to a fixed model), and b is the operation of relational composition. Groenendijk and Stokhof observe that given a compositionality principle of the sort usually used in Montague Grammar we should get for the donkey sentence in (3), repeated below, the logical form in (8):

(3) If a man owns a donkey, he beats it.

(8) $\exists x(\text{man}(x) \wedge \exists y(\text{donkey}(x) \wedge \text{owns}(x, y))) \rightarrow \text{beats}(x, y)$

However, what DRT provides is the logical form in (3)′:

(3)′ $\forall x(\text{man}(x) \rightarrow \forall y(\text{donkey}(x) \rightarrow (\text{owns}(x, y) \rightarrow \text{beats}(x, y))))$

This poses problems for the compositionality principle unless one provides a non-standard translation for indefinite NPs as is done in DRT. DPL proposes another semantics so that the formula (8) can represent the meaning of (3) and come out with the same truth conditions as expressed by the first-order formula in (3)′. As stressed in Groenendijk and Stokhof (1991), DPL is inspired by systems of dynamic logic as they are used in the denotational semantics of programming languages.

The syntax of DPL is that of standard first-order logic syntax with equality. Let G be the set of assignments of objects in M to variables in the language, $\mathcal{M} = \langle M, I\rangle$ be a model, and let g be an assignment. Define $\|t\|_g^{\mathcal{M}} = g(t)$ if t is a variable and $\|t\|_g^{\mathcal{M}} = I(t)$ if t is a constant. Then, the interpretation function $\|.\|^{\mathcal{M}} \subseteq G \times G$ (that is, $\|.\|^{\mathcal{M}}$ is a relation between assignment functions) has the following definition. Let $g =_x h$ mean that g and h are equal everywhere except possibly at x.

$$\begin{aligned}
\|Rt_1, \ldots, t_n\|^{\mathcal{M}} &= \{(g, h)\colon g = h \wedge I(R)(\|t_1\|_h^{\mathcal{M}}, \ldots, \|t_n\|_h^{\mathcal{M}})\}\\
\|t_1 = t_2\|^{\mathcal{M}} &= \{(g, h)\colon g = h \wedge \|t_1\|_h^{\mathcal{M}} = \|t_2\|_h^{\mathcal{M}})\}\\
\|\neg\varphi\|^{\mathcal{M}} &= \{(g, h)\colon g = h \wedge \neg\exists k(h, k) \in \|\varphi\|^{\mathcal{M}}\}\\
\|\varphi \wedge \psi\|^{\mathcal{M}} &= \{(g, h)\colon \exists k((g, k) \in \|\varphi\|^{\mathcal{M}} \wedge (k, h) \in \|\psi\|^{\mathcal{M}})\}\\
\|\varphi \rightarrow \psi\|^{\mathcal{M}} &= \{(g, h)\colon g = h \wedge \forall k((g, k) \in \|\varphi\|^{\mathcal{M}} \rightarrow \exists l(k, l) \in \|\psi\|^{\mathcal{M}})\}\\
\|\varphi \vee \psi\|^{\mathcal{M}} &= \{(g, h)\colon g = h \wedge \exists k((g, k) \in \|\varphi\|^{\mathcal{M}} \vee (g, k) \in \|\psi\|^{\mathcal{M}})\}\\
\|\exists x\varphi\|^{\mathcal{M}} &= \{(g, h)\colon \exists k(g =_x k \wedge (k, h) \in \|\varphi\|^{\mathcal{M}})\}\\
\|\forall x\varphi\|^{\mathcal{M}} &= \{(g, h)\colon \forall k(g =_x k \rightarrow \exists j(k, j) \in \|\varphi\|^{\mathcal{M}})\}
\end{aligned}$$

To finish off the semantics, we need to give a notion of satisfaction from which we can define truth and logical consequence. We say that an assignment g *satisfies* a formula φ in $\mathcal{M}$ iff $\exists k(g, k) \in \|\varphi\|^{\mathcal{M}}$, and a formula is *true* in $\mathcal{M}$ iff it is satisfied in $\mathcal{M}$ by all assignments.

The binder rule for the interpretation of a text is to take relational composition. So the clause for interpreting $T.S$, $\|T.S\|^{\mathcal{M}} = \|T\|^{\mathcal{M}} \circ \|S\|^{\mathcal{M}}$. Full stops are interpreted as equivalent to conjunctions in DPL. This makes it easy to compute the semantic values for intersentential anaphoric examples like (1a) (the computation is slightly abbreviated for readability):

The 1st sentence:

$$\|\exists x(\text{man}(x) \wedge \text{walked-in}(x))\|^{\mathcal{M}} = \{(g, h) \colon \exists k(g =_x k \wedge (k, h) \in \|\text{man}(x) \wedge \text{walked-in}(x)\|^{\mathcal{M}})\}$$

The 2nd sentence:

$$\|\text{drank an orange juice}(x)\|^{\mathcal{M}} = \{(g, h) \colon g = h \wedge I(\text{drank an oj})(\|x\|_h^{\mathcal{M}})\}$$

The two sentences together:

$$\|\exists x(\text{man}(x) \wedge \text{walked-in}(x))\|^{\mathcal{M}} \circ \|\text{drank an oj}(x)\|^{\mathcal{M}}$$
$$= \{(g, h) \colon \exists k(g =_x k \wedge (k, h) \in \|\text{man}(x) \wedge \text{walked-in}(x)\|^{\mathcal{M}} \wedge I(\text{drank an oj})(\|x\|_k^{\mathcal{M}}))\}$$

Thus (1a) is true just in case there is a man who walks in and who orders an orange juice, which is what is intuitively desired.

It is easy enough to check that the donkey sentences get an interpretation as well. The antecedent of (3) yields the set of assignment pairs (g, h) such that $(g =_{x,y} h \wedge (h, h) \in \|\text{man}(x) \wedge \text{donkey}(y) \wedge \text{owns}(x, y)\|^{\mathcal{M}})$; putting this together with the meaning of the conditional and the meaning of the consequent, we get the following set of assignments:

(9) $\{(g, h) \colon g = h \wedge \forall k((g =_{x,y} k \wedge (k, k) \in \|\text{man}(x) \wedge \text{donkey}(y) \wedge \text{owns}(x, y)\|^{\mathcal{M}}) \to (k, k) \in \|\text{beats}(x, y)\|^{\mathcal{M}})\}$

And this provides truth conditions equivalent to those given by the first-order formula (3)′. More generally, we can establish the equivalences:

$$((\exists x\varphi) \to \psi) \leftrightarrow \forall x(\varphi \to \psi)$$
$$((\exists x\varphi) \wedge \psi) \leftrightarrow \exists x(\varphi \wedge \psi)$$

This means that the underlying logic of DPL is rather different from classical logic.

Dynamic logic has been used, for instance, to account for anaphora (Groenendijk and Stokhof, 1991), presupposition (Beaver, 1997, 2001), Update Semantics (Veltman, 1996), and modal subordination (Stone and Hardt, 1999; Asher and McCready, 2007). Nevertheless, despite its many attractions, there remain certain problems. It suffers from the destructive assignment problem. This is analogous to a problem in imperative programming languages. The problem is that an assignment $x := 2$ in a program hides or destroys previous assignments (for instance $x := 1$). Suggestions relying on states have been made to recover from this drawback, such as Predicate Logic with Anaphora (Dekker, 1994). There is also a problem with compositional interpretation. We have seen that DPL provides a compositional treatment of indefinite noun phrases and their discourse-binding properties. When we delve into the types that are assigned to expressions in virtue of their semantic value, however, things look somewhat peculiar; a reconstruction of the semantic values, say of individual expressions and their projections like noun phrases, makes use of types that involve assignments and variables or something like them. This is strange from a standard semantic point of view.

4.4 Continuation style semantics

Logical forms and logics of composition are easily constructable for DPL or relational versions of DRT, using a suitably dynamicized version of the lambda calculus (Muskens, 1996; Dekker, 1999; Roussarie and Amsili, 2002). This is all to the well and good since this makes dynamic semantics more comparable to ordinary truth-conditional semantics. This allows us to follow standard practice in semantics and take logical forms to provide truth conditions (of the static or dynamic variety) and thus to be a basic component of semantics. A theory of meaning composition must yield interpretable logical forms for meaningful clauses; and a theory of discourse structure must yield logical forms for discourses. So the move toward compositional treatments of dynamic semantics is important.

On the other hand, the composition logic and the validity notion that results from such dynamic semantic frameworks is quite non-standard. Types that involve assignments of objects to variables or some equivalent become part of the type system in the lexical theory. This makes it hard to evaluate lexical entries within dynamic semantics with entries in classical theories like Montague Grammar. However, recently, researchers have used more sophisticated tools from computer science known as *continuations* to build contextually sensitive semantics within the confines of classical higher-order logic. Continuations permit a faithful embedding of dynamic semantics into higher-order logic. Without getting into the technical details, the idea of continuations is to build into lexical entries a "left" context parameter, which provides elements of discourse context relevant to interpretation like available discourse referents, together with a "right" context of the discourse to come. The trick is to get, for instance, indefinites to "pass on" the discourse referents they introduce to subsequent discourse while remaining within the framework of classical logic, according to which we end up with a classically valued proposition for a discourse. This is what various versions of continuation style semantics manage to do (Barker and Shan, 2006; de Groote, 2006; Bernardi and Moortgat, 2007).[4] Roughly, anaphoric expressions in continuation style semantics select elements from the left context, while indefinites update the left contexts with an element and the updated left contexts are then passed on to the right contexts. It is continuation style semantics that allows us to build the simpler lexical entries with a standard interpretation that are comparable to those developed in Montague Grammar.

Doing compositional semantics for DRT or DPL leads to the introduction of "odd" types whose inhabitants are variables, assignments or other "representational" elements. We also have problems of destructive assignment in DPL and with variable clash in DRT or versions of DPL that use partial assignment functions. It is difficult to avoid these problems in a purely compositional environment. The approaches by de Groote (2006) and Pogodalla (2008) and Barker and Shan (2006) offer a way to avoid these problems. They give us a purely objectual semantics for at least some dynamic notions. They also separate out the interactions between discourse context and logical operators from the semantics of those logical operators, allowing for a standard, classical interpretation of the quantifiers and connectives. The continuation-based discourse semantics of (de Groote, 2006) and (Barker and Shan, 2006) do this by complicating the lexical entries of expressions and the binder rule.

I will look at de Groote's implementation of continuation style semantics as a representative example. De Groote's idea is to make continuations a basic property of all lexical items. That is for each term, we will have a left (i) and a right (o) context to which it is sensitive.

(10) $\lambda i \lambda o \varphi$

An additional element of the idea, however, is that the final outcome of a discourse should be a proposition. So an output context is defined as in (11), where PROP is the type of propositions (sets of worlds, other more complex indices, or simply truth values).

(11) $o = i \Rightarrow \textsc{prop}$

The last bit of the basic idea is to say how a text T which is sensitive to both a left and a right context and so has the form $\lambda i \lambda o \varphi$ combines with a sentence to its right. That is, we have to specify the binder function. With

[4] The details often differ in these theories between how the syntax semantics interface is characterized. Bernardi and Moortgat are more interested in the construction of a syntactic structure in proof-theoretic terms; they then translate the result of their proof from the Grishin Lambek calculus into a semantics that uses continuations. De Groote and those who use his formalism like Asher and Pogodalla (2010), take the syntactic structure and the semantic logical form to issue from a single Abstract Categorial Grammar (ACG). The ACG issues directly in the continuation style semantic representations.

this notion in place, we will be able to compute the meanings of discourses incrementally by going from left to right (for most languages) but for Arabic and Hebrew we can go from right to left and for Chinese we can go from top to bottom. Here is the equation for the binder function, where $\|T\|$ stands for the λ term or meaning of T:

(12) $\|T.S\| = \lambda i \lambda o \|T\| i (\lambda i' \|S\| i' o)$

That is, the text to date T takes the meaning of S as its right context, or rather the meaning of S suitably applied and abstracted so that it can be of o type. A quick type check on $\lambda i' \|S\| i' o$ confirms that this is indeed the right output: $\|S\| : i \Rightarrow (o \Rightarrow \text{PROP})$; $\lambda i'[\|S\| i' o] : i \Rightarrow (i \Rightarrow o \Rightarrow \text{PROP})[i][o]$ which is just $i \Rightarrow \text{PROP})$.

To give a concrete example of what is at issue, let us for a minute see how this approach might treat a simple example like (13).

(13) A man is sleeping. He is snoring.

Imagine a completely classical interpretation of these two sentences *except* that the first sentence has both a left and right context and that the second sentence fills in the right context. Imagine also, as we shall see clearly below, that the existential determiner introduces an individual into the right context – a witness that will be "selected" by the pronoun. With this in mind, the meaning representation of the first sentence looks like this:

(14) $\lambda i \lambda o \exists x (\text{man}(x) \wedge \text{sleeping}(x) \wedge o(i + x))$

Let's imagine that the second sentence now provides a meaning representation of the following kind:

(15) $\lambda i \lambda o (\text{snoring}(\text{sel}(i)) \wedge o(i))$

Now let us put the meanings of these two sentences together to get a meaning of (13) using the rule above:

(16) $\lambda i \lambda o [\lambda i \lambda o \exists x (\text{man}(x) \wedge \text{sleeping}(x) \wedge o(i + x))]$
$i (\lambda i' (\lambda i \lambda o (\text{snoring}(\text{sel}(i)) \wedge o(i)) i' o) \longrightarrow_\beta$

(17) $\lambda i \lambda o [\lambda o \exists x (\text{man}(x) \wedge \text{sleeping}(x) \wedge o(i + x))]$
$(\lambda i' (\lambda i \lambda o (\text{snoring}(\text{sel}(i)) \wedge o(i)) i' o) \longrightarrow_\beta$

(18) $\lambda i \lambda o [\exists x (\text{man}(x) \wedge \text{sleeping}(x) \wedge (\lambda i' (\lambda i \lambda o$
$(\text{snoring}(\text{sel}(i)) \wedge o(i)) i' o)(i + x))] \longrightarrow_\beta$

(19) $\lambda i \lambda o [\exists x (\text{man}(x) \wedge \text{sleeping}(x) \wedge (\lambda i' (\lambda o$
$(\text{snoring}(\text{sel}(i')) \wedge o(i')) o)(i + x))] \longrightarrow_\beta$

(20) $\lambda i \lambda o [\exists x (\text{man}(x) \wedge \text{sleeping}(x) \wedge (\lambda i' \ (\text{snoring}(\text{sel}(i')) \wedge o(i'))(i + x))] \longrightarrow_\beta$

(21) $\lambda i \lambda o [\exists x (\text{man}(x) \wedge \text{sleeping}(x) \wedge \text{snoring}(\text{sel}(i + x)) \wedge o(i + x))]$

At this point we see that the anaphoric pronoun can select the bound variable x, falling within the scope of the original existential quantifier.

From Montagovian static types to dynamic denotational types

De Groote's idea is to push the left right context sensitivity of terms all the way down into the lexicon. With a judicious choice of lexical entries, we can get the right dynamic behavior for existentials, other quantifiers, and operators. So let us see how this is done.

The types are defined as follows. I shall continue to use the abbreviation o for the right context, which is in fact $i \Rightarrow \textsc{prop}$.

- The type $\textsc{s}$ of a sentence in de Groote's system is : $i \Rightarrow o \Rightarrow \textsc{prop}$ instead of $\textsc{prop}$.
- The type of a noun: In Montague Grammar we have $\textsc{e} \Rightarrow \textsc{s}$; so here we have following this

  $\textsc{e} \Rightarrow i \Rightarrow o \Rightarrow \textsc{prop}$

- The type $\textsc{dp}$ of a DP or determiner phrase in both systems is $(\textsc{e} \Rightarrow \textsc{s}) \Rightarrow \textsc{s}$. However, in de Groote's system, this means that we have:

  $(\textsc{e} \Rightarrow i \Rightarrow o \Rightarrow \textsc{prop}) \Rightarrow (i \Rightarrow o \Rightarrow \textsc{prop})$

- The types of verb phrases (and intransitive verbs) and transitive verbs is similar in both systems:

  the type $\textsc{vp}$ of a VP is: $\textsc{dp} \Rightarrow \textsc{s}$
  the type $\textsc{tv}$ of a transitive verb is: $\textsc{dp} \Rightarrow \textsc{dp} \Rightarrow \textsc{s}$

- The type of determiners is as usual:

  $\textsc{n} \Rightarrow \textsc{dp}$

- The type of adverbs and adjectives can remain as usual.

Now let us look to various lexical entries. Of particular interest will be the determiners which can introduce or block certain continuations that exploit what dynamic semantics calls discourse referents. What is novel about the system here is that discourse referents are ordinary objectual variables, at least in this fragment. There are no syntactic types as in compositional reconstructions of DRT or DPL.

Let us see how this works out. Determiners are really of two kinds: the anaphoric determiners *select* elements from the input context as their semantic values or at least contribute to them, whereas determiners like the indefinites *a*, *some*, the definite *the* and the so-called strong determiners like *every, each, all* all introduce values into the right context. The difference in anaphoric potential between these determiners lies in how the right context is exploited in composition. The same holds for proper names; they are value introducers. Let's look at some entries:

Mary:	$\lambda P \lambda i \lambda o P m i(\lambda i' o(i' + m))$
she:	$\lambda P \lambda i \lambda o P \mathrm{sel}(i) i o$
a:	$\lambda P \lambda Q \lambda i \lambda o \exists x P x i(\lambda i' Q x(i' + x) o)$
every:	$\lambda P \lambda Q \lambda i \lambda o(\forall x(\neg(P x i(\lambda i' \neg Q x(i' + x) \lambda i \top))) \wedge o(i))$
not:	$\lambda P \lambda i \lambda o(\neg P i(\lambda i' \top) \wedge o(i))$
if ... then:	$\lambda P \lambda Q \lambda i \lambda o(\neg(P i(\lambda i' \neg Q i'(\lambda i \top))) \wedge o(i))$

Once we add the lexical entries for verbs, this will suffice to reproduce the basic DRT fragment (actually more than what is found in Kamp, 1981b). Notice that some determiners and proper names pass variables onto their right context, but notice also that these variables are all bound in the standard sense of first order logic. Thus, each λ term here is closed and does not depend for its denotation on a notion of assignment. Moreover, there is no need to assume assignments, let alone discourse referents, as semantic values in the system.

4.5 More elaborate theories of discourse structure

So far we have looked at theories of discourse semantics that have investigated how contextual information propagates through the logical structure of the discourse, as given by the first-order quantifiers and operators. We have also concentrated on how such accounts deal with anaphoric expressions and anaphoric dependencies. However, while anaphoric expressions like pronouns, verb tenses, and ellipsis constructions are the clearest examples of discourse context-dependent interpretations, they are by no means the only examples. The point of view of theories that posit more elaborate discourse structures involving discourse relations, theories like *Segmented Discourse Representation Theory* (SDRT), is that *all* units of information that serve as constituents of discourse structure, in particular all clauses and parenthetical expressions, appositions, and non-restrictive relative clauses, have context-dependent interpretations. To cash out this idea, however, we have to re-examine the model of discourse contexts.

Theories like SDRT assign texts a meaning involving a rich discourse structure, and so the representation of the context and the specification of the binder rule will be more complex. More concretely, the way $\|S\|$ combines with $\|T\|$ will sometimes depend on details of the lexical entries of the words in $\|S\|$. The basic premise of a discourse semantics like SDRT is that the way $\|S\|$ will combine with $\|T\|$ will depend on the rhetorical or discourse function that $\|S\|$ has in the context of $\|T\|$.

Discourse relations are types of relational speech acts (D-speech acts). They are often, but not always, underspecified by lexical semantics, the syntax/semantics interface and the principles of composition. They are anaphors (and cataphors). Speech acts in the Anglo-Saxon literature are typically characterized as unary properties of utterances or sentences-in-a context, except for the speech act type "answer", which is in fact a relational speech act. (Conversational analysts [Sacks, 1992] countenance many more relational speech acts.) What the standard picture missed is the *relational* nature of many speech acts. There are *many* relational "discourse" speech acts, things people do with sentence contents in a discourse context. Here is a short and non-exhaustive list.

- They explain a previous position or why something happened.
- They narrate a story of what happened.
- They provide backgrounding for some event.
- They elaborate on the properties of entities they've already mentioned, or on an event or a plan.
- They describe the result of a previously mentioned event or state.
- They correct themselves or others' discourse contributions.
- They ask questions whose answers will help determine answers to previously asked questions.
- They offer greetings and insults, and say good-bye.

These particular relations group naturally into general categories – Narrative, Causal, Thematic, Structural similarity, which seem to be universal (Leth, 2011).

Each clause in a well-formed discourse gives rise to a discourse constituent that is linked with one or more discourse relations to the discourse context. Thus, discourse constituents must be something akin to speech acts (items with linguistic context uttered in a particular discourse). At the very least, we cannot identify the contribution of a clause with a proposition or sentence content, since one and the same sentence content can have different, incompatible rhetorical roles in different contexts:

(22) Max fell. John pushed him.

(23) John and Max were at the edge of a cliff. Max felt a sharp blow to the back of his neck. Max fell. John pushed him. Max rolled over the edge of the cliff.

This gives rise to the notion of a discourse context and even a sentence's contribution to discourse as a relational structure involving constituents and discourse relations between them. In SDRT, these structures are known as SDRSs. There are many ways of representing SDRSs and for interpreting them. In Asher and Lascarides (2003b), SDRSs are defined as a triple $\langle A, \mathcal{F}, Last \rangle$, where:

- A is a set of labels;
- *Last* is a label in A (intuitively, this is the label of the content of the last clause that was added to the logical form); and
- $\mathcal{F}$ is a function which assigns each member of A an SDRS formula – e.g., $Explanation(\pi_1, \pi_2)$, $\pi_1 : K$, where K is a DRS or DPL formula.

Here is an example of an SDRS.

(24) π_1 John bought an apartment
π_2 but he rented it.

(24)′
$$\begin{aligned} A &= \{\pi_0, \pi_1, \pi_2\} \\ \mathcal{F}(\pi_1) &= \exists x \exists e(e \prec now \wedge apartment(x) \wedge buy(e, j, x)) \\ \mathcal{F}(\pi_2) &= \exists e'(e' \prec now \wedge rent(e', j, x)) \\ \mathcal{F}(\pi_0) &= Narration(\pi_1, \pi_2) \wedge Contrast(\pi_1, \pi_2) \\ Last &= \pi_2 \end{aligned}$$

Note the two discourse relations between π_1 and π_2.

We can use a DRS-like representation for SDRSs as well. The following example from Asher (1993):

(25) John drives a car. It is red.

(25)′
$$\begin{array}{|c|} \hline \pi_1, \pi_2 \\ \hline \pi_1 : \begin{array}{|c|} \hline x, y \\ \hline john(x), car(y), drive(x, y) \\ \hline \end{array} \quad \pi_2 : \begin{array}{|c|} \hline z \\ \hline red(z), z = y \\ \hline \end{array} \\ Elab(\pi_1, \pi_2) \\ \hline \end{array}$$

SDRSs also can be encoded with continuation style semantics. We assign SDRSs a distinct type κ, which is a record, consisting of a set of labels, a subset of the labels where one can attach new information, a set of discourse entities, and an intensional content. We also reinterpret the type PROP for SDRT: it is a function from labels to intensional contents (sets of points of evaluation). A sentence's contribution to an input record is to add to a label and a content that links the sentence's contribution to some available label via one or more discourse relations. For more details see Asher and Pogodalla (2011). Inevitably, SDRT needs some kind of dynamic semantics. Probably the continuation style semantics is the most elegant of these, abstracting away from irrelevant representational details. It also provides the cleanest separation between logic and linguistics.

I now turn to the rationale for introducing discourse relations and structured discourse contexts. Discourse relations have effects on content (causal and temporal structure, anaphora and ellipsis resolution, presupposition, scalar implicature triggering) and on prosody. I give a couple of examples below of how discourse relations and the structured discourse contexts of SDRT take us beyond the predictions of classical dynamic semantics (DRT, DPL, Update Semantics) for the domains these semantic theories were designed for.

Let us consider first propositional anaphora. What is the referent of *this* in (26)?

(26) a. One plaintiff was passed over for promotion three times.
b. Another didn't get a raise for five years.
c. A third plaintiff was given a lower wage compared to males who were doing the same work.
d. But the jury didn't believe this.

Classical dynamic semantic theories don't offer an answer to this question. However, if we look at the SDRT graph for this example, where some relations are coordinating (horizontal lines) and some relations are subordinating (vertical lines), we see something interesting.

(26)′

Three badly treated plaintiffs make claims

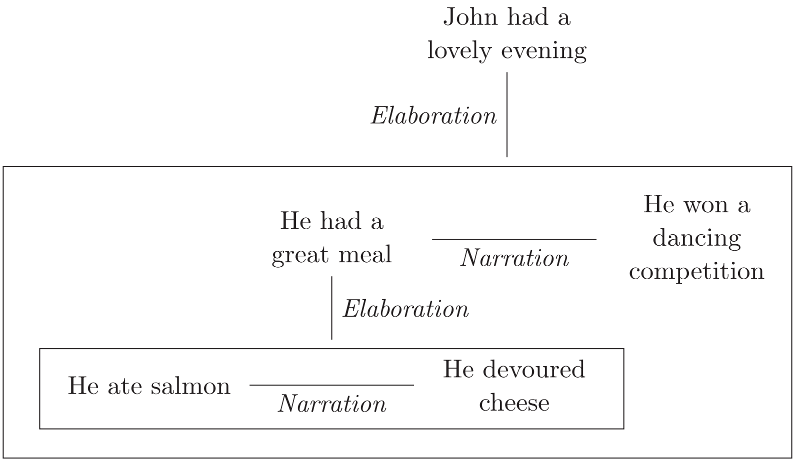
$$\boxed{(26a) \xrightarrow[\textit{Continuation}]{} (26b) \xrightarrow[\textit{Continuation}]{} (26c)}$$

Consider the right frontier of this graph: it contains just the material from the third sentence (26c) as well as the topic constructed for the discourse as a whole. And just (26c) as well as the constructed topic provide available attachment points. SDRT and other theories that postulate a richly structured discourse context point to an interesting generalization: the discourse entities for anaphora resolution are to be found along the right frontier of the graph.

This generalization holds by and large for anaphoric expressions referring to concrete individuals as well. Consider the following:

(27) a. John had a lovely evening last night.
b. He had a great meal.
c. He ate salmon.
d. He devoured lots of cheese.
e. He then won a dancing competition.
f. ??The salmon tasted great.

Here is the SDRS graph for this example:



The right frontier of the graph contains discourse entities corresponding to John, the lovely evening and the dancing competition, but crucially not the salmon, making the continuation in (27f) difficult.

Discourse functions affect many aspects of discourse meaning, including the resolution of anaphoric expressions and ellipsis, temporal structure, presupposition, and the interpretation of adverbials (Hobbs, 1979; Asher, 1993; Hobbs et al., 1993; Lascarides and Asher, 1993; Asher and Lascarides, 2003b; Vieu et al., 2005). To compute these components of interpretation, we need to compute the discourse functions of discourse constituents (which for the moment we may continue to think of as sentences or clauses).

Sometimes, a relatively small class of adverbs or adverbial phrases, what Knott (1995) and others have called *discourse connectors* or *discourse markers*, suffices to determine the discourse functions and hence a method of combination in SDRT.[5] Syntactic constructions may also yield important clues as to discourse structure and how a new sentence, or rather discourse constituent, must combine with the text's meaning. But sometimes the method of combination will depend on open class words like verbs, their arguments, and their modifiers. To illustrate, consider the following:

(28) a. John fell. He slipped.
b. John fell. He got hurt.
c. John fell. He went down hard, onto the pavement.

In each of (28)a–c, the second sentence has a different rhetorical or discourse function, which is reflected in the way SDRT integrates its content with the discourse context. For example, SDRT would relate the discourse

[5] These are conjunctions like *but, because*, and *for*, adverbs like *also* and *too*, and adverbial phrases like *as a result*, and *and then*. Knott (1995) contains a long list of such markers, and computational linguists like Manfred Stede have constructed lists for other languages.

constituents denoted by the two sentences in (28a) by Explanation – John fell because he slipped. The constituents in (28b) would be related by Result, while the constituents in (28c) would be related by Elaboration. In each case, the rhetorical function can be traced to the meanings of the verb phrases.

In SDRT each sentence introduces a speech act discourse referent with an associated content that is linked via one or more discourse relations to its discourse context. All of these examples feature the same sequences of tenses but intuitively different temporal structures. Dynamic semantics can't explain these differences. What does explain the different temporal structures are the discourse relations that relate the discourse constituents derived from the clauses in these mini discourses. These discourse relations determine the discourse or rhetorical functions associated with the speech act. In (28a), the speech act a_1, whose content is that John fell, and the speech act a_2, associated with *He slipped*, are related by Explanation; a_2 explains why John fell. In (28b), the speech act b_2, introduced by the second sentence, is linked to the speech act b_1, introduced by *John fell*, via Result. In (28c) the speech act c_2, introduced by the second sentence, is related by Elaboration to c_1. Each one of these discourse relations imposes different temporal constraints on the eventualities introduced by the clauses the relations relate: Explanation(a, b) entails that the eventuality in b happens before that in a (causes precede effects), whereas Result(a, b) entails that the eventuality in a happens before that in b; Elaboration(a, b) entails that the eventuality in b is a subevent of the eventuality in a. This accords with intuitions.

4.6 Conclusions

Investigations of discourse connectives, syntax, and prosody have yielded a finer understanding of discourse relations, and these in turn have yielded many new insights concerning the context-sensitive nature of meaning in discourse. Nevertheless, much work remains to be done. For one thing, a full formalization of discourse relation triggering rules is not available due to impoverished lexical resources. Researchers have turned to statistical methods for building discourse structures, which try to learn discourse structures automatically from a list of features gleaned from a corpus of texts annotated with discourse structure. However, the annotation task is difficult and expensive, resulting in a lack of data. Furthermore, the data we have is often noisy or biased, leading to very suboptimal results. There are two paths that have yet to be pursued. Unsupervised statistical methods offer a hope of learning discourse structure from unannotated data, but it is not known how to get complex relational structures with these methods. The second option is to pursue hybrid models that combine statistical and symbolic methods, but for discourse structure this approach is still in its infancy.

5

Semantics of dialogue

Jonathan Ginzburg

5.1 Introduction

The semantics of dialogue is a fundamental topic for a number of reasons. First, dialogue is the primary medium of language use, phylogenetically and ontogenetically. Second, studying dialogue forces one to a particularly careful study of the nature of context. The context has a role to play in determining *what* one can or should say at a given point and also *how* to say it. Conversely, it affords the interlocutors a very impressive economy of expression – there is much subtlety that can be achieved with relatively little effort drawing simply on material that is *in* the context.

Consequently, two themes will drive this article, relating to two fundamental problems a semantic analysis in dialogue has to tackle:

(1) **Conversational relevance**: given that a conversation is in a certain state, what utterances can be produced coherently by each conversational participant in that state?
Conversational meaning: what conversational states are appropriate for a given word/construction and what import will that word have in such a state?

Conversational relevance is without doubt a very fundamental and difficult problem. It is closely connected to the Turing test and solving this problem in full generality is, as Turing pointed out, a possible basis for understanding the nature of intelligence (Turing, 1950; see also Łupkowski and Wiśniewski, 2011). However, is it a *semantic*, as opposed to a *pragmatic* problem or one connected to generalized notions of cognition? We will not deal with this issue of territorial demarcation in anything but passing (see also Schlenker, Chapter 22). Nonetheless, we will offer a detailed empirical and theoretical analysis of the components of conversational relevance.

Conversational meaning is *semantic* enough, but the obvious question one might ask is – why *conversational*? Why should we consider meaning in the context of conversations? One might turn the question on its head and ask, noting, as I already have above, that conversation is the primary linguistic medium in which language evolved and existed for millennia and that it is the setting in which language is acquired: how could we *not* take conversation as the basic setting for semantic theory? I think this perspective is highly attractive – I have offered some evidence for it in Ginzburg (2012) and establishing this point – more generally that *grammar* should be viewed as characterizing talk in interaction – is the main topic of Ginzburg and Poesio (2014). For current purposes, it will suffice to point to the existence of various words and constructions whose import is tied to a conversational setting. These in themselves justify the need for at least some of semantics to be conversationally oriented. In Section 5.5 we will also encounter phenomena from dialogue that motivate an incremental view of semantic composition.

The structure of this article is as follows: I start by pointing to work in the philosophy of language, pragmatics, cognitive psychology, and conversational analysis, which provides current formal work on dialogue with key phenomena and concepts. I then point to a number of core phenomena that linguistic theories of dialogue need to account for. I subsequently sketch an account of certain of these phenomena in contemporary dialogue frameworks. Finally, I point to a number of additional phenomena that seem to require significant modifications of our view of semantics, context, and language.

5.2 Antecedents of Formal Dialogue Theory

5.2.1 Language is or could be dialogical

Wittgenstein (1953) introduced the notion of a *language game*. Now the notion of *language* game is no more definite than the notion of a game *simpliciter*, which Wittgenstein put forward as an example of a concept difficult to characterize in hard and fast terms. Still a language game can be viewed as a type of interaction involving language use within a more or less restricted set of associated actions. For dialogue researchers it is important for at least two reasons. First, in discussing the hypothetical 'builder's language' Wittgenstein illustrates that within a specific domain 'non-canonical' utterances, particularly non-sentential ones such as 'Slab!' or 'Beam!', can be as canonical or even more natural than fully spelled out, sentential utterances. Indeed Wittgenstein provides one of the first challenges to the 'sententialist' view of ellipsis that will subsequently, from the 1960s onwards, predominate in generative grammar:

> But what about this: is the call 'Slab!' in example (2) a sentence or a word? If a word, surely it has not the same meaning as the like-sounding word of our ordinary language, for in §2 it is a call. But if a sentence, it is surely not the elliptical sentence: 'Slab!' of our language. As far as the first question goes you can call 'Slab!' a word and also a sentence; perhaps it could be appropriately called a 'degenerate sentence' (as one speaks of a degenerate hyperbola); in fact it *is* our 'elliptical' sentence. But that is surely only a shortened form of the sentence 'Bring me a slab', and there is no such sentence in example (2). But why should I not on the contrary have called the sentence 'Bring me a slab' a *lengthening* of the sentence 'Slab!'? Because if you shout 'Slab!' you really mean: 'Bring me a slab'. But how do you do this: how do you *mean that* while you *say* 'Slab!'? Do you say the unshortened sentence to yourself? (Wittgenstein, 1953, §19)

Tying utterance interpretation to facts characteristic of specific domains provides a potential way of dealing with a variety of actually occurring non-sentential utterances (NSUs) in various domains:

(2) a. [A advances to bar, addresses barman]
A: A Franziskaner and a Duwel.
b. (1) 'Your name?' asked Holmes.
(2) 'Patrick Cairns.'
(3) 'Harpooner?'
(4) 'Yes, sir. (5) Twenty six voyages.'
(6) 'Dundee, I suppose?'
(7) 'Yes, sir.' (Doyle, 1905)

More generally, it opens up the way to talk about domain specificity of language. *Variation* is a big, perhaps one of the biggest issues in contemporary sociolinguistics (Tagliamonte, 2006). This view of language lies at present in big contrast to the domain-independent view almost universally assumed in formal grammar of most stripes. However, workers on speech recognition assume such a view via the notion of *language model* (Chelba, 2010). Given that one of the main concerns of dialogue is characterizing relevance and that, as demonstrated in (2), this is clearly domain relative, the importance of a language game perspective is evident.

In fact, there is a long tradition predating Wittgenstein by centuries of logic games or formal dialectic. This tradition, expunged from mainstream attention in post-Fregean logic until recently, is documented in Hamblin (1970) and has been active in argumentation theory (Walton, 2011). This perspective is narrower than the Wittgensteinian, with a normative intent, but more directly tractable. Thus, Hamblin's *Why-Because System with Questions* (1970, pp. 265–276) can be viewed as one of the first modern attempts to provide a formal description of two-person discussion: moves are characterized in terms of formulas of propositional logic which can affect a set of *commitments*. In addition to moves corresponding to assertion and the posing of alternative questions, the system provides for moves that elicit the justification of an assertion, retraction, and a request to resolve an inconsistency.

5.2.2 Meaning from rationality

From our current perspective, Gricean pragmatics (Grice, 1989b) is very much focused on the issue of Conversational relevance: Grice's maxims constitute a quasi-calculus for establishing what utterance to select at a given point in a conversation. And, consequently, what inferences to draw in case this selection does not get realized in practice.

The big gaping hole in Grice's account, one which he was fully aware of, was the lack of substance concerning the maxim of Relevance. Two crucial ingredients are missing: an explicit notion of *current conversational state* and a means for generating the range of *potentially relevant* contributions. While there has been much insightful work in mainstream pragmatics since Grice, whether closely following Grice (e.g. Levinson, 2000) or radically changing his vision (e.g. relevance theory, Sperber and Wilson, 1995), it has not filled these lacunes.

On the other hand, for workers on the semantics of dialogue Grice has provided inspiration in significant ways. Groenendijk (2006) shows how using a relatively simple extension of first-order logic that also contains questions can enable one to simultaneously define notions of Quality, Quantity, and Relevance (his technical term is *pertinence*). Dekker (2006), on the basis of a synthesis of dynamic semantics, Gricean pragmatics, and relevance theory, shows how to characterize the optimality of a discourse. This general strategy is taken a step further in *Inquisitive Semantics* (Groenendijk, 2009; Groenendijk and Roelofsen, 2009), discussed in detail in Dekker, Aloni, and Groenendijk, Chapter 19.

As we discuss in Section 5.4, accounts which emphasize a notion of Questions-Under-Discussion (QUD) as fundamental to context offer detailed explications of relevance, some of which emphasize Gricean rationality and cooperativeness (e.g. Asher and Lascarides, 2003b; Ginzburg, 2012; Asher and Lascarides, 2012; Roberts, 2012a).

5.2.3 Structure from interaction

A third tradition, Conversational Analysis (CA) (Sacks et al., 1974; Schegloff et al., 1977; Schegloff, 1987), puts interaction as the primary scene for linguistic use. CA's contributions to developing a theory of dialogue address primarily **move relevance**:

Adjacency pairs: CA provides extensive evidence for the existence of strong preference for a certain class of responses (*second part pairs*) as follow-ups to a given class of *first part pairs*:

(3) a. A: Who left? B: Bill (query/reply)
b. A: Open the window please! B: Sure (command/acceptance)
c. A: Hi! B: Hiya! (greeting/counter-greeting)

Repair: perhaps an even more important contribution of CA is introducing the notion of *repair*:

> By 'repair' we refer to efforts to deal with trouble in speaking, hearing, or understanding talk in interaction. 'Trouble' includes such occurrences as misarticulations, malapropisms, use of a 'wrong' word, unavailability of a word when needed, failure to hear or to be heard, trouble on the part of the recipient in understanding, incorrect understandings by recipients, and various others. Because anything in talk can be a source of trouble, everything in conversation is, in principle, 'repairable'. (Schegloff, 1987, p. 210)

Schegloff et al. (1977) show that there are many commonalities between *self-repair* (A repairing her own utterance) and *other repair* (B repairing A's utterance). This work was the first of many to show the regularity of repair, still very much neglected in generative and formal work, possibly under the influence of the competence/performance distinction, which consigns most self-repair to the performance dustbin. Both self-repair and other-repair have subsequently been the object of much study by researchers in other disciplines: as we discuss in Sections 5.3.3 and 5.5.1 respectively, self-repair by psychologists and speech scientists, whereas other-repair by Human Computer Interaction (HCI) and dialogue system designers and by developmental psychologists.

Turn taking: a third crucial contribution of CA was to initiate the study of *turn taking* in Sacks et al. (1974). A remarkable feature of conversation is that there are relatively few overlaps but at the same time correspondingly few intervals of extended silence. Indeed gaps longer than 600 msec are understood to imply that a dispreferred response will be supplied and gaps longer than 1500 msec are relatively rare. Sacks, Jefferson, and Schegloff proposed a basic principle for determining how a next turn is assigned interactively, as a basis for explaining the efficacy of the turn-taking system. This principle has withstood the ravages of time, serving as the basis for detailed psycholinguistic experimentation (see, e.g., de Ruiter et al., 2006) and for typological investigations (e.g. Stivers et al., 2009), which provide some evidence for the account's cross-linguistic and cross-cultural validity.

5.3 Core dialogue phenomena

In this section I list some phenomena any theory of dialogue needs to account for or underpin other modules' accounts thereof, in line with the driving issues outlined in (1) on pages 130–131.

5.3.1 'Direct' relevance

The first such phenomenon, at the level of utterance content, is characterizing what one might call *direct relevance*. That is, the relationship that holds between moves m_1 and m_2 when m_2 constitutes a direct response to m_1. While the CA literature offers some data on this issue when adjacency pairs are discussed, this is an area that has been studied systematically primarily in the domain of question/answer relations (i.e. where m_1 is a query move and m_2 is assertoric). Here notions such as *partial answerhood* (Groenendijk and Stokhof, 1984), Aboutness (Ginzburg, 1995a; Ginzburg and Sag, 2000), and licensing (Groenendijk, 2006) have been proposed.

(4) a. Jo: When is the train leaving?
Carrie: At 2:58, 17.333398 seconds, according to our caesium clock. / At 2:58. / In about an hour. / In a short while.
b. Chris: Did Merle leave?
Kim: Yes. / Probably. / It's not likely. / No.
c. Sandy: Who will help the President?
Tracy: His close friends. / Few people we know. / Merle Africa or Merle Haggard.
(Ginzburg and Sag, 2000, example 103)

More recently, Ginzburg (1996, 2012) suggested that the appropriate notion for 'direct' responses to queries (his notion of a q-specific utterance, relative to a question q) should encapsulate both answer responses and query responses. The idea being that whenever an issue is being addressed there can be 'direct responses' of both assertoric and interrogative nature. A similar intuition seems to underlie the notion of *compliance* (Groenendijk and Roelofsen, 2009).

(5) a. A: Bo left. B: Right. / Did he? / Isn't he still around?
b. A: Who shall we invite to the party? B: Jack and Jill. / Who is available?

This raises in a particular the issue of how to characterize the range of queries that can coherently follow a query. A large proportion of these are clarification requests, discussed in Section 5.3.3, and these do not address the query as such. However, results from a corpus study of the British National Corpus (BNC) (Łupkowski and Ginzburg, 2014), which offers a comprehensive characterization of such responses, show the existence of a number of other classes, including the following three:[1]

(6) **Dependent questions**
A: Do you want me to <*pause*> push it round?
B: Is it really disturbing you? (BNC, FM1, 679–680)
(cf. *Whether I want you to push it depends on whether it really disturbs you.*)
Situationally pertinent questions
A: Well do you wanna go down and have a look at that now?
<*pause*> While there's workmen there?
B: Why haven't they finished yet? (BNC, KCF, 617–619)
Rebound questions
A: Yeah what was your answer?
B: What was yours? (BNC, KP3, 636–637)

Apart from clarification questions, dependent questions are by far the commonest class of query response – their existence was pointed out by Carlson (1983). The other two classes, somewhat less common, are not 'meta' as such – they, pretheoretically, address the subject matter associated with the query. Rebound questions, which do indeed strongly implicate reluctance to address the issue originally raised, go against any idea that reduces query response felicity to their being a means of finding an answer to the initial query, as in, e.g., Asher and Lascarides (2003b); indeed while their intended effect of imposing a distinct issue is easy to characterize, the range of such questions is difficult to characterize a priori. Situationally pertinent questions illustrate that the 'queried situation', not merely the 'queried predicate' can be significant in calculating a possible (query) response.

5.3.2 Interjections and non-sentential utterances

One characteristic of conversation is the prevalence of utterances without an overt predicate. A semantics for dialogue needs to explain the meaning (= felicity and import) of such utterances. From among these one can mention initially *sentential fragments* – predicateless utterances whose content is propositional or interrogatory. Semantically oriented taxonomies for this class and corpus studies based on them can be found in Fernández and Ginzburg (2002) and Schlangen (2003). Common types of NSUs are exemplified in bold face in (7):

(7) a. Ann: Can you hear the birds singing? Listen.
James: Er (pause) **yeah.**
Ann: Can you hear?
Bryony: I hear birds singing.
Ann: You can hear the birds singing. **Yes.** [BNC, KB8]

[1] Many attested examples in this article come from the BNC (Aston and Barnard, 1998). I use the convention of referring to the file from which it is extracted, e.g. K7D and usually also the line number within that file.

b. Ann: Well put it on the draining board and I'll wash it and then put it back <*pause*>
James: Right, I'll see ya tonight.
Ann: **Mhm, mhm** <*pause*>
James: Tarrah.
Ann: mm, **bye** (conversation ends) [BNC, KB6]

c. A: Who's that?
B: My Aunty Peggy [**last or full name**]. My dad's sister. [BNC, G58, 33–35]

d. Tim: Those pink things that af after we had our lunch.
Dorothy: **Pink things?**
Tim: Yeah. Er those things in that bottle.
Dorothy: Oh I know what you mean. For your throat? [BNC, KBW]

e. Cherrilyn: Are you still <*pause*> erm <*pause*> going to Bristol <*pause*> on Monday?
Fiona: Dunno.
Cherrilyn: **No?**
Fiona: I dunno. Doubt it, **why?** (= *Why do you ask if I'm going to Bristol?*) [BNC, KBL]

A second class of predicate-less utterances are *interjections* (for descriptive work, see, e.g., Schelfhout et al., 2005; Norrick, 2009; for formal treatments of some case studies, see Kaplan, 2001; Jayez, 2004; Potts, 2007; McCready, 2008), which, as (8) makes clear, fulfil a variety of functions, including conversation initiation and closing, expressing emotional attitudes towards events, and attention-getting devices:

(8) a. Mark: that's poison oak.
Christa: **damn**. I don't want that on my body.
(Longman Grammar of Spoken American English Corpus, LSWEC-AC) (Norrick, 2009, p. 869)

b. A: because they go at six fifty a pop.
C: ((laughs))
B: **god** I know.
(London Lund Corpus, Svartvik and Quirk, 1980, 1–10, example from Norrick, 2009, p. 877)

c. Cooper: can I have a bite of that cookie?
Sara: **hey** they're low calorie. you can have the whole cookie.
Cooper: thank you.
(LSWEC-AC, Norrick, 2009, p. 881)

Sentential fragments and interjections pose various challenges both to the semantics and to the organization of the grammar. The most basic challenge is to ensure that context is organized so as to enable resolution of the content and its relevance in the context. There is the pervasive problem that in many cases deciding what the content on a given use is and how many distinct senses to reify is not straightforward as already noted by Wittgenstein. I will exemplify this below with metacommunicative utterances. For now, I illustrate the issue of relevance specification in a case where the content resolution is straightforward. The Arabic word *marxabteyn* is used exclusively as a response to an initial greeting, indeed typically where the initial greeting had the form *marxaba* (*marxabteyn* is the dual form of *marxaba*). Thus, in its lexical specification we need to find a way to encode this information.

This already hints that the notion of context required must be rich and structured, intrinsically more than the dynamic notions introduced to explicate textual meaning in the 1990s (see Asher, Chapter 4). Indeed, NSUs exhibit varying degrees of structural parallelism between the source and the target. For example, both short answers and sluicing cross-linguistically require cross-categorial concord between the antecedent *wh*-phrase and the target (as first pointed out, respectively, by Ross, 1969; Morgan, 1973), whereas a reprise fragment on its *intended content* reading requires segmental phonological identity between source and target (Ginzburg and Cooper, 2004):

(9) a. A: lemi hixmeta? B: #moti/lemoti.
to-who flattered-2SG? moti/to-moti
A: Who did you flatter? B: Moti.
b. A: et mi šibaxt? B: et moti/#lemoti.
DEF-ACC who praised-2SG? DEF-ACC moti/to-moti
A: Who did you praise? B: Moti.
c. A: Did Bo leave? B: Bo? (Intended content reading: **Who are you referring to?** or **Who do you mean?**) /Max? (lacks intended content reading; can only mean: **Are you referring to Max?**)

Since such parallelism can be carried across a number of turns, particularly in multi-party dialogue (Ginzburg and Fernández, 2005), this means that information needed to ensure parallelism is satisfied needs to be projected into context.

5.3.3 Other-repair

The pervasiveness of NSUs and interjections in dialogue is a symptom of the richness of context available to the interlocutors. There is another aspect which is absolutely fundamental to dialogue and concomitantly still missing from most formal approaches to semantics – metacommunicative interaction.

If all goes well with an utterance, we are rarely aware of the communicative process, though it's always there ticking in the background, evinced by the constant stream of back-channelling utterances and gestures produced by the participants of a conversation (for empirical work on back channels see, e.g., Novick and Sutton, 1994; Muller and Prevot, 2003; Nakano et al., 2003). Switch that off and bizarreness ensues. This process, establishing that the most recent move has been understood to the satisfaction of the conversationalists, has come to be known as *grounding*, following extensive empirical work by Herb Clark and his collaborators (Clark and Wilkes-Gibbs, 1986; Clark, 1996; Clark and Schaefer, 1989). A particularly detailed semantic theory of grounding has been developed in the PTT (not an acronym!) framework, discussed further below in section 5.4.3. One concrete task for a dialogical theory is to account for the potential for and meaning of acknowledgement phrases, as in (10), either once the utterance is completed, as in (10a), or concurrently with the utterance as in (10b):

(10) a. Tommy: So Dalmally I should safely say was my first schooling. Even though I was about eight and a half. Anon 1: Mm. Now your father was the the stocker at Tormore is that right? (BNC, K7D)

b. A: Move the train . . .
B: Aha
A: . . . from Avon . . .
B: Right
A: . . . to Danville. (Adapted from the Trains corpus, Allen et al., 1995)

An additional task is to characterize the range of (potential) presuppositions emerging in the aftermath of an utterance, whose subject matter concerns both content and form:

(11) a. A: Did Mark send you a love letter?
b. B: No, though it's interesting **that you refer to Mark/my brother/our friend.**
c. B: No, though it's interesting **that you mention sending.**
d. B: No, though it's interesting **that you ask a question containing seven words.**
e. B: No, though it's interesting **that the final two words you just uttered start with 'l'.**

Developing a semantic theory that can fully accommodate the challenges of grounding is far from straightforward. A more radical challenge, nonetheless, is to explicate what goes on when an addressee cannot ground his or her interlocutor's utterance.

More radical because this ultimately leads to seemingly radical conclusions of an intrinsic *semantic indeterminacy* (Davidson, 1986): in such a situation the public context is no longer identical for the interlocutors – the original speaker can carry on, blissfully unaware that a problem exists, utilizing a 'grounded context', whereas if the original addressee takes over the context is shifted to one which underwrites a *clarification request*. This potential context-splitting is illustrated in (12), originally discussed in Ginzburg (1997). Example (12) illustrates that the contextual possibilities for resolving the fragment 'Bo?' are distinct for the original speaker A and the original addressee B. Although there is one common possibility, the short answer reading, only B has the two clarification request readings, whereas only A has a self-correction reading, albeit one that probably requires an additional elaboratory follow-up:

(12) a. A: Who does Bo admire? B: Bo?
Reading 1 (**short answer**): Does Bo admire Bo?
Reading 2 (**clausal confirmation**): Are you asking who BO (of all people) admires?;
Reading 2 (**intended content**): Who do you mean ‘Bo’?
b. A: Who does Bo admire? Bo?
Reading 1 (**short answer**): Does Bo admire Bo?
Reading 2 (**self correction**): Did I say ‘Bo’?

Clarification Requests (CRs) can take many forms, as illustrated in (13):

(13) a. A: Did Bo leave?
b. **Wot** : B: Eh? / What? / Pardon?
c. **Explicit (exp)** : B: What did you say? / Did you say ‘Bo’? / What do you mean ‘leave’?
d. **Literal reprise** : B: Did BO leave? / Did Bo LEAVE?
e. **Wh-substituted Reprise** : B: Did WHO leave? / Did Bo WHAT?
f. **Reprise sluice** : B: Who? / What? / Where?
g. **Reprise fragments** : B: Bo? / Leave?
h. **Gap** : B: Did Bo . . .?
i. **Filler** : A: Did Bo . . . B: Win? (Purver, 2006, Table I)

Now, as (14a) indicates, a priori ANY sub-utterance is clarifiable, including function words like *the*, as in (14c). While the potential for repetition-oriented CRification clearly applies to all utterances and their parts, it is an open question whether this is true for semantically/pragmatically oriented CRification. For empirical studies on this, see Healey et al. (2003), Purver et al. (2003, 2006).

(14) a. Who rearranged the plug behind the table?
b. Who? / rearranged?/ the plug? / behind? / the table?
c. A: Is that the shark? B: The? B: Well OK, *A*. (based on an example in the film *Jaws*.)

Moreover, a priori CRs can concern any aspect of the communicative process. Nonetheless, a key finding of recent corpus studies of CRs in both a general corpus (Purver et al., 2001) and task-oriented ones (Rodriguez and Schlangen, 2004; Rieser and Moore, 2005), indicate that there are four main categories of CRs:

Repetition: CRs that request the previous utterance to be repeated:

(15) a. Tim (1): Could I have one of those (unclear)?
Dorothy (2): Can you have what? (BNC, KW1)

b. s bust: Great memorial I think really isn't it?
e bust: Beg pardon?
s bust: Be a good appropriate memorial if we can afford it.
(BNC, KM8)

Confirmation: CRs that seek to confirm understanding of a prior utterance:

(16) a. Marsha: yeah that's it, this, she's got three rottweilers now and
Sarah: three? (= Are you saying she's got THREE rottweilers now?)
Marsha: yeah, one died so only got three now (BNC, KP2)
b. A: Is George here?
B: You're asking if George Sand is here.

Intended content: CRs that query the intended content of a prior utterance:

(17) a. Tim (5): Those pink things that af after we had our lunch.
Dorothy (6): Pink things?
Tim (7): Yeah. Er those things in that bottle.
Dorothy (8): Oh **I know what you mean.** For your throat? (BNC, KW1)
b. A: Have a laugh and joke with Dick.
B: Dick?
A: Have a laugh and joke with Dick.
B: Who's Dick? (BNC, KB7)

Intention recognition: CRs that query the goal underlying a prior utterance:

(18) a. X: You know what, the conference might be downtown Seattle. So I may have to call you back on that.
PT: OK. Did you want me to wait for the hotel then?
Communicator Corpus (National and Technology, 2000)
b. Norrine: When is the barbecue, the twentieth? (pause) Something of June.
Chris: Thirtieth.
Norrine: A Sunday.
Chris: Sunday.
Norrine: Mm.
Chris: Why? (= *Why do you ask when the barbecue is*)
Norrine: Because I forgot (pause) That was the day I was thinking of having a proper lunch party but I won't do it if you're going out. (BNC, KBK)

As ever, these data impose a requirement on a theory of dialogue to characterize the relevance of such utterances and to be able to describe precisely how the content of utterances such as the CRs in (15)–(18) emerge. An additional twist, exemplified in (19), is that the context required for this task has to be linguistically rich:

Hyperintensionality: The terms *lawyer* and *attorney* are synonymous but give rise to distinct CRification conditions:

(19) a. Ariadne: Jo is a lawyer. Bora: A lawyer? / What do you mean a lawyer? /# What do you mean an advocate?/# What do you mean an attorney?
b. Ariadne: Jo is an advocate. Bora: #What do you mean a lawyer? / An advocate? / What do you mean an advocate?/#What do you mean an attorney?

Parallelism: The existence of syntactic and phonological parallelism conditions on certain interpretations of CRs. See (9c) above and for detailed discussion, see Ginzburg and Cooper (2004) and Ginzburg (2012).

Utterance tokens: A theory of dialogue must further underwrite reference to utterance tokens, given that they are constituents of the content of CRs, though in fact this is a more general requirement concerning quotative acts in dialogue:

(20) a. A: Max is leaving. B: leaving? (= What does *leaving* mean in the context of A's sub-utterance, NOT in general.)
b. A: Did Bo leave? B: Who is Bo?
c. A: We're fed up. B: Who is we? (= *Who is we* **in the sub-utterance needing clarification**)

We briefly discuss a tie-in of these considerations with work on quotation in the section on metacommunicative interaction, page 158.

5.3.4 Genre sensitivity

The extent to which one can make linguistic generalizations in a way that *evades* genre relativity is perhaps an open question; it is of course also very much a question for those concerned with demarcating the semantics/pragmatics boundary. Nonetheless, for anyone engaged in designing systems that can interact with humans the importance of domain specificity is taken for granted.

Genre specificity is one of the principal factors in determining, to use Herb Clark's phrase, *what drives the dialogue* – the basic intentions underlying participation in a particular conversation. That is, the range of topics that can be relevantly introduced for discussion: e.g. discussing the price of bread is reasonable in a bakery, but not – putting aside specialized circumstances – in a courtroom. In certain cases a genre determines the existence of special moves, e.g. the opening and closing moves in an English court ('The court is in session', 'The court will rise') or even their form (e.g. the fact that in addressing a judge, one needs to end the utterance with the vocative 'm'lud').

Let us distinguish this notion of genre specificity (*interaction determining genre specificity*) from *language determining genre specificity*, where a genre determines its own language – namely, its own lexicon and constructions. The existence of this kind of lexical genre specificity is familiar to us via the notion of *jargon*, the latter less so, but its reality should be clear – different genres have distinct language models, and constructions appropriate for some domains are less so for others; for discussion of how to combine this with formal grammar, see Cooper and Ranta (2008). I will restrict attention here to *interaction determining genre specificity*, though any serious theory of dialogue will require integration with the other notion as well.

In addition to conversational relevance, genre specificity is also clearly implicated in conversational meaning, as we noted already in (2). NSUs can appear as initiating moves (i.e., without a prior linguistic antecedent or segment initially). These seem to require a rather stereotypical interactional setting (e.g. buying tickets at a train station, querying for directions in a taxi).

(21) a. Buying a train ticket:
Client: A return to Newcastle please. (= I want a return . . . , please give me a return . . . , . . .)
b. Driver to passenger in a taxi: Where to?

Explicating how such NSUs get resolved is a basic requirement for a theory of dialogue.

5.3.5 Core dialogue phenomena as theoretical benchmarks

In this section I have compiled a collection of dialogue phenomena which can be used as benchmarks for theories of conversational relevance and meaning.

Taken as a whole, they make clear the need for a significantly different view of context and its evolution from the influential Stalnakerian view, essentially that the effects of utterances on the state of the conversation can be derived entirely from truth-conditional meaning (suitably enriched dynamically) in interaction with general pragmatic principles.

For a start, there is the fact that in dialogue one cannot appeal in general to a single context, given *context branching phenomena* discussed with respect to clarification interaction; there is the evidence that 'direct relevance' is parametrized by agent-specific intentional factors, as illustrated by rebound questions; there is the need to maintain non-content-oriented information in context due to parallelism constraints on non-sentential utterances and the hyperintensionality of clarification potential.

5.4 Dialogue frameworks

5.4.1 KoS

In the first part of the chapter, I suggested two problems a theory of dialogue should strive to solve, conversational relevance and conversational meaning. In this section I will indicate how some existing frameworks tackle these problems and, in particular, the empirical challenges discussed in the previous section; for a thoughtful comparison of recent dialogue frameworks, see Poesio and Rieser (2010). Perhaps the central development enabling progress is the emergence of a formally well-defined notion of the structure of a *conversational state* and, correspondingly, notions of how such states change.

Dialogue gameboards

I start by considering the framework KoS (Ginzburg, 1994; Larsson, 2002; Ginzburg and Cooper, 2004; Fernández, 2006; Purver, 2006; Ginzburg and Fernández, 2010; Ginzburg, 2012). KoS – a toponym, not an acronym – is a theory that combines an approach to semantics inspired by situation semantics and dynamic semantics with a view of interaction influenced by CA. On the approach developed in KoS, there is actually no single context – instead of a single context, analysis is formulated at a level of information states, one per conversational participant. Each information state consists of two 'parts', a private part and the dialogue gameboard that represents information that arises from publicized interactions. For recent psycholinguistic evidence supporting this partition, see Brown-Schmidt et al. (2008), an issue we return to in Section 5.5.3.

The type definition – in a formal sense we will shortly elucidate – of an information state is given in (22a). We defer until somewhat later (brief) discussion of the structure of the private part, which typically constitutes a 'hidden variable' of dialogue analysis. For now we focus on the dialogue gameboard. Its structure is given in (22b) – the *spkr,addr* fields allow one to track turn ownership, *Facts* represents conversationally shared assumptions, *Moves* represents the contents of moves that have been grounded, *QUD* tracks the questions currently under discussion:

(22) a. TotalInformationState (TIS) $=_{def}$

$$\begin{bmatrix} dialoguegameboard & : DGBtype \\ private & : Private \end{bmatrix}$$

b. DGBType (provisional definition) $=_{def}$

$$\begin{bmatrix} \text{spkr} & : \text{Ind} \\ \text{addr} & : \text{Ind} \\ \text{utt-time} & : \text{Time} \\ \text{c-utt} & : \text{addressing(spkr,addr,utt-time)} \\ \text{Facts} & : \text{Set(Proposition)} \\ \text{Moves} & : \text{list(illocutionaryProposition)} \\ \text{QUD} & : \text{poset(Question)} \end{bmatrix}$$

To understand better the specification in (22), we need to make a brief digression concerning the logical underpinnings of KoS. KoS is formulated within the framework of Type Theory with Records (TTR) (Cooper, 2005, 2012; Cooper and Ginzburg, 2015), a model-theoretic descendant of Martin-Löf Type Theory (Ranta, 1995) and situation semantics (Barwise and Perry, 1983; Cooper and Poesio, 1994; Seligman and Moss, 1997; Ginzburg and Sag, 2000). TTR enables one to develop a semantic ontology, including entities such as events, propositions, and questions, whence types characterizing questions and propositions, in (22). With the same means, TTR enables the construction of a *grammatical* ontology consisting of utterance types and tokens and of an interactional domain in which agents utilize utterances to talk about the semantic universe. What makes TTR advantageous for our dialogical aims is that it provides access to both types and tokens at the object level. This plays a key role in developing metacommunicative interaction, as we shall see below, in that it enables simultaneous reference to both utterances and utterance types. I propose that this constitutes a fundamental requirement on logical frameworks that aim to characterize dialogue.

For current purposes, the key notions of TTR are the notion of a *judgement* and the notion of a *record*.

The typing *judgement*: $a : T$ classifying an object a as being of type T.

Records: A record is a set of fields assigning entities to labels of the form (23a), partially ordered by a notion of *dependence* between the fields – dependent fields must follow fields on which their values depend. A concrete instance is exemplified in (23b). Records are used here to model events and states, including utterances, and dialogue gameboards.[2]

[2] Cooper and Ginzburg (2015) suggest that for events with even a modicum of internal structure, one can enrich the type theory using the *string theory* developed by Tim Fernando (see, e.g., Fernando, 2007).

(23) a.
$$\begin{bmatrix} l_1 = val_1 \\ l_2 = val_2 \\ \ldots \\ l_n = val_n \end{bmatrix}$$

b.
$$\begin{bmatrix} x & = 28 \\ \text{e-time} & = \text{2AM, Feb 17, 2011} \\ \text{e-loc} & = \text{Nome} \\ c_{temp-at-in} & = \text{o1} \end{bmatrix}$$

Record types: A record type is simply a record where each field represents a judgement rather than an assignment, as in (24):

(24)
$$\begin{bmatrix} l_1 : T_1 \\ l_2 : T_2 \\ \ldots \\ l_n : T_n \end{bmatrix}$$

The basic relationship between records and record types is that a record r is of type RT if each value in r assigned to a given label l_i satisfies the typing constraints imposed by RT on l_i. More precisely,

(25) The record

$$\begin{bmatrix} l_1 = a_1 \\ l_2 = a_2 \\ \ldots \\ l_n = a_n \end{bmatrix} \text{ is of type: } \begin{bmatrix} l_1 : T_1 \\ l_2 : T_2 \\ \ldots \\ l_n : T_n \end{bmatrix}$$

iff $a_1 : T_1, a_2 : T_2, \ldots, a_n : T_n$

To exemplify this, (26a) is a possible type for (23b), assuming the conditions in (26b) hold. Record types are used to model utterance types (aka as *signs*) and to express rules of conversational interaction.

(26) a.
$$\begin{bmatrix} x & : \text{Ind} \\ \text{e-time} & : \text{Time} \\ \text{e-loc} & : \text{Loc} \\ c_{\text{temp-at-in}} & : \text{temp\_at\_in(e-time, e-location, } x) \end{bmatrix}$$

b. -28 : Ind; 3:45AM, Feb 17, 2011 : Time; Nome : Loc; o1 : temp_at_in(3:45AM, Feb 17, 2011, Nome, -28)

The final logical notion we introduce is the situation semantics notion of an Austinian proposition (Barwise and Etchemendy, 1987). These are records of the form (27a). The type of Austinian propositions is the record type (27b), where the type *RecType*† is a basic type which denotes the type of (*non-dependent*) record types closed under meet, join, and negation. Truth conditions for Austinian propositions are defined in (27c):

(27) a.
$$\begin{bmatrix} \text{sit} & = s \\ \text{sit-type} & = T \end{bmatrix}$$

b.
$$\text{AustProp} =_{def} \begin{bmatrix} \text{sit} & : \mathit{Rec} \\ \text{sit-type} & : \mathit{RecType}^{\dagger} \end{bmatrix}$$

c.
$$\text{A proposition } p = \begin{bmatrix} \text{sit} & = s_0 \\ \text{sit-type} & = ST_0 \end{bmatrix} \text{ is true iff } s_0 : ST_0$$

One important subtype of *AustProp* is the type of *illocutionary propositions* (IllocProp). These are the content of conversational moves. An example of such a proposition is in (28a), where in addition to the two standard fields for a proposition, fields exist for speaker, addressee, and utterance time and descriptive content. (28b) is the general characterization of the type IllocProp. For notational economy I will typically abbreviate (28a) as (28c), omitting the fields, retaining only the illocutionary predicate type component:

(28) a.
$$\begin{bmatrix} \text{sit} & = u1 \\ \text{spkr} & = x \\ \text{addr} & = y \\ \text{utt-time} & = t \\ a & = p \\ R & = \text{Assert} \\ \text{sit-type} & = \begin{bmatrix} c1 : R(x, y, t, p) \end{bmatrix} \end{bmatrix}$$

b. IllocProp $=_{def}$

$$\begin{bmatrix} \text{sit} & : \text{Record} \\ \text{spkr} & : \text{Ind} \\ \text{addr} & : \text{Ind} \\ \text{utt-time} & : \text{Time} \\ a & : \text{AbstSemObj} \\ R & : \text{IllocRel} \\ \text{sit-type} = \begin{bmatrix} c1 : R(\text{spkr, addr, utt-time}, a) \end{bmatrix} & : \text{RecType} \end{bmatrix}$$

c. R(spkr, addr, utt-time, p)

Armed with these basic logical notions, let us return to characterizing conversational states. A conversational state $c1$ will be a record $r1$ such that (29a) holds; in other words $r1$ should have the make-up in (29b), and the constraints in (29c) need to be met:

(29) a. $r1$: DGBType

b.
$$\begin{bmatrix} \text{spkr} & = A \\ \text{addr} & = B \\ \text{utt-time} & = t1 \\ \text{c-utt} & = \text{p}_{utt(A,B,t1)} \\ \text{Facts} & = \text{cg1} \\ \text{Moves} & = \langle \text{m1}, \ldots, \text{mk} \rangle \\ \text{QUD} & = Q \end{bmatrix}$$

c. A: Ind, B: IND, $t1$: TIME, $\text{p}_{utt(A,B,t1)}$: addressing(A, B, $t1$), cg1: Set(Proposition), $\langle$m1, . . . ,mk$\rangle$: list(illocutionaryProposition), Q : poset(Question)

Our job as dialogue analysts is to construct a theory that will explain how conversational interactions lead to observed conversational states. Let us consider what an initial conversational state looks like: initially, no moves have been made and no issues introduced, so a dialogue gameboard will have the form in (30):

(30)
$$\begin{bmatrix} \text{spkr} & = A \\ \text{addr} & = B \\ \text{utt-time} & = t1 \\ \text{Moves} & = \langle\rangle \\ \text{qud} & = \{\} \\ \text{facts} & = \text{cg1} \end{bmatrix}$$

This allows us to write a lexical entry for a greeting word such as *hi*, as in (31), whose context – specified via the field 'dgb-params' – is supposed to be the initial state of a conversation. For a justification of this analysis of 'hi' and, more generally, the integration of illocutionary information in the grammar, see Ginzburg et al. (2003) and Ginzburg (2012).

(31)
$$\begin{bmatrix} \text{phon} : \texttt{hi} \\ \text{cat.head} = \text{interj} : \text{syncat} \\ \text{dgb-params} : \begin{bmatrix} \text{spkr} : \text{IND} \\ \text{addr} : \text{IND} \\ \text{utt-time} : \text{TIME} \\ \text{Moves} = \langle\rangle : \text{list(LocProp)} \\ \text{qud} = \{\} : \text{set(Question)} \end{bmatrix} \\ \text{cont} = \text{Greet(spkr,ind,utt-time)} : \text{IllocProp} \end{bmatrix}$$

How do we specify the effect of a conversational move? The basic units of change are mappings between dialogue gameboards that specify how one gameboard configuration can be modified into another on the basis of dialogue moves. We call a mapping between DGB types a *conversational rule*. The types specifying its domain and its range we dub, respectively, the *pre(conditions)* and the *effects*, both of which are subtypes of DGBType. A conversational rule that enables us to explain the effect a greeting, the initial conversational move, has on the DGB is given in (32). The preconditions state that both Moves and QUD need to be empty; the sole effect is to initialize Moves with the illocutionary proposition *greet*(A, B), A the speaker, B the addressee.

(32) *Greet*

$$\begin{bmatrix} \text{pre} & : & \begin{bmatrix} \text{spkr :} & \text{Ind} \\ \text{addr :} & \text{Ind} \\ \text{utt-time :} & \text{TIME} \\ \text{Moves} = \langle\rangle : & \text{list(IllocProp)} \\ \text{qud} = \{\} : & \text{poset(Question)} \\ \text{facts :} & \text{Prop} \end{bmatrix} \\ \text{effects} & : & \begin{bmatrix} \text{spkr} = \text{pre.spkr :} & \text{Ind} \\ \text{addr} = \text{pre.addr :} & \text{Ind} \\ \text{utt-time} = \text{pre.utt-time :} & \text{TIME} \\ \text{Moves} = \langle\text{Greet(spkr,addr,utt-time)}\rangle : & \text{list(IllocProp)} \\ \text{qud} = \text{pre.qud :} & \text{poset(Question)} \\ \text{facts} = \text{pre.facts :} & \text{Prop} \end{bmatrix} \end{bmatrix}$$

In the sequel I employ a number of abbreviatory conventions. First, instead of specifying the full value of the list Moves, we usually record merely its first member, which we call 'LatestMove'. Second, the preconditions can be written as a *merge* of two record types $DGBType^{-} \wedge_{merge} PreCondSpec$, one of which $DGBType^{-}$ is a strict supertype of DGBType and therefore represents *predictable information common to all conversational rules*; *PreCondSpec* represents information specific to the preconditions of this particular interaction type. Similarly, the effects can be written as a merge of two record types $DGBType^{0} \wedge_{merge} ChangePrecondSpec$, where $DGBType^{0}$ is a supertype of the preconditions and *ChangePrecondSpec* represents those aspects of the preconditions that have changed. So we can *abbreviate* conversational rules as in (33a). For example, the abbreviated version of (32) *Greet* would be as in (33b).

(33) a.
$$\begin{bmatrix} \text{pre} & : \text{PreCondSpec} \\ \text{effects} & : \text{ChangePrecondSpec} \end{bmatrix}$$

b.
$$\begin{bmatrix} \text{pre} & : & \begin{bmatrix} \text{moves} = \langle\rangle : & \text{list(IllocProp)} \\ \text{qud} = \{\} : & \text{poset(Question)} \end{bmatrix} \\ \text{effects} & : & \begin{bmatrix} \text{LatestMove} = \text{Greet(spkr,addr,utt-time)} : & \text{IllocProp} \end{bmatrix} \end{bmatrix}$$

One final remark on this score relates to the specification of turn ownership via the labels 'spkr', 'addr'. In two-person interaction there are three basic possibilities: the turn remains the same (32), the turn necessarily changes (exemplified in (35) and occurring in cases such as assertion acceptance, where one cannot accept one's own assertion), or the turn is underspecified, as specified in (34a) – which picks the speaker from among the conversationalists and the addressee as the distinct other element in this set. *No turn change* gets abbreviated away in the notational convention introduced in (33). The other two cases will get notated explicitly – *turn change* by specifying the effects, whereas *turn underspecification* by means of a merge type conjunction, as in (34b), exemplified below in (37b) and many other cases:

(34) a. Turnholder-underspecified $=_{def}$

$$\begin{bmatrix} \text{pre} & : & \begin{bmatrix} \text{spkr} & : \text{Ind} \\ \text{addr} & : \text{Ind} \end{bmatrix} \\ \text{effects} & : & \begin{bmatrix} \text{PrevAud} & : \text{Set(Ind)} \\ \quad = \{\text{pre.spkr,pre.addr}\} & \\ \text{spkr} & : \text{Ind} \\ \text{c1} & : \text{member(spkr, PrevAud)} \\ \text{addr} & : \text{Ind} \\ \text{c2} & : \text{member(addr, PrevAud)} \\ & \wedge \text{ addr} \neq \text{spkr} \end{bmatrix} \end{bmatrix}$$

b. Effects : TurnUnderspec $\wedge_{merge}[\ldots]$

As a first illustration, we provide a lexical entry for a word like *marxabteyn*, discussed in Section 5.3.2: this entry assumes that the word presupposes that its contextual background requires the LatestMove to be a greeting, and it expresses a countergreeting; strengthening the presupposition to require the *form* of the antecedent greeting to be *marxaba* is possible within the refinement to KoS sketched in the section on metacommunicative interaction, page 158.

(35)
$$\left[\begin{array}{l}
\text{phon} : \texttt{marxabteyn} \\
\text{cat.head} = \text{interj} : \text{syncat} \\
\text{dgb-params} : \left[\begin{array}{l}
\text{spkr} : \text{IND} \\
\text{addr} : \text{IND} \\
\text{utt-time} : \text{TIME} \\
\text{utt-time}' : \text{TIME} \\
\text{Moves} = \langle \text{Greet(addr,spkr,utt-time)} \rangle : \text{list(IllocProp)} \\
\text{qud} = \{\} : \text{poset(Question)}
\end{array}\right] \\
\text{cont} = \text{CounterGreet(spkr,ind,utt-time}') : \text{IllocProp}
\end{array}\right]$$

Parting, and concomitantly the termination of a conversation can be specified in quite similar terms, though as Ginzburg (2012) shows, they involve quite subtle presuppositions that seem absent from greeting interaction.

Querying and assertion in dialogue

Before considering how the actual dialogical interaction gets regulated, it is worth saying something about the 'direct', coherent responses to a question q. As we discussed above, there seem to be two types of such responses – propositional answers and queries. With respect to the latter, I assume that dependence is the central coherence relation; see Łupkowski and Ginzburg (2014) for an account that shows how to capture the coherence of other types of question responses. Given that, I introduce the notion of a q-specific utterance:

(36) Given a question q, an utterance u is q-specific iff either:
  a. $u.cont = p$: Prop and About(p, q)
  b. $u.cont = q1$: Question and Depend(q, $q1$)

Example (37a) says that given a question q and ASK(A, B, q) being the LatestMove, one can update QUD with q as QUD-maximal. QSPEC can be thought of as KoS' 'relevance maxim': it characterizes the contextual background of reactive queries and assertions. Example (37b) says that if q is QUD-maximal, then subsequent to this either conversational participant may make a move constrained to be q-specific:

(37) a. *Ask QUD-incrementation*

$$\left[\begin{array}{lll}
\text{pre} & : & \left[\begin{array}{l}
q : \text{Question} \\
\text{LatestMove} = \text{Ask(spkr,addr,utt-time}, q) : \text{IllocProp}
\end{array}\right] \\
\text{effects} & : & \left[\text{qud} = \langle q, \text{pre.qud} \rangle : \text{poset(Question)}\right]
\end{array}\right]$$

b. *QSPEC*

$$\begin{bmatrix} \text{pre} & : & \begin{bmatrix}\text{qud} = \langle q, Q\rangle : \text{poset(Question)}\end{bmatrix} \\ \text{effects} & : & \text{TurnUnderspec} \wedge_{merge} \\ & & \begin{bmatrix} r : \text{Prop} \vee \text{Question} \\ R : \text{IllocRel} \\ \text{LatestMove} = R(\text{spkr,addr,utt-time}, r) : \text{IllocProp} \\ c1 : \text{Qspecific}(r, q) \end{bmatrix} \end{bmatrix}$$

QSPEC involves factoring out turn taking from the assumption that A asking q means B answering it. In other words, the fact that A has asked q leaves underspecified who is to address q (first or at all). This is justified by data such as that in (38a)–(38b) where the querier can or indeed needs to keep the turn, as well as multi-party cases such as (38c) where the turn is multiply distributed. It is also crucial for describing parent/infant interaction, where invariably the parent answers their own questions (Ginzburg and Moradlou, 2013):

(38) a. Vicki: When is, when is Easter? March, April? (BNC, KC2)
b. Brian: you could encourage, what's his name? Neil. (BNC, KSR)
c. A: Who should we invite? B: Perhaps Noam. C: Martinu. D: Bedrich.

Considering assertion from a dialogical perspective means above all taking seriously the fact that in two-person interaction A's asserting p requires B to react, either by producing an explicit acceptance utterance or gesture (Clark, 1996; Nakano et al., 2003) or by discussing whether p is indeed the case.

Example (39) illustrates some interesting patterns involving post-assertoric contexts: Examples (39a) and (39b) indicate that 'yes' can occur both in such a context and in one following polar query. Examples (39c) and (39d) illustrate that acceptance utterances need to be supplied by the addressee of the assertion; however such utterances are not acceptable if the asserter asks for explicit commitment, as in Example (39e). Example (39f) shows that the confirmation particle 'Right?' is only available to the original asserter, whereas the dubitative particle 'Really?' is only available to the addressee, while a same polarity tag, as in Examples (39h) and (39i), is available to both speakers:[3]

(39) a. A: Bo is leaving. B: Yes.
b. A: Is Bo leaving? B: Yes.
c. A: Bo is leaving. B: I see.
d. A: Bo is leaving, ♯I see.
e. A: Bo is leaving, right?. B: Right/Yes /♯I see.

[3] Thanks to Elisabet Engdahl for pointing out to me the contrast between Examples (39f) and (39g).

f. A: Bo is leaving. B: Really?/♯Right?
g. A: Bo is leaving, ♯really?
h. A: Bo is leaving, is he?
i. A: Bo is leaving. B: Is he?

A full treatment of this pattern would take us too far afield and is a matter of vigorous current debate (see Beyssade and Marandin, 2009; Farkas and Bruce, 2010; Ginzburg, 2012; Malamud and Stephenson, 2015) – one issue being in what cases to assume that the move (e.g. 'pure assertion', 'confirmation') involves introducing p? into QUD, using a rule analogous to (37a). However this debate gets resolved, one thing this data emphasizes is how **grammar needs to make reference to the fine structure of conversational context** to explicate subtle differences such as those between 'Right?' and 'Really?' Possible lexical entries for these particles are sketched in Example (40):

(40) a.
$$\left[\begin{array}{ll} \text{phon} : \texttt{right} & \\ \text{cat.head} = \text{interj} : \text{syncat} & \\ \text{dgb-params} : & \left[\begin{array}{l} \text{spkr} : \text{IND} \\ \text{addr} : \text{IND} \\ \text{utt-time} : \text{TIME} \\ \text{utt-time}' : \text{TIME} \\ \text{LatestMove.content} \\ \quad = \text{Assert}(\text{spkr,addr,utt-time}, p) : \text{IllocProp} \end{array}\right] \\ \text{cont} = \text{Check}(\text{spkr,addr,utt-time}', p?) : \text{IllocProp} & \end{array}\right]$$

b.
$$\left[\begin{array}{ll} \text{phon} : \texttt{really} & \\ \text{cat.head} = \text{interj} : \text{syncat} & \\ \text{dgb-params} : & \left[\begin{array}{l} \text{spkr} : \text{IND} \\ \text{addr} : \text{IND} \\ \text{utt-time} : \text{TIME} \\ \text{utt-time}' : \text{TIME} \\ \text{LatestMove.content} \\ \quad = \text{Assert}(\text{addr,spkr,utt-time}, p) : \text{IllocProp} \end{array}\right] \\ \text{cont} = \text{Doubt}(\text{spkr,addr,utt-time}', p?) : \text{IllocProp} & \end{array}\right]$$

FACTS and QUD are coupled: a question q can be introduced only in so far as FACTS does not contain information resolving q. Hence, updating FACTS involves a simultaneous downdate of QUD. This is formulated in Example (41): given an acceptance or confirmation of p by B, p can be unioned into FACTS, whereas QUD is modified by the function NonResolve. NonResolve is a function that maps a partially ordered set of questions poset(q) and a set of propositions P to a partially ordered set of questions poset$'$(q) which is identical to poset(q) modulo those questions in poset(q) resolved by members of P.

(41) *Fact update/ QUD downdate* $=_{def}$

$$\left[\begin{array}{ll} \text{pre} & : \left[\begin{array}{ll} p & : \text{Prop} \\ \text{LatestMove} & \\ \quad = \text{Accept(spkr,addr,utt-time}, p)\vee & \\ \text{Confirm(spkr,addr,utt-time}, p) & : \text{IllocProp} \\ \text{qud} = \langle p?, \text{pre.qud}\rangle & : \text{poset(Question)} \end{array}\right] \\ \text{effects} & : \left[\begin{array}{ll} \text{facts} = \text{pre.facts} \cup \{p\} & : \text{Set(Prop)} \\ \text{qud} = \text{NonResolve(pre.qud, facts)} & : \text{poset(Question)} \end{array}\right] \end{array}\right]$$

The notion of q-specificity and the conversational rules sketched above provide us with an initial characterization of query relevance and how it emerges in interaction. The approach to relevance and contextual structure and change discussed up to this point resembles closely the approach developed in work by Roberts (1996, 2011a, 2012a). Roberts' framework differs from KoS with respect to certain assumptions and in terms of its basic methodological aims. Roberts abstracts away from metacommunicative interaction, and hence she assumes only the existence of a single, communal context which tracks fields corresponding to FACTS, MOVES, and QUD. One of her principal aims is to offer a precise fleshing out of the Gricean program using this view of context, identifying, for instance, as the primary intention at any time to be the intention to address the agreed-upon (maximal element) of QUD. She uses this framework to develop detailed accounts of intonational focus, definiteness, and presupposition/implicature.

We need to consider how to incorporate genre specificity and metacommunicative interaction into our account of relevance.

Incorporating genre specificity

Psycholinguistic labs aside, all meaningful interaction occurs within a particular conversational genre/activity type/language game. As I emphasized above, this is the fundamental entity determining *what drives a dialogue* – what issues can and need to be discussed and also *how* such discussion will take place (in terms of constructions and lexica), though this latter aspect I cannot consider here.

A very basic issue is how to classify a conversation into a genre? The approach I describe here originates with Larsson (2002), building on earlier work in artificial intelligence (AI), and subsequently somewhat recast in Ginzburg (2012). The essential idea is to provide a description of an information state of a conversational participant who has successfully completed such a conversation. This is a reasonable way of doing things as long as the final state does not lose 'significant' information concerning what took place during the conversation. On the view of contextual evolution described here, the final state of a conversational participant will be a DGB of the type in (42):

(42)
$$\begin{bmatrix} \text{facts} & : \text{Set(Prop)} \\ \text{qud} = \{\} & : \text{poset(Question)} \\ \text{moves} & : \text{list(IllocProp)} \end{bmatrix}$$

At the end of a conversation QUD is empty,[4] but the issues that have been discussed during the conversation can be recovered by examining FACTS: we can introduce a simple refinement of *FACTS update/QUD downdate* such that every acceptance leads to the recording of not solely the facts added but also which questions were resolved by these facts and downdated. We can track such questions using a field labelled QNUD (Questions-No-longer-Under-Discussion). [5] Final states of a conversation will then be records of type T for T a subtype of DGBType$_{fin}$. I rename this latter to *GenreType* since it may be identified as the general type of all conversational genres:

(43) GenreType $=_{def}$

$$\begin{bmatrix} \text{facts} & : \text{Set(Prop)} \\ \text{qnud} & : \text{set(question)} \\ \text{moves} & : \text{list(IllocProp)} \end{bmatrix}$$

Let us consider two toy examples. Casual conversation among acquaintances seems to be governed by a convention that an initial greeting optionally raises as MaxQUD an issue glossable as $\lambda P.P(A)$ ('How is A'), $\lambda P.P(B)$ ('How is B'), A and B being the conversational participants. QSpec then licenses assertions such as 'You look well/as young as ever/pale'. In contrast, interaction in a bakery is more specifically delimited: the client needs to indicate what baked goods are desired, whereas the vendor needs to indicate how much needs to be paid. Specifications for both types are in (44):

[4] Or rather, in order to end a conversation CPs need to ensure QUD is empty.

[5] Such information is also what underwrites presuppositions of *resolvedness*. Such presuppositions characterize the complements of fact-embedding verbs that combine with interrogative clauses, as discussed in Ginzburg (1995b).

(44) a. CasualChat $=_{def}$

$$\begin{bmatrix} A & : \text{Ind} \\ B & : \text{Ind} \\ \text{utt-time} & : \text{TimeInterval} \\ c1 & : \text{Speak}(A, t) \vee \text{Speak}(B, t) \\ \text{facts} & : \text{Set(Prop)} \\ \text{qnud} & : \text{list(question)} \\ c2 & : \{\lambda P.P(A), \lambda P.P(B)\} \subset \text{qnud} \\ \text{moves} & : \text{list(IllocProp)} \end{bmatrix}$$

b. BakeryBuy $=_{def}$

$$\begin{bmatrix} A & : \text{Ind} \\ B & : \text{Ind} \\ \text{utt-time} & : \text{TimeInterval} \\ c1 & : \text{Speak}(A, t) \vee \text{Speak}(B, t) \\ \text{facts} & : \text{Set(Prop)} \\ \text{qnud} & : \text{list(question)} \\ c2 & : \left\{ \begin{array}{l} \lambda x.\text{InShopBuy}(A, x), \\ \lambda x.\text{Pay}(A, x) \end{array} \right\} \subset \text{qnud} \\ \text{moves} & : \text{list(IllocProp)} \end{bmatrix}$$

Differing effects – e.g. whether questions need to be discussed in a certain order – can also be described depending on whether we assume QNUD to be an unordered set, partially ordered, or a list. The appeal to genres is most crucial in explicating topic choice in *initiating* moves, where without some such notion one could in principle address any issue whatever. For reasons of space, I will not enter into the issue of initiating move specification and merely hint at how this can be done. A genre type provides a specification of how a conversation can unfold. Assuming that information states encode this information, one can then express in precise terms the constraints a genre sets on moves in the following terms:

(45) $m0$ is felicitous relative to the current DGB $dgb0$, and $G0$, the genre one assumes the conversation to be, if and only if one believes that updating $dgb0$ with $m0$ results in a final state $dgb1$ which is a conversation of type $G0$.

Metacommunicative interaction

Integrating metacommunicative interaction (MCI) into the DGB involves two modifications to the picture we have had so far, one minor and one major. The minor modification, drawing on an early insight of CA, is that repair can involve 'putting aside' an utterance for a while, a while during which the utterance is repaired. That in itself can be effected without further ado by adding further structure to the DGB, specifically an additional field we will call *Pending*.

'Putting the utterance aside' raises the issue of *what is it that we are 'putting aside'*. In other words, how do we represent the utterance? Most work on (dialogue) context to date involves reasoning and representation solely on a semantic/logical level. However, if we wish to explicate MCI, we already saw at the end of section 5.3.3 data from hyperintensionality, parallelism, and utterance tokens reasons indicating that we cannot limit ourselves in this way.

These considerations lead Ginzburg (2012) to conclude that the type of *Pending* must combine tokens of the utterance, its parts, and of the constituents of the content with the utterance type associated with the utterance. An entity that fits this specification is the *locutionary proposition* defined by the utterance: in the immediate aftermath of a speech event u, *Pending* gets updated with a record of the form $\begin{bmatrix}\text{sit}=u\\ \text{sit-type}=T_u\end{bmatrix}$ (of type *locutionary proposition* (LocProp)). Here T_u is a grammatical type for classifying u that emerges during the process of parsing u. In other words, an entity such as the *sign* in the sense of sign-based grammars such as Head-Driven Phrase Structure Grammar (HPSG), Categorial Grammar (see, e.g., Calder et al., 1988; Moortgat, 1997), or in versions of Lexical Functional Grammar (see, e.g., Muskens, 2001). The relationship between u and T_u – describable in terms of the proposition $p_u = \begin{bmatrix}\text{sit}=u\\ \text{sit-type}=T_u\end{bmatrix}$ – can be utilized in providing an analysis of grounding/CRification conditions:

(46) a. Grounding: p_u is true: the utterance type fully classifies the utterance token.
b. CRification: p_u is false, either because T_u is weak (e.g. incomplete word recognition) or because u is incompletely specified (e.g. incomplete contextual resolution – problems with reference resolution or sense disambiguation).

This means that – incorporating also the assumption regarding non-resolvedness of questions in QUD, mentioned above – the DGB now has the type definition in (47); there is an interesting theoretical and empirical issue as to what type to associate with the elements of Moves: the LatestMove also needs to be a locutionary proposition, not merely a content, at least within a system such as that developed in Ginzburg (2012): speakers are assumed to update the DGB with the content of their utterances as soon as the utterance is completed. However, given the potential need to engage in clarificatory discussion concerning the utterance, backtracking to the locutionary proposition needs to be possible. Whether this applies to other moves remains to be addressed experimentally.

(47) DGBType (final version) $=_{def}$

$$\begin{bmatrix} \text{spkr} & : \text{Ind} \\ \text{addr} & : \text{Ind} \\ \text{utt-time} & : \text{Time} \\ \text{c-utt} & : \text{addressing(spkr,addr,utt-time)} \\ \text{Pending} & : \text{list(LocProp)} \\ \text{Moves} & : \text{list(LocProp)} \\ \text{Facts} & : \text{Set(Prop)} \\ \text{QUD} & : \text{poset(Question)} \\ \text{non-resolve-cond} & : \forall q \in \text{QUD}\big[\neg\text{Resolve(FACTS}, q)\big] \end{bmatrix}$$

In principle one could have a theory of CRification based on generating all available CRs an utterance could give rise to. However, in practice, as the data in (14) showed us, there are simply too many to be associated in a 'precompiled' form with a given utterance type.

Instead, repetition and meaning-oriented CRs can be specified by means of a uniform class of conversational rules, dubbed *Clarification Context Update Rules* (CCURs) in Ginzburg (2012). Each CCUR specifies an accommodated MaxQUD built up from a sub-utterance $u1$ of the target utterance, the maximal element of Pending (*MaxPending*). Common to all CCURs is a licence to follow up *MaxPending* with an utterance which is *co-propositional* with MaxQud. Example (48) is a simplified formulation of one CCUR, *Parameter identification*, which allows B to raise the issue about A's sub-utterance $u0$: *what did A mean by u0?*:

(48) Parameter identification

$$\begin{bmatrix} \text{pre} & : \begin{bmatrix} \text{Spkr : Ind} \\ \text{MaxPending : LocProp} \\ u0 \in \text{MaxPending.sit.constits} \end{bmatrix} \\ \text{effects} & : \begin{bmatrix} \text{MaxQUD} = \begin{bmatrix} q = \lambda x \text{Mean}(A, u0, x) \\ \text{fec} = u0 \end{bmatrix} : \text{InfoStruc} \\ \text{LatestMove : LocProp} \\ c1 : \text{CoProp(LatestMove.cont, MaxQUD}.q) \end{bmatrix} \end{bmatrix}$$

Parameter identification (48) underpins CRs such as (49b)–(49c) as follow-ups to (49a). We can also deal with corrections, as in (49d). B's corrective utterance is co-propositional with λxMean$(A, u0, x)$, and hence allowed by the specification:

(49) a. A: Is Bo here?
b. B: Who do you mean 'Bo'?
c. B: Bo? (= Who is 'Bo'?)
d. B: You mean Jo.

As a final point, I should add a remark concerning the considerable philosophical literature on the various kinds of quotation (see, e.g., Cappelen and Lepore, 2012, for a survey) and a growing linguistic literature (see, e.g., De Brabanter, 2010, for a survey). On the whole, this work has not had much tie-in with dialogue, though works such as Clark and Gerrig (1990) and Recanati (2010) propose a view of (direct) quotation as involving a demonstration to a previous speech or other sound-producing event. Ginzburg and Cooper (2014) argue that by utilizing utterance types and locutionary propositions as denotations for quotative constructions, many of the seemingly mysterious aspects of quotation disappear.

Combining relevance

So far we have characterized dialogical relevance in a modular fashion – indicating various sources of relevance – illocutionary, genre-specific, and metacommunicative. This modularity, while helpful methodologically, is clearly a theoretical artefact. One might ponder whether we actually, in practice, need a means of combining the various strands into a single, unified notion of relevance.

One argument for the need derives from cases where relevance is manifestly absent. One such case was pointed out originally by Grice and relates to cases where an explicitly irrelevant response is provided in order to communicate the lack of wish to address a previous utterance, as in (50a)–(50b). A related case are utterances which trigger CRs about their relevance, exemplified by (50c):

(50) a. A: Horrible talk by Rozzo. B: It's very hot in here.
b. Harry: Is that you James? Stella: What? No, it isn't. Who is it? Harry: Where's James? Stella: He's out. Harry: Out? Oh, well, all right. I'll be straight round. Stella: What are you talking about? Who are you? (Harold Pinter 'The Collection'. In: *Plays Two*, p. 133)
c. Marjorie: Don't touch that cos she hasn't had it yet. Dorothy: Does she eat anything? Marjorie: What do you mean? (BNC)

To the extent we wish to write rules that capture these inferences and/or preconditions, we need to have an *IrRelevance* predicate, directly relatable to a *Relevance* predicate.

What then does Relevance amount to? Pretheoretically, Relevance relates an utterance u to an information state I just in case there is a way to successfully update I with u. Let us restrict attention to the case where the input context is a query. Given a set of conversational rules $\mathcal{C}$, a grammar $\mathcal{G}$ and an information state $I_0 : TIS$, an utterance u is $\mathbf{U(tterance)}_{\mathcal{C},\mathcal{G}}{}^{I_0}$**-relevant** iff there exist $c_1, \ldots, c_{k+1} \in \mathcal{C}, T_u \in \mathcal{G}, k \geq 0$ such that $c_1(I_0) = I_1, \ldots, c_{k+1}(I_k) = I_{k+1}$, where C's information state I_0 satisfies (51a); where by means of a sequence of updates the locutionary proposition $p_u = prop(u, T_u)$ becomes the value of LatestMove (condition (51b); and the final element of the sequence of updates I_{k+1} is such that one of the conditions in (51c)–(51f) is satisfied – u is either q-specific, an appropriate CR, relates to the issue of willingness to discuss q, or is genre-relevant:

(51) a. I_0.DGB.LatestMove = v; v.content = Ask(A,q),
b. $I_{k+1}.DGB.LatestMove = p_u$
c. $p_u.content$ is q-specific relative to I.DGB, Or
d. $p_u.content$ is CoPropositional with some question q0 that satisfies q0 = CCUR1.effects. maxqud($I_0.DGB.MaxPending$) for some Clarification Context Update Rule CCUR1, Or
e. $p_u.content$ is q_0-specific, where q_0 is the question ?WishDiscuss(B, q), Or
f. One of C's beliefs in I_0 is that: for some G0 there exists dgb1 such that $(I_0.DGB \bigoplus p_u) \sqsubset dgb1$, and such that dgb1 : G0

A number of remarks can be made about (51), primarily about the relata of this notion.

1. The definition is relative to both the set of conversational rules and to a grammar from which the types T_u of locutionary propositions originate.
2. Relevance is, by and large, DGB oriented. Only (51f) explicitly involves reference to the entire information state.

Non-sentential utterances

The detailed theory of context/relevance developed in previous sections enables the development of a grammar of the various types of sentential fragments discussed earlier. The basic strategy adopted in KoS to analyse NSUs is to specify construction types where the combinatorial operations integrate the (surface) denotata of the fragments with elements of the DGB. I sketch how this can be done with one such construction type; a detailed account of a wide variety of sentential fragments analysed in such terms can be found in Fernández (2006); Ginzburg (2012).

B's utterance in (52) can receive a variety of contents, depending on the context in which it is uttered: it can be interpreted as a *short answer*, as in

(52b); it can be interpreted without any prior utterance, as in (52c), though in such a case – as per Wittgenstein and Clark – the paraphrase provided here is only one of several possible; it can also be interpreted as the ('metalinguistic') correction in (52d). The different mechanisms underlying these resolutions can be uniformly described by the schema in (52e). This indicates that the content of the construction type *Declarative-fragment-clause* arises by predicating the propositional function constituted by the maximal element of QUD of the content of the bare fragment utterance, a generalization of a rule proposed already in Hausser and Zaefferer (1979). The particular content exhibited in (52b) could arise because the issue 'What did you buy in the bakery' is MaxQUD as a result of A's query; (52c) arises given that the issue 'What does the current customer want to buy' is a characteristic issue of the BakeryShopping genre (as it is of many related genres); the content in (52d) could arise if B decided not to ground A's utterance, but using the *parameter identification* conversational rule to initiate repair interaction, accommodates the issue 'What did you mean by utterance "four crescents"?' as MaxQUD.

(52) a. B: Four croissants.
b. (Context: A: What did you buy in the bakery?) Content: I bought four croissants in the bakery.
c. (Context: A: (smiles at B, who has become the next customer to be served at the bakery.)) Content: I would like to buy four croissants.
d. (Context: A: Dad bought four crescents.) Content: You mean that Dad bought four croissants.
e. *Declarative-fragment-clause*: Cont = DGB.MaxQUD(u-frag.cont) : Prop

I have also emphasized that different NSU constructions exhibit morphosyntactic and/or phonological parallelism with their antecedents. In other words, not only the combinatorial semantics of NSU constructions but also the morphosyntactic and phonological specifications of such constructions integrate information from the DGB. Given that parallelism, typically, exhibits a similar time course to the salience of the relevant entity of QUD, we can capture such effects by viewing QUD as tracking not simply questions qua semantic objects, but pairs of entities: a question and an antecedent sub-utterance. This latter entity provides a partial specification of the focal (sub)utterance, and hence it is dubbed the *focus establishing constituent* (FEC) (cf. *parallel element* in higher-order unification-based approaches to ellipsis resolution, e.g., Gardent and Kohlhase, 1997). Thus, the FEC in the QUD associated with a *wh*-query will be the *wh*-phrase utterance, the FEC in the QUD emerging from a quantificational utterance will be the QNP utterance, whereas the FEC in a QUD accommodated in a clarification context will be the sub-utterance under clarification. Hence, the type of QUD is *Info-Struc*, as defined in (53):

(53) $$\text{Info-struc} = \left[\begin{array}{ll} q : & \text{Question} \\ \text{fec} : & \text{set(LocProp)} \end{array}\right]$$

In light of this, we can write a specification of *decl-frag-cl* as in (54). Categorially the construction is sentential, it has one dgb parameter – i.e. contextual parameter – the maximal element of QUD. Its content arises by functional application of MaxQUD to the entity denoted by the fragment and categorially the fragment has to match the categorial specification of the FEC:

(54) Declarative-fragment-clause

$$\left[\begin{array}{l} \text{cat} = v : \text{syncat} \\ \text{dgb-params.max-qud} : \left[\begin{array}{l} q : \text{UnaryWhQuestion} \\ \text{fec} : \text{LocProp} \end{array}\right] \\ \text{cont} = \text{max-qud}.q(\text{hd-dtr.cont}.x) : \text{Prop} \end{array}\right]$$

$$\Big|$$

$$\text{hd-dtr} : \left[\begin{array}{l} \text{cat} = \text{max-qud.fec.cat} : \text{Syncat} \\ \text{cont} : [x : \text{IND}] \end{array}\right]$$

5.4.2 Segmented Discourse Representation Theory (SDRT)

SDRT, discussed in more detail in Asher's chapter on theories of discourse (Chapter 4), emerged from DRT by adding to DRT discourse relations inspired by theories of text structure such as Rhetorical Structure Theory (Mann and Thompson, 1987) – the relations involved include *narration*, *explanation*, *elaboration*, *parallel*. Although SDRT was originally developed as a theory of coherence for texts (Asher, 1993), it was subsequently scaled up to apply to dialogue (Asher and Lascarides, 1998b, 2003b). This involves positing coherence relations across turns, including relations such as *QuestionAnswerPair (QAP)* and *Query-Elaboration*. These are used in an account of Query–Response coherence, indirect responses, discourse connectives, and non-sentential utterances (Schlangen, 2003).

In its initial formulations, SDRT implicitly emphasized the continuity between text and dialogue coherence. Such continuity can indeed be recognized, to a first approximation, in that a single speaker's (uninterrupted) turn, for instance in an extended narrative, has many points in common with a text:

(55) A: Max had a great evening last night. He had a great meal. He ate salmon. He devoured lots of cheese. He then won a dancing competition.

Nonetheless, there is an intrinsic difference: the dialogical version must allow for various potential moves along the way by other interlocutors, possibilities that do not exist in a text.

(56) A: Max had a great evening last night.
B: That's not what I heard.
A: He did though. He had a great meal.
B: Meaning what?
A: He ate salmon. He devoured lots of cheese.
B: Perhaps.
A: He then won a dancing competition.

In recent versions of SDRT intended for dialogue (e.g. Lascarides and Asher, 2009), the need to develop a distinct theory of relevance for dialogue has been emphasized, motivated in particular in work on *propositional grounding* – the assumptions dialogue participants all accept for conversational purposes. Dialogue SDRSs (DSDRSs) are defined by associating an SDRS for each participant at each turn, and accordingly the semantics of a dialogue turn is the product of the dynamic semantics for each constituent SDRS. As with its approach to text, SDRT for dialogue divides in two the task of semantico-pragmatic analysis: a glue-logic is developed to map syntactic structures to DSDRSs, whereas a defeasible cognitive logic explicates reasoning about agents' cognitive states in virtue of what they say (represented in the DSDRSs). The cognitive logic extends dynamic logics of public announcement (e.g. Baltag et al., 1998) to provide default links between public announcements and cognitive attitudes. It also provides for links between game-theoretic principles and general axioms of rationality and cooperativity.

Similarly, whereas SDRT's analyses of dialogue have until recently been developed assuming cooperativity was maintained, a recent development (e.g. Asher and Lascarides, 2012) has been the abandonment of this assumption to deal with settings where this does not obtain.

5.4.3 PTT

PTT (Poesio and Traum, 1997; Poesio and Rieser, 2010, 2011) shares certain commonalities with both KoS and with SDRT. Like KoS, it is an information-state-based dialogue theory; it also draws inspiration from the Situation Semantics view of utterances. Indeed PTT pioneered an emphasis on incrementality in dialogue, via the notion of *micro-conversational events* (MCEs), a notion inspired by Barwise and Perry's realist view of grammar (Barwise and

Perry, 1983, p. 122); see recent discussion in Ginzburg (2011). PTT shares with SDRT a DRT-inspired theoretical underpinning.

To date, work in PTT has focussed on providing highly detailed accounts of *grounding*, taking as its starting point Traum's computational model (Traum, 1994), of a variety of dialogue acts (Poesio and Traum, 1997), of collaborative utterances (Poesio and Rieser, 2010), of anaphora in dialogue, involving also visual antecedents (Poesio and Rieser, 2011), gesture (Rieser and Poesio, 2009), and pointing (Rieser, 2004).

An information state is assumed to consist of three main parts:

- A private part, with information available to the participant, but not introduced in the dialogue.
- A public part consisting of the moves that are assumed by that agent to have become part of the common ground.
- A semi-public part, consisting of the information introduced with contributions that have not yet been acknowledged. This information is not yet grounded, but it is accessible.

Recent work in PTT has built on work in the philosophy of action (Bratman, 1992; Tuomela, 2000) to offer a refined view of how intention recognition can drive interaction. Hence, the fact that one or more agents have a certain (possibly collective) intention, and that they are under certain obligations, may become part of the private, semi-private, and public parts of an information state.

From a semantic point of view, PTT takes DRT as its starting point, specifically the compositional version from Muskens (1996). However, the DRSs it uses to represent a discourse situation include not solely the standard DRS constituents (discourse referents for individuals, states, and events) but also discourse referents for *conversational events* and associated conditions characterizing such events. This enables such events to be constituents of other conditions, for example, acknowledgements, turn–control.

From its inception PTT has emphasized incremental interpretation, inspired by a wealth of psycholinguistic evidence (for extensive discussion and references, see Rieser and Schlangen, 2011). The assumption being that the information state of a conversational participant is updated at frequent intervals – minimally, word-by-word. The term *micro-conversational event* (MCE) is used to refer to an event of uttering a sub-sentential constituent. The update triggered by such an event involves characterizing the event on the phonological, syntactic, and meaning levels.

This incremental perspective is at the basis of PTT's analyses of various aspects of grounding, for instance back-channel moves that can occur in parallel to another interlocutor's ongoing utterance. They are also a crucial component of one of PTT's signal achievements (see Poesio and Rieser, 2010), a highly explicit account of collaborative utterances such as utterance (1.2) in (57):

(57) 1.1 Instructor: So jetzt nimmst Du [pause]
well now you take
1.2 Constructor: eine Schraube
a screw
1.3 Inst: *eine* < − > orangene mit einem Schlitz.
an < − > *orange one with a slit*
1.4 Cnst: Ja
Yes (from the Bielefeld Toy Plane Corpus, cited in Poesio and Rieser, 2010)

Completions generally involve guesswork by the addressee of the current speaker's intended next word/phrase. This guesswork becomes more justified in a collaborative task-oriented setting, as in (57). Using MCEs and the Bratman/Tuomela theory of shared cooperative activity, PTT offers a detailed account of how completions can occur as a consequence of incremental intention recognition. This account is one of the most detailed existing analyses of interpretation in dialogue that integrates grammar, updates of information states in dialogue, and rich domain-specific information underpinning joint action.

5.5 Extensions: incrementality, learning, and entrainment

In this section I consider some dialogue phenomena that have not as yet been studied extensively but have far-reaching consequences for our view of semantics.

5.5.1 Self-repair

Disfluencies are ubiquitous and observable in all but the briefest conversational interaction. Disfluencies have been studied by researchers in CA (Schegloff et al., 1977), in great detail by psycholinguists (e.g. Levelt, 1983; Brennan and Schober, 2001; Clark and Fox Tree, 2002; Bailey and Ferreira, 2007), and by computational linguists working on speech applications (e.g. Shriberg, 1994; Heeman and Allen, 1999). To date, they have mostly been excluded from semantic analysis, primarily because they have been assumed to constitute low-level 'noise', without semantic import. In fact, disfluencies participate in semantic and pragmatic processes such as anaphora, conversational implicature, and discourse particles, as illustrated in (58). In all three cases, the semantic process is dependent on the *reparandum* (the phrase to be repaired) as the antecedent:

(58) a. [Peter was + { well } he was] fired. (Example from Heeman and Allen, 1999)
b. A: Because I, [[[any, + anyone,] + any friend,] + anyone] I give my number to is welcome to call me (Example from the

Switchboard corpus) (implicature: 'It's not just her friends that are welcome to call her when A gives them her number')

c. From yellow down to brown - NO - that's red. (Example from Levelt, 1983)

They also provide a particularly natural example of self-addressed queries, queries where the intended responder is the original querier:

(59) a. Carol: Well it's (pause) it's (pause) er (pause) what's his name? Bernard Matthews' turkey roast. (BNC, KBJ)

b. A: Here we are in this place, what's its name? Australia.

Since they can occur at just about any location in a given utterance and their effect is local, disfluencies provide strong motivation for an incremental semantics, that is, a semantics calculated on a word-by-word, left-to-right fashion (see, e.g., Steedman, 1999; Kempson et al., 2000; Morrill, 2000). Moreover, they require the content construction process to be non-monotonic, since initial decisions can be overridden as a result of self-repair.

Ginzburg et al. (2014) show how, given an incremental dialogue semantics, accommodating disfluencies is a straightforward extension of the account discussed in the section on metacommunicative interaction (page 158), for clarification interaction: the monitoring and update/clarification cycle is modified to happen at the end of each word utterance event, and in case of the need for repair, a repair question gets accommodated into QUD. Overt examples for such accommodation are exemplified in (59).

5.5.2 Learning

The lion's share of contemporary semantic work operates under the assumption that one is analyzing language qua static, shared entity, albeit one where a given form can convey radically distinct contents due to the constantly shifting context. The pervasive nature of metacommunicative interaction, discussed in Sections 5.3.3, 5.5.1 and the section on metacommunicative interaction (page 158), indicate that we cannot maintain the simplifying assumption about a *shared* linguistic entity. For the child and the foreigner, it is clear that the linguistic entity needs to be treated as dynamic. But of course the same is true for a mature speaker – in (60) Boris' lexicon changes, and just like the emergence of non-linguistic shared knowledge he can subsequently take the new knowledge for granted. Note that, in contrast to most (adult) clarification interaction, at issue here is information about a linguistic type, not token:

(60) Anja: My arrhythmia is causing me problems. Boris: arrhythmia? Anja: Erratic heart pace. Boris: Ah. (Later) Boris: Anja's arrhythmia is causing her problems. Cyprian: Oh.

The importance of a dialogical perspective for language acquisition has been emphasized in work by Clark (e.g., Clark, 2012). Some formal semantic work on learning in a dialogue setting can be found in Larsson and Cooper (2009). Learning in a dialogue setting has been the focus of much recent computational work (e.g., Henderson et al., 2008), though the paradigm in which such work is set (reinforcement learning) requires copious data, in contrast to (60) and the fast learning exhibited by children (Fernández et al., 2011).

5.5.3 Conceptual pacts and mutual adaptation

I have argued above that considerations of repair and of utterance-related presuppositions require dialogue participants to keep track of a very fine-grained record of utterances in their immediate aftermath. An obvious issue is how to construe ‘immediate’ and what aspects of this fine grain get retained in the longer term. Consider (61) – Belinda’s decision to use a different word from Alex could easily be construed either as corrective or reference as to a distinct entity:

(61) Alex: My sweater is really quite comfortable. Belinda: I’ve never seen this pullover.

There is a long-standing debate in psycholinguistics concerning the extent to which common ground is actually used by participants in referential resolution. Some accounts have argued for an ego-centric perspective as a default (the Perspective-Adjustment model, Keysar et al., 2003) or as a predominant factor (the Anticipation-Integration model, Barr, 2008). However, there is now significant evidence, reviewed in Brown-Schmidt (2009) and Brennan et al. (2010), that dialogue participants are aware of the history of reference acts to an entity – how the entity has been referred to and by whom, so that changes in the means of reference are taken to be significant. Thus, for instance, Metzing and Brennan (2003) showed in an experiment incorporating interaction between confederate speakers and naïve addressees that the initial looks by the addressees to familiar target objects (that they had previously grounded during interaction with a speaker) were delayed by a few hundred milliseconds when the same speaker uttered an entirely new expression for the familiar object, but not when a new speaker uttered the same new expression. This is the basis for the notion of *conceptual pacts* (Brennan and Clark, 1996) between conversational participants, pacts that are not only partner-specific but also quite flexible: the first looks to the target by addressees are not delayed when a new speaker used a new expression.

Stent (2011) discusses how dialogue systems can exhibit behaviour of this kind in restricted tasks by means of keeping track of a restricted class of variables relating to an interaction (e.g. in a system that allows students to review their courses, successful adaptation can be achieved by having the system track the form used in rating the course currently under discussion, the verb tense being used in this dialogue, and the form used to refer to the instructor).

5.6 Conclusions

Although dialogue is the primary medium of language use, phylogenetically and ontogenetically, it has yet to take centre stage in semantics. Studying dialogue forces one to a particularly careful study of the nature of context, fundamental in much of human (inter)activity. I have focussed here on two essential tasks for a theory of dialogue, characterizing conversational relevance and conversational meaning. As far as conversational relevance goes, I have sketched both empirical and theoretical characterizations, which underline it has at least three quite independent dimensions: (a) illocutionary, (b) metacommunicative, (c) genre-based. With respect to conversational meaning, I have exemplified the existence of various classes of words and constructions, notably interjections and non-sentential utterances, whose meaning is irreducibly tied to conversational contexts and can be strongly tied to their relevance.

All formal frameworks that have engaged in detailed description (including KoS, SDRT, and PTT) seem to share the assumption that semantic analysis in dialogue requires entities representing the publicized information, (a) one per conversational participant, (b) with significant internal structure, (c) tying in to a genre/task/language game, while (d) making intrinsic reference to non-semantic aspects of utterances.

I concluded by pointing to new challenges by phenomena such as disfluencies, learning, and mutual adaptation, which suggest the need for an incremental semantics for language qua dynamic entity, with long-term, fine-grained memory of interactions.

The emergent common view concerning dialogical semantics is a very distinct picture of the nature of semantics from the standard discourse representation view (e.g. van Eijck and Kamp, 1997), or dynamic semantics view (described, e.g., in Dekker, 2011), let alone from more classical views of semantics.

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Part II

Theory of reference and quantification

6

Reference

Paul Dekker and Thomas Ede Zimmermann

6.1 Introduction

Natural language is often used to say what the actual world is like, and we refer not only to this actual world but also to the things that we find in there, and that strike us as distinguished and relevant enough to talk about. All known languages have devices to refer to things in the world, *our world*, if you want. It seems to be a characteristic property of language that a special category of expressions serves especially this device of reference: names. This chapter is not on names though. It is on the role that reference plays according to prevailing theories of the meaning of natural language expressions, that is, in formal semantics.

We take it for granted that it is clear to the reader what we mean when we say things such as the following.

(1) The name "Barack Obama" refers to the current president of the United States, and the phrase "the name 'Barack Obama' " has his name as its referent.

(2) When Wittgenstein referred to the author of the *Tractatus* he was referring to himself.

(3) The referent $I_M(a)$ of a proper name a in a model M is the individual in the domain of M assigned to a by the interpretation function I_M of the model.

The word *reference* is taken here not as in a "reference manual", in the "references section" of an article, or in the "professional references" in your CV, although the expressions are of course lexically related. Reference is considered from a linguistic perspective, as a phenomenon related to language. We will mostly speak of the reference of linguistic items, be they words, phrases, sentences, or uses or utterances thereof. Often it is associated with a specific syntactic category, that of noun phrases, or with a specific type of linguistic items, most particularly names and singular or plural nouns. The references of the expressions are taken to be individuals, objects, sets of objects, or any kind of things one can, indeed, *refer* to. The objects can be physical, perceptible objects, times, places, events, as well as abstract objects, imaginary objects, objects of any kind. Briefly, but not very informatively, we could say that objects thus conceived of can be anything one can refer to, or equivalently that anything one can refer to is an object.

Because of its very general, and equally underdetermined, nature the phenomenon of reference has constituted a subject of prime interest for mostly logicians and philosophers of language. The variable nature of their interests, however, shows from the divergent views on reference that scholars have adopted. In this chapter we sketch the views that have been advocated by some of the most prominent scholars in these fields.

In order to set the stage, we first outline, in the remainder of this section, an appealing but naive picture of meaning as reference and discuss some of its limitations. In Section 6.2 we discuss the views of Frege, Russell, and Quine on the reference and meaning of mainly proper names and definite descriptions. In Section 6.3 we discuss theories of rigid reference, from Kripke, Putnam, and Kaplan, on mainly proper names, common nouns, and demonstratives. In Section 6.4 we discuss the views of, in particular, Strawson and Donnellan on the referential use of definite and indefinite descriptions and various approaches to the somewhat popular notion of discourse reference. We end the chapter with a glossary of some of the core terms that have been discussed.

As we said at the beginning, we use natural language to talk about the world, or the universe, and the stuff that inhabits it. Reference can be conceived of as the primary means of linking up expressions from a natural language with the things out there that we talk about. So let us assume we have a domain of individuals which we can think of as having properties, and standing in relations with one another, all of which we can name. Each expression of a language thus can be assumed to have a *reference*, or *extension*, and this may inform a theory of *meaning*. This conception conveys a certain picture of language, which Wittgenstein has ascribed to Augustinus, and which he characterized (and subsequently seriously questioned) as follows: "In this picture of language we find the roots of the idea: Every word has a meaning. This meaning is assigned to the word. It is the object which the word stands for" (Wittgenstein, 1953, §1). Indeed one might be inclined to think of reference as the prime and foremost feature of language, or the significant use of it, but, as Wittgenstein observed, by molding the description of the meanings of expressions into one and the same format, one does not make the use of these expressions, in natural speech, that is, any more alike.

> Aber dadurch, daß man so die Beschreibungen des Gebrauchs der Wörter einander anähnelt, kann doch dieser Gebrauch nicht ähnlicher werden! Denn, wie wir sehen, ist er ganz und gar ungleichartig.
> "But, assimilating the descriptions of the uses of words in this way, one cannot make the uses any more similar! For, as we see, that is altogether unlike." (Wittgenstein, 1953, §10)*

> Wenn wir sagen: "jedes Wort der Sprache bezeichnet etwas" so ist damit vorerst noch *gar* nichts gesagt (. . .).
> "When we say: "Every word of the language signifies something" then we have so far said nothing at all." (Wittgenstein, 1953, §13)

There are many good reasons to qualify the referential theory of meaning, and come up with much more sophisticated, and fine-grained conceptions of the phenomenon of reference.

First of all, as emphasized by such notable philosophers and logicians as Frege, Russell, and Wittgenstein, the meaning of a sentence is not just an amalgam of referents, a collection or tuple of the referents of its constituent parts. Different parts of speech, or parts of expressions, may play distinctive, non-referential roles. For instance, sentences can be, and generally are, taken to be of the subject-predicate form. The subject-predicate distinction has actually served as a model for the logical analysis of sentences ever since Aristotle, and this has remained so, also after Frege and Peirce extended logic with relational expressions and genuine quantifiers.

> One of the main purposes for which we use language is the purpose of stating facts about things and persons and events. If we want to fulfill this purpose, we must have some way of forestalling the question, "What (who, which one) are you talking about?" as well as the question, "What are you saying about it (him, her)?" The task of forestalling the first question is the referring (or identifying) task. The task of forestalling the second is the attributive (or descriptive or classificatory or ascriptive) task. In the conventional English sentence which is used to state, or to claim to state, a fact about an individual thing or person or event, the performance of these two tasks can be roughly and approximately assigned to separable expressions. And in such a sentence, this assigning of expressions to their separate roles corresponds to the conventional grammatical classification of subject and predicate. There is nothing sacrosanct about the employment of separable expressions for these two tasks. (Strawson, 1950, p. 335)

* Translations are by the authors of this chapter.

The categories of subject and predicate can be taken to play distinct semantic roles, and the function of predicates, devices of predication, does not obviously or primarily appear to be referential. (See Pagin, Chapter 3 on sentential semantics for the varieties of the composition of meaning.)

In this chapter we focus on the referential devices, and this implies that we are mainly concerned with expressions that typically occur in subject (or object) positions in natural language: nominal expressions, or noun phrases – with the exclusion of quantifying noun phrases, dealt with in Chapter 7; plural, indefinite, and generic (uses of) noun phrases are discussed in other chapters as well. All of this is not to say, of course, that reference is not involved in predication. In the predicative, or if you want verbal, non-nominal, domain, we find natural and structural devices for temporal reference and for (co-)reference to events and states of affairs. The ontology, individuation, and mechanisms of reference employed in that domain, however, constitute a subject of their own and are separately dealt with in the chapters in Part III of this handbook. (We may also have to point out that we here restrict ourselves to what may be called the descriptive, or "indicative" uses of language. Sentences and other expressions of natural language may play a host of other roles, notably, e.g., instructive or "directive" ones. These are dealt with in Part IV.)

In the second place, obviously, the above picturesque, "Augustinian", interpretation of a language is utterly simplistic and idealized. In the domain of individuals, it does not distinguish between the various types of things we talk about; it does not reflect any of the structural, mereological, or other relations between these extensions; there is no dynamics or change in the domain; and all terms (predicates, relation expressions) have a fixed and rigid interpretation. Such simplifications may suit certain mathematical and scientific applications, but they seem to be at odds with the everyday use of language and its practical applications.

The picture model also leaves no room, it seems, for the essentially context-dependent nature of expressions of natural language. In natural language, the specific interpretation of a term or expression is, sometimes almost completely, often to a certain extent, determined by its context of use, and this context may include the particular syntactic and semantic properties of the larger expression in which the term, on its occasion of use, occurs. As we will see, such context dependence constitutes a subject of continuous concern in theories of reference. (Such concerns can go very deep, since the domain of reference and quantification itself can be conceived of as being contextually determined, relativized to views of the world, whole scientific theories of it, or culturally informed perceptions of it. Surely, such "ontological relativity" may deeply affect our notion of reference, even up to the point of rendering it "inscrutable" (Quine, 1968).)

In the third place, even while there may be agreement about a common domain of reference and quantification, the users of a language may have incomplete knowledge of it. Not only is it pointless to assume that everybody knows everything about every thing in such a domain, but also it is common practice that people fail in (totally) identifying objects in that domain. Maybe it serves a purpose to assume that structures in mathematics and logic are totally known and identified, but in the use of natural language, and especially in the use of its referring devices, questions of identity cannot be assumed to be settled once and for all. Linguists and logicians alike tend to fail to fully realize – what the police always start out assuming – that a person known in one way may be not known in another way, and a person not known in one way, may be known in another way. An even harder problem here is that, sometimes, a person or thing that seems to be known one way or another may fail to exist. Gottlob Frege was aware of the problem and deemed the phenomenon an imperfection of natural language, where we may if need be substitute "natural thought" for "natural language". Russell acknowledged the very same point, as when he stated, quite concisely and perplexingly, that "[a] phrase may be denoting, and yet not denote anything" (1905, p. 479). Again, the issue is not just a logician's problem. As we will see, problems of identification run in the background through most of this chapter.

Returning to our point of departure, we may conclude that language is used to talk about things and stuff "out there", that names and other terms seem to be suited to that purpose, but that this should not be taken to imply that we, the speakers of a language, *know* in a non-trivial sense what a name refers to, or that intended reference always gets us "out there". We often consult dictionaries when we want to learn the meaning of an unknown word, but when it comes to names, these dictionaries do not contain the individuals that are their referents. Also, when a name is used and successfully connects to its referent, we may fail to realize how this connection comes about, the so-called mechanism of reference. This last issue, however, will not be pursued as something that has to be explained empirically, naturalistically, or conventionally here. The next sections are mainly concerned with the more modest, but still pertinent, role of reference in theories of meaning, broadly conceived.

6.2 Reference and meaning

6.2.1 "Bedeutung" and "Sinn"

In his ground-breaking "Über Sinn und Bedeutung", Gottlob Frege took the referential use of names as his starting point and, eventually, as the point of return. His concerns were by and large set by the parameters of what is known as the "logicistic program", which he had set out to develop, among others, in his *Begriffschrift* (1879). As pronounced there and elsewhere, Frege was concerned with the laws of truth and (logical) validity, and with developing a *conceptual notation* (indeed: "Begriffschrift") for making these laws completely transparent. As is well known, in so doing he invented, roughly at the same time as Charles Sanders Peirce, the system nowadays going by the name of "predicate logic". As we have seen, in such a system names (individual constants) are taken to refer to objects (and variables are taken to *range over* such objects), and these objects figure as the subjects of propositions which are either true or false, depending on whether the objects have the properties ascribed to them, or whether they stand in certain attributed relations. The truth and falsity of such propositions, then, solely depends on the objects referred to, and the properties they have.

Frege observed, therefore, that in non-deranged cases the truth of a proposition about an object is independent of the way in which the object is specified. That is to say, that if a term is used to specify an object, then what is said about that object remains true if we use a different term, perhaps specifying the same object in a different way. A sentence that expresses a true proposition remains true if we replace names in that sentence by other names that have the same reference. (A very general formulation of this idea has become known as "Frege's principle" or, more commonly, as the principle of compositionality of reference. The logical foundation for the principle Frege found in Gottfried Leibniz' principle of the "indiscernibility of identicals".)

Frege realized that this referential role of names leaves something crucial unexplained. In the aforementioned paper he focuses on identity statements, statements of the form "*A* is (the same object as) *B*". For as far as mathematics is part of logic, and for as far as mathematics is concerned with equations, the analysis of such statements is of course crucial to the logicistic enterprise. Some time later, Ludwig Wittgenstein formulated the problem with these identity statements in an almost brutely concise manner.

> Beiläufig gesprochen: Von zwei Dingen zu sagen, sie seien identisch, ist ein Unsinn, und von Einem zu sagen, es sei identisch mit sich selbst, sagt gar nichts.
> "Casually speaking: to say of two things they are identical is [a] nonsense, and to say of one [thing], it is identical to itself, doesn't say anything." (Wittgenstein, 1921, #5.5303)

Frege considers the proposition that Hesperus (the Evening star, which is Venus) is Phosphorus (the Morning star, which is Venus as well). Since Hesperus is Phosphorus, the statement that Hesperus is Phosphorus says, of Hesperus (Venus) that it is Phosphorus (Venus), that is, it says of Venus that it is identical with itself. This, at least, is what one would get if only the referents of the names *Hesperus* and *Phosphorus* were relevant to the proposition expressed. But surely, the proposition expressed by the statement that Hesperus is Phosphorus is not that trivially true. But then, if we assume that all that counts is the referents of the names, and the proposition is not trivially true, then we should take the proposition to state of two different referents that they are the same, which is nonsense, as Wittgenstein puts it.

Frege did not give up on the idea that the truth of "Hesperus is Phosphorus" resides in the identity of the referents of the two names. In fact, he accepted that the cognitive value of the sentence, its "Erkenntniswert", is more than just knowledge of the self-identity of a certain object and concluded that the meaning of the sentence, the proposition or "Gedanke" expressed, must be determined by more than only the referents of the two names figuring in the sentence. Consequently, the meaning of the names are supposed to be more than just their referents:

> Eine Verschiedenheit kann nur dadurch zustande kommen, daß der Unterschied des Zeichens einem Unterschied in der Art des Gegebenseins des Bezeichneten entspricht . . . Es liegt nun nahe, mit einem Zeichen . . . außer dem Bezeichneten, was die Bedeutung des Zeichens heißen möge, noch das verbunden zu denken, was ich den Sinn des Zeichens nennen möchte, worin die Art des Gegebenseins enthalten ist.
> "A difference can only arise because the distinction in the signs ('Zeichen') comes along, with a distinction in the mode of presentation of the signified ('Bezeichnete') . . . It is natural, now, to think of there being connected with a sign, besides the signified ('Bezeichnete'), which may be called the reference ('Bedeutung'), also what I would like to call the meaning ('Sinn') of the sign, wherein the mode of presentation is contained." (Frege, 1892b, p. 26)

Since, obviously, one and the same object can be given (presented, determined) in many different ways, it is not at all trivial to ascertain that an object presented one way is the same object as it is presented another way. Thus, the meaning of the statement "Hesperus is Phosphorus" is not that Venus is self-identical, but, rather, that the object determined as a certain heavenly body seen in the evening sky is the one also determined as a certain heavenly body observed in the morning sky. The meaning of the sentence, a thought ("Gedanke"), is constructed from the meanings of the names *Hesperus* and *Phosphorus*, which, hence, are not their referents, but ways of determining these referents. More generally, then, the thought or proposition expressed by a sentence featuring a name "A", does not contain the referent of that name as a constituent.

It is important to note that although the "meanings" of sentences and of names are abstract, not perceptibly observable, entities, they are nevertheless objective, or intersubjective. This conviction led Frege to his famous statement of a Platonic realm of meanings.

> So scheint das Ergebnis zu sein: Die Gedanken sind weder Dinge der Außenwelt noch Vorstellungen. Ein drittes Reich muß anerkannt werden.
> "The conclusion appears to be: the thoughts are neither things from the outside world nor representations. A third realm has to be acknowledged." (Frege, 1918a, p. 69)

Needless to say, the acknowledgment of such a realm of meaning has inspired a lot of investigation into that domain within the philosophy of language.

Frege distinguishes the “Sinn” (meaning, in a certain theoretical sense) from the “Bedeutung” (reference, in its customary sense) of a name. Regarding sentences, systematically, he also distinguishes the Sinn of a sentence (the meaning in a fairly customary sense, the “Gedanke” or “proposition” expressed by the sentence) from the sentence’s “Bedeutung” (the reference in a fairly theoretical sense, a “Wahrheitswert” or “truth value”). Frege emphasizes that, while we should indeed acknowledge the relevance of the “Sinn” of sentences and names, we should not at all neglect their “Bedeutung”. After all, the “Bedeutung” is what is signified (“bezeichnet”) by a name or sentence. More importantly, for Frege it is the *truth* of the propositions, i.e., their truth value or reference, that is of primary interest, particularly in science. Moreover, in order to judge the truth of scientific or other empirical statements, we have to proceed to the references of the names figuring in the expression of these statements. Thus, Frege’s interest in the third, Platonic, realm of meanings certainly did not distract him from the second realm, where we find the referents of the terms we use in language.

> Warum wollen wir denn aber, daß jeder Eigenname nicht nur eine Sinn, sondern auch eine Bedeutung habe? Warum genügt uns der Gedanke nicht? Weil und soweit es uns auf seinen Wahrheitswert ankommt.
> “But then why do we want that every name not only has a meaning (‘Sinn’), but also a reference (‘Bedeutung’)? Why are we not satisfied with the thought (‘Gedanke’)? Because, and to the extent that, we are concerned with its truth value.” (Frege, 1892b, p. 33)

6.2.2 Description and denotation

Bertrand Russell dismissed Frege’s Platonic realm of meanings, though he did share his interest in logic, truth, and validity. His view on names, although ontologically quite different from Frege’s, turns out remarkably similar in spirit. When Frege discussed names, he included among these referential devices phrases that we would now call definite descriptions, that is definite noun phrases like “the intersection of the lines *a* and *b*”. In his equally ground-breaking “On Denoting” (1905), Russell mainly focused on such definite descriptions, and while he permitted himself to speak of such phrases as denoting expressions, that is, expressions denoting the specific objects, if any, uniquely described by these descriptions, he as a matter of fact employed the term *denoting* as a theoretical term that had to be explained away.

Upon the views exposed in (Russell, 1905), a phrase like *the present king of France* can be characterized as denoting the individual that is the present king of France, provided that there presently is a unique king of France. If

France happens to lack a king, the phrase is said not to denote at all, without this rendering the phrase void of meaning. Rather, the description *the present king of France* contributes to the proposition expressed by *The present king of France is bald*, by entailing the existence of a unique king of France, who is stated to be bald. The present king of France, if such exists, is not part of that proposition and under no analysis of it does it ascribe the property of baldness to a particular referent. Russell's "denoting phrases" – among which he included, for instance, indefinite descriptions – therefore may be denoting, may be ambiguously denoting, or may not be denoting anything at all.

The crucial idea of Russell's analysis of definite descriptions is that they are not referring devices and do not contribute a referent to the proposition expressed by a sentence in which they occur. Instead, one was supposed to analyze the complete sentences in which such descriptions occur, and then see to it that the descriptions, upon such analysis, as a matter of fact get explained away. The same goes for their meaning. In effect, then, Russell assimilated definite descriptions to quantificational locutions such as *every horse*, *no horse*, which is why later semantic treatments of the definite article as a quantifier have been dubbed "Russellian", even though they fail to preserve the general spirit of Russell's analysis of denoting terms as incomplete.

In short, Russell's, famous, analysis of the complete sentence *The king of France is bald* turns out to be paraphrasable as follows.

(4) There exists something that is a king of France and such that if anything is king of France it is him, and such that he is bald.

Russell gently, and quite appropriately, asks the reader not to make up his mind against this at first sight rather unwieldy analysis. More importantly, the reader should notice that upon this analysis baldness is not attributed to a specific person. The property of being bald is part of a general description of individuals, and it is asserted that something of the described kind exists. The result is, formally, a general proposition, a proposition that asserts the existence of a certain kind of object satisfying a complex description. Equally importantly (and simply), if nothing of the described kind exists, the proposition is false.

It is clear that, upon Russell's analysis, definite descriptions involve a uniqueness condition. A simple statement employing the phrase *the so-and-so* implies the existence not only of a so-and-so, but also of a unique one. This part of the analysis has been severely criticized, observing that most uses of such definite descriptions in natural language do not appear to entail such strong claims. In response, Russell's analysis can be, and has been, adjusted in various not mutually incompatible ways. Uniqueness can be qualified as uniqueness relative to a specific world, location, or situation; the uniqueness claim can be interpreted relative to a contextually restricted domain of quantification; and the distinguishing description can be assumed to be elliptic, and in need of pragmatic enrichment (see, e.g., Neale, 1990, for some discussion).

Russell's analysis was in part motivated by analytical/philosophical considerations, and formed an attempt to clean our ontology from a category of "possible objects", or even "impossible objects", that one seemed to be able to construct into existence by, precisely, such definite descriptions. Not only the "winged horse that was captured by Bellerophon", the "round square", but also "that greater than which nothing can be conceived", all of them still have to be proven to exist and cannot be assumed to exist merely by definition. Upon Russell's analysis, these phrases remain meaningful, without this entailing any ontological commitments. Notice that also upon Frege's analysis these phrases may have a meaning without actually having a reference, or denotation. The main difference is that, for Frege, these phrases and their meanings ultimately are referring devices, residing in this third realm of meaning, whereas, for Russell, these phrases have a more down-to-earth meaning which he, however, could not explicitly formulate independently from the propositions in which they occur. "According to the view which I advocate, a denoting phrase is essentially *part* of a sentence, and does not, like most single words, have any significance on its own account" (Russell, 1905, p. 488).

Let us return to Russell's analysis and its application to the three puzzles he issued. First, Russell considered what George IV was wondering about when he wished to know whether Scott was the author of *Waverley*. George IV's doubts surely related to Scott, who was the author of *Waverley*, but George IV was not interested in the question of whether Scott was himself, of course. Upon Russell's analysis this comes out fine, in that George IV may have wondered whether the individual Scott had the property of being the unique author of *Waverley*. Second, Russell avoided the predicament that one seems to be committed to hold that either *The present king of France is bald* is true or *The present king of France is not bald* is true. Not so, however, on Russell's analysis, because both sentences are false, then, by the non-existence of a king of France.

Regarding his third puzzle, Russell could be brief.

> The whole realm of non-entities, such as "the round square," "the even prime other than 2," "Apollo," "Hamlet," etc., can now be satisfactorily dealt with. All these are denoting phrases which do not denote anything . . . So again "the round square is round" means "there is one and only one entity *x* which is round and square, and that entity is round," which is a false proposition, not, as Meinong maintains, a true one. (Russell, 1905, p. 491)

This quote again relates to Russell's ontological concerns. Russell's interest was not purely analytical though, it also had epistemological ramifications. The analysis of the sentence about the king of France may serve to explain how one can know that the king of France is bald or not without actually knowing the man. Less casually, upon Russell's analysis of descriptions, they may serve in an explanation of how we can have knowledge of the center of mass of the solar system at the first instant of the twentieth century, without anybody ever having been there (Russell, 1910). This type of knowledge that we may obtain is knowledge not of propositions, which do involve individual objects, or points in space, as constituent objects, but knowledge of propositions constructed from general terms, like *center*, *mass*, *solar*, with which we *are* acquainted. So, while we have knowledge of the world, and of objects in that world, by direct *acquaintance*, we also have knowledge of the world, and of objects, by *descriptions*, with descriptions being constructed from objects and properties and objects with which we are acquainted.

6.2.3 Ontological parsimony

Russell's conception of denoting was primarily one that applied to definite descriptions, even though he also meant it to apply to proper names. This clue has been taken up more explicitly by the logician and philosopher Willard Van Orman Quine in his "On What There Is." Quine (1948) discusses a stubborn problem with *existence*-statements, and the *ontological question* that they give rise to: "What is there?" Quine first observes that it is very difficult to counter philosophers who, like Meinong, accept an ontology of possible objects. For as soon as one makes a claim like *Pegasus does not exist*, one seems to be referring to something, Pegasus, and to be denying is existence. In order to make sense of a non-existence claim like *Pegasus does not exist* the term *Pegasus* figuring in it must make sense and therefore must have a reference, and consequently Pegasus must exist – in some sense. (One might, for instance, ask, like Quine, "What is it that there is not?" or "What are you actually claiming does not exist?" but this seems to commit one to the claim that there is something that does not exist.) *Pegasus*, thus, is understood to refer to a possible object that is asserted to actually not exist. Advocates of possible objects are hard to counter, because one cannot escape the argument by simply countering that *Pegasus is not a possible object* because this seems to deny a property, that of being a possible object, of Pegasus.

For good philosophical and methodological reasons Quine is unhappy with an ontology of possible objects and proceeds to counter the argument. The main point is that, he says, for the sentence *Pegasus does not exist* to make sense, the term *Pegasus*, while not being denied significance, need not have a reference. Quine's solution, then, is essentially that of Russell. Proper names, like *Pegasus*, are like definite descriptions, which are, in Russell's terms, denoting expressions, that may fail to denote anything. Quine therefore proposes to analyze the name *Pegasus* as essentially a (definite) description which combines all the properties of what it is to be Pegasus – like being a winged horse, for example. These properties can, if need be, be combined in a predicate, "to pegasize" for instance, and then saying that Pegasus does not exist amounts to no more nor less than stating that the predicate fails to have a non-empty extension. (In formal logical terms, the analysis of the non-existence claim is not taken to read $\neg Ep$, or $\neg\exists x(x = p)$, with p an individual constant as a substitute for *Pegasus*, but it reads $\neg\exists xPx$, with P a predicate constant figuring as a substitute for the predicate "to pegasize".)

Quine thus adopts Russell's method to counter commitments to the existence of possible objects, but he does not, and does not even want to, answer the ontological problem. For Quine it does not make sense to ask, out of the blue, what things there are. The only sensible thing we can say is what are the things that we commit ourselves to there being. As elaborated in the influential Quine (1960a), all the things we can say under the assumption of, or the commitment to, a domain of individual objects can in principle be stated, empirically equivalently, without such a commitment or with other commitments. Talking about his task of "radical translation", Quine states:

> We cannot even say what native locutions to count as analogues of terms as we know them, much less equate them with ours term for term, except as we have also decided what native devices to view as doing in their devious ways the work of our own various auxiliaries to objective reference: our articles and pronouns, our singular and plural, our copula, our identity predicate. The whole apparatus is interdependent, and the very notion of term is as provincial to our culture as are those associated devices. (Quine, 1960a, §12)

As Quine emphasizes, nature does not force an ontology of objects on us; rather, it is we, who, by some conceptual scheme, arrange our experiences in such a way that they concern objects having properties and standing in relations with one another. This, in turn, implies, that reference, and the whole business of identity, is provincial to our conceptual scheme. Quine pushes the insight further, and eventually lifts the issue of what there is to the very practical question as to what we consider an agreeable, workable, efficient ontology. Thus, his belief in the existence of individual objects, and not of, say, Homer's Gods, is motivated by principles of economy and methodological principles of scientific practice.

> Physical objects are conceptually imported into the situation as convenient intermediaries – not by definition in terms of experience, but simply as irreducible posits comparable, epistemologically, to the gods of Homer. Let me interject that for my part I do, qua lay physicist, believe in physical objects and not in Homer's gods; and I consider it a scientific error to believe otherwise. But in point of epistemological footing the physical objects and the gods differ only in degree and not in kind. Both sorts of entities enter our conception only as cultural posits. The myth of physical objects is epistemologically superior to most in that it has proved more efficacious than other myths as a device for working a manageable structure into the flux of experience. (Quine, 1951, §VI)

Quine's insights may be conceived to be those of a philosopher of science, but they have surely served to relativize the notion of reference as an unquestionable phenomenon.

6.3 Direct reference

6.3.1 Rigid Reference

The philosophers and logicians discussed in the previous section, while emphasizing the importance of reference or denotation, have in one way or the other relativized the concept of reference to meanings (Frege), descriptions (Russell), or, even more generally, conceptual schemes or whole bodies of knowledge (Quine). In the second half of the previous century, several authors have, however, put reference itself again at the top of the philosopher's agenda. Their inspiration can be found in John Stuart Mill's observation about proper names: "Proper names are not connotative: they denote the individuals who are called by them; but they do not indicate or imply any attributes as belonging to those individuals" (Mill, 1843).

Ruth Barcan Marcus, Saul Kripke, Hilary Putnam, David Kaplan, but also Nathan Salmon and Scott Soames, to name a few, have argued that reference, and more emphatically, rigid reference, is a constitutive part of our nominal engagement with reality. Marcus (1961) may have been the first to revive the Millian theory of names, if somewhat less pronounced than, e.g., Kripke (1972) and Putnam (1973).

Theories of rigid reference build on the strong intuition that in actual speaking and thinking we speak and think about, or intend to speak and think about, the real objects "out there", not mediated by any sense or description, or even web of beliefs. As Kripke (1972) argues, the proposition that Nixon had to resign from the presidential office is a proposition about that real individual, just as we have referred to him: that very person, Nixon, and nobody or nothing else. And the proposition that some meteor will collide with Venus, likewise, concerns the possibility that some meteor will collide with the very planet, the planet itself in our solar system, the physical object, that is Venus, the object referred to by the name *Venus* (and by the name *Hesperus*, and *Phosphorus*, for that matter).

One of the appealing arguments for this position is that when we consider, in thought or speech, possibilities that are not actual, we take up in those possibilities the very objects that we refer to in reality. We conceive of these possibilities as possibilities concerning precisely *them*.

> Why can't it be part of the *description* of a possible world that it contains *Nixon* and that in that world *Nixon* didn't win the election? It might be a question, of course, whether such a world *is* possible. . . . There is no reason why we cannot *stipulate* that, in talking about what would have happened to Nixon in a certain counterfactual situation, we are talking about what would have happened to *him*. (Kripke, 1972, p. 44)

This point constitutes a strong argument against the alternative view, attributed to, for example, Frege or Russell, because according to them it would be a contingent matter who, in some counterfactual world or possibility, Nixon would be. As Kripke argues, it might give rise to the – stupid, if not absurd – question how, if one is considering the possibility that Nixon didn't win the election, one knows who Nixon is in that possibility. According to Kripke, it is a matter of stipulation that Nixon in any conceived possibility is Nixon, and this stipulation is part of our common practice regarding names. Names are, technically speaking, *rigid designators*. A name like *Nixon* refers to the same individual in any possibility. (At least if he exists there, but this qualification is irrelevant at this point.)

There is one obvious problem with names in natural language that deserves to be at least mentioned here. Many people share their name with others, and so do many places: there are millions of Marias and Johns, and there are two states by the name of Georgia. Which of them should count as the referent of these names? There are at least three approaches to tackling that question. Names could be analyzed as special count nouns that can be used without an article. *Georgia* would be short for, e.g., "[the] Georgia", or "[that] Georgia", with a phonologically unrealized occurrence of *the* or *that*. A name thus could retain its status as count noun when we say, e.g., that there are many *Marias*. Alternatively, and perhaps more in line with the work of Kripke, one could argue that names are disambiguated by an intention to employ them according to a particular naming convention, a different convention for each individual, so labeled. Finally, names can be taken to be ambiguous, so that *Georgia* is just the surface form of an underlying expression like "Georgia$_{\textit{North-America}}$" or "Georgia$_{\textit{Caucasia}}$". Each of these three options has been worked out and defended in various forms, and none is without problems. See, e.g., Haas-Spohn (1995, Ch. 4) for some discussion.

Kripke (1972) argued that we also have rigid reference to kinds, as observed analogously by Putnam (1973). While the discussion so far had been mainly concerned with reference to individuals, by mostly singular individual noun phrases, Kripke and Putnam also considered general terms, common nouns, which, they said, rigidly refer to substances, kinds, and sorts. While the philosophical focus of the two was slightly different – Kripke defending (arguably Aristotelian) essentialism, and Putnam fighting (arguably Platonistic) mentalism – their insights were strikingly similar. When we use terms or nouns like *gold*, *water*, *tiger*, but also *light* and *heat*, we are taken to refer to the real substances gold, water, tiger, and so on. The idea is that we do not refer to anything that satisfies some contingent description, like, for example, whatever transparent liquid boils at 100 degrees Celcius. In order to be water, and to be referred to by the name, or noun, *water*, something simply must be water, in whatever guise, or under whatever conditions. Both Kripke and Putnam, among many others, maintained that there is supposed to be some underlying substance that constitutes being water, or gold, or being a tiger, and that it is not by a definition, or sense, contingently determining what satisfies a certain description or determination that gives us the reference of the term.

> If we put philosophical prejudices aside, then I believe that we know perfectly well that no operational definition does provide a necessary and sufficient condition for the application of any such word . . . Rather we use the name '*rigidly*' to refer to whatever things share the *nature* that things satisfying the description normally possess. (Putnam, 1975, p. 193)

The views argued for by Kripke, Putnam, and others have convinced many philosophers, including the im- or explicit rejection this entails of views like those of Frege and Russell. A good part of the literature therefore has been concerned with arguments against (and also in favor of) the "descriptivism" attributed to Frege and Russell, and also with the question of how a theory of rigid designation can handle the problems that descriptivist theories were developed for.

As for the first point, Kripke vehemently argued against the descriptivist conception of reference. If – one of his arguments goes, the argument referred to as the "modal" or "epistemological" argument – the meaning of the name *Aristotle* is a certain description, for instance, the pupil of Plato who was also the teacher of Alexander the Great, then this would render the following true sentence as expressing a necessary proposition and one known a priori.

(5) Aristotle was the teacher of Alexander the Great.

For upon the suggested descriptivist analysis, the statement would amount to the claim that "The pupil of Plato who was the teacher of Alexander was the teacher of Alexander the Great", and it is of course necessary that the teacher of Alexander the Great was the teacher of Alexander the Great; and of course we know this without any *a posteriori* investigation of the facts. However, equally obviously, without a certain extremely deterministic conception of history, there is nothing necessary, it seems, about Aristotle having taught Alexander. Anything *might* have happened to *him*, Aristotle, that would have precluded him from leaving Athens and going to teach Alexander. And equally surely, nobody who understands the sentence *Aristotle was the teacher of Alexander the Great* knows that this is true by mere introspection and reflection. This example, then, and a series of similar examples, is taken to show that there must be something wrong with the descriptivist conception of the meaning of names.

Another argument, also known as the "semantic argument", ridicules the descriptivist conception of names as it would apply in some counterfactual or unexpected situations. Suppose, the argument goes, that Aristotle had not taught Alexander, but that somebody else had replaced him, say a certain Philippos from Macedon. In that situation, whenever *we* use the name

Aristotle, we would refer, according to the description theory, to the teacher of Alexander, i.e., Philippos. However, we certainly do not. As a matter of fact, we *describe* the situation as one in which Aristotle, the real one, was *not* the teacher of Alexander, contrary to the description associated with it. This kind of possible or factual misattribution is not purely imaginary, as Kripke demonstrates.

> What do we know about Peano? What many people in this room may "know" about Peano is that he was the discoverer of certain axioms which characterize the sequence of natural numbers, the so-called "Peano axioms". . . . [As a matter of fact, it appears that Dedekind was the discoverer, ed.] So on the theory in question [the description theory, ed.], the term "Peano", as we use it, really refers to – now that you've heard it you see that you were really all the time talking about – Dedekind. But you were not. (Kripke, 1972, p. 85)

Yet another argument is given with Putnam's (1973) famous and ingenious Twin Earth thought experiment. Putnam invites us to consider a constellation, labeled "Twin Earth" which is completely like ours, labeled "Earth", except for the fact that, as it is stipulated, the stuff that people there (our twins) call "water", is not really water, but some different substance. By stipulation, again, the stuff called "water" there has all the observables properties there on Twin Earth that the real water has here on Earth. As a consequence neither we, without further consultations, nor our twins are able to distinguish, by any description or property, the stuff that we call "water" here, from the stuff that is called "water" there. Yet, we are required, even stipulated, to say that the stuff that is called "water" on Twin Earth is not water. However, this then means that no description or property determines the reference of the term *water*, because no such description discriminates real water from the stuff called "water" on Twin Earth. People generally tend to agree with this conclusion. Effectively, the conclusion is that the description theory of meaning is wrong, or that it misses something crucial at least.

6.3.2 Direct reference

Against the above criticisms, various defenses of the descriptivist approach have been given, famous ones including Evans (1982) and Neale (1990). However, let us see how theories of rigid reference respond to the arguments that motivated description theories of reference. We can discern four issues: the determination of reference; the apparent informativity of identity statements; true (e.g., negative existence) statements involving fictional characters and mythical kinds; and beliefs that arise from mistaken (non-)identities.

Descriptivist theories provide an explanation, or at least characterization, of how reference comes about, in particular reference to individuals or objects we are not acquainted with. None of us nowadays has been acquainted with Aristotle, yet we somehow refer to him and communicate propositions about Aristotle. As Russell proposed, we can have knowledge of such individuals in the sense that they are the denotation of the descriptions we associate with these names; for Frege it is the senses we grasp that determine the references – if any. By doing away with the medium of descriptions or senses, directly referential theories of names have to explain how we can, thus, directly refer to an individual by using a name. To this end, many advocate an explanation known as the *causal intentional chain theory of reference*. The core idea is that reference initiates from a factual *baptism*, whereby an individual or object is associated with a name, the individual being either ostensibly presented, or, indeed, rigidly identified by a description. From here, the users of a language keep on using the name, transmitting it as in a chain, with the intention to refer to the individual or object that the name was initially associated with. The name, with its rigid reference, is thus passed on among the speakers of that language and across generations of speakers. The literature presents many questions about, and qualifications of, this very rough sketch, which at least provides an idea of how a connection may come about between our use of the name *Aristotle*, and a person that lived in the fourth century BC.

As to the problem of identity statements, Kripke has a lucid, perhaps surprising, reply. Like Marcus (1961) he maintains that, indeed, if Hesperus is Phosphorus, this could not have been otherwise. And for good reasons. Because if Hesperus *is* Phosphorus, how could Hesperus *not* have been Phosphorus? That would, given that Hesperus *is* Phosphorus, have meant that *Phosphorus* is not Phosphorus, which it of course cannot and could not be. The problem, Kripke observes, lies in our *thinking* that Hesperus could not have been Phosphorus. This, as said, is a mistake, if Hesperus is indeed Phosphorus. Kripke points out that we have to distinguish metaphysical from epistemological possibility. Given that Hesperus is Phosphorus, the identity is necessary, constitutive of things being the things they are. But the fact that the statement is metaphysically necessary does not imply that we know it a priori.

Kripke observes, first, that the notions *necessary* and *a priori* are by no means equivalent by definition. The first, according to him, is a metaphysical or ontological notion, the latter belongs to the realm of epistemology. Next he argues that we already know of propositions that are necessary, but at least arguably not a priori. Mathematical propositions, if true, are necessarily true, or so it is said. But the truth of quite a few of them is unknown, and it is an open question whether they can be known a priori at all. Such questions, touching on the foundations of mathematics, serve to show that necessity and a prioricity do not need to coincide, and this paves the way for subsuming identity statements involving rigid designators under them. That Hesperus is Phosphorus, if true, is necessarily true, but it may not have been known, let alone known a priori.

Negative existence statements do pose a persistent problem for the referential theory of names. Philosophically, and formally, there seems to be no problem with positive existence claims, and with the idea that existence is contingent. One can perfectly well state that Aristotle might not have existed, realizing that there are conceivable situations in which *he*, referring to the actual Aristotle by means of his name *Aristotle*, is simply not *there*. However, we cannot, by any naming of, say, Pegasus, state that he is there in a possible situation, but unfortunately not actually in the real world. For anything to count as the referent of the name *Pegasus*, it must be an actual individual that is named so in the actual world, so for the name *Pegasus* to possibly refer, Pegasus must actually exist or have existed. There is no way of baptizing an individual that does not exist. Non-existence claims, therefore, have to be analyzed or interpreted differently. If someone claims that Pegasus does not exist, one way of interpreting her would be as stating that there is no individual ever dubbed by the name *Pegasus* as we use it. (See Kripke, 1972, Addenda (a); 2011; and Stalnaker, 1978, pp. 273–276 for some discussion.) Actually, such a (re-)evaluation properly applies to an empty name like *Vulcan*. In the nineteenth century the existence of a planet was inferred and *that planet*, the target of speculation and investigation, was dubbed *Vulcan*. Once it turned out that no such planet existed, this left the name without a referent and, practically, without significance. In the field of astronomy, the name at best serves only in non-existence statements to the effect that *no such planet* exists. However, such rare and exceptional *empty* names should not be confused with much more common *fictional* names, like *Pegasus*, or *Sherlock Holmes*, that can at least be taken to refer to fictional characters – whatever these may be. Surely *within* pieces of fiction such names have a proper use, under a pretense to name ordinary, be it fictional, characters, which have been so-named – in the fiction. Also from a fiction-external perspective, we can and do deliberate and quarrel about the properties that such fictional characters may or might have. In the remainder of this chapter, however, we will ignore the intriguing ontological and semantic questions that fictions raise. (However, see, e.g., Parsons, 1980; Thomasson, 2010, for relevant discussion.)

6.3.3 Demonstrative reference

Probably the most immediately convincing cases of direct reference are those involving so-called *demonstratives*, and other indexical elements in language that seem to just pick out, in a context of use, a referent. Such cases have been brought forward and discussed most notably in a series of notes and papers by David Kaplan (1978; 1989b). Consider someone pointing at an object on a table, and asserting:

(6) That is a good pencil.

If there is any such thing as “a proposition expressed” – which is debatable: see Lewis (1980, sec. 11) – it must be something like that the property of being a good pencil applies to the very object pointed at. The fact that the object is identified by a pointing, that the pointing took place at the location where it took place, and that it was done by the speaker of the utterance are intuitively no constitutive part of this proposition. As Kaplan argues, the part corresponding to the utterance of *that*, in conjunction with the pointing that goes into the proposition, is just that very object.

> [W]e shall take the component of the proposition which corresponds to the demonstrative to be the individual demonstrated . . . The demonstration "gives us" the element of the proposition corresponding to the demonstrative. (Kaplan, 1978, p. 231)

The point does not just seem to be intuitively convincing; it is further supported by the use of these expressions in modal contexts. Suppose the same person as above had continued as follows:

(7) You almost broke it [that pencil].

What is expressed, then, is that you almost brought about, but did not bring about, a kind of circumstance or situation in which *that pencil*, the very same object, was broken. In this context the utterance should not be taken to mean that it almost happened that you brought about a situation in which the speaker was pointing at an object that was broken. Thus, what was almost the case, and is not the case, is something concerning the object pointed at in the actual context; what the speaker says is surely not that what was almost the case is that he pointed at something you did break.

The last example also contains another demonstrative, or better, indexical, element, the personal pronoun *you*. Like the first person pronoun *I*, these pronouns behave like rigid designators. *You* is used to single out a/the addressee as a referent, but does not contribute the description "whoever I am talking to" to the proposition expressed. If it did, then (7) could be taken to mean that it was almost the case that the person the speaker is talking to broke a pencil he is pointing at. Now suppose that this is indeed true: that the speaker had been about to accuse another person in the audience of breaking a piece of glass that he would have pointed out to that person. In that case it would be true that it was almost the case that the speaker addressed a person who broke an object that the speaker was pointing at. But surely this is not what (7) means.

Demonstratives, personal pronouns, but also other deictic or indexical elements such as *here*, *there*, *now*, *tomorrow*, then, seem to pick out an object, person, time or place, fixed in the context of utterance, but not as "any object that satisfies a contextual description". Obviously, they, thus, behave like rigid designators. As a matter of fact, we have already encountered such an indexical element in Putnam's account of how common nouns refer (and, implicitly, in that of Kripke).

> Our theory can be summarized as saying that words like "water" have an unnoticed indexical component: "water" is stuff that bears a certain

> similarity relation to the water *around here*. Water at another time or in another place or even in another possible world has to bear the relation *same*$_L$, to *our* "water" *in order to be water*. (Putnam, 1973, p. 710)

(The emphasis is from the original, but in the present context the emphasis is indeed also on *around here* and *our*.) One could say we are inclined, or committed, or . . . , to use the terms *water*, *gold* to apply to whatever has the same substance as a very actual specimen of, for example, water or gold. Analogously, we use the name *Hesperus* to make assertions about the object, no matter how it appears to us, in the evening sky, in the morning sky, or under whatever guise. As Kaplan points out, this – in the case of demonstratives, too – may lead to apparently paradoxical situations like those already discussed above.

> It should be immediately apparent that we are in store for some delightful anomalies. Erroneous beliefs may lead a speaker to put on a demonstration which does not demonstrate what he thinks it does, with the result that he will be under a misapprehension as to *what* he has said. Utterances of identity sentences containing one or more demonstratives may express necessary propositions, though neither the speaker nor his auditors are aware of it. (Kaplan, 1978, p. 231)

When we say "A Goddess inhabits *that* heavenly body", pointing at Hesperus, in the evening, we say, according to the direct referentialists, that a Goddess lives on Venus, even though we may be highly inclined to reject the very same statement made in the morning pointing at the very same heavenly body. The exact same case arises with respect to nouns referring to substances.

> The extension of our terms depends upon the actual nature of the particular things that serve as paradigms, and this actual nature is not, in general, fully known to the speaker. (Putnam, 1973, p. 711)

According to Putnam, Archimedes might not have recognized a piece of gold as gold, even though he would eventually have been inclined to agree with us, upon some cross-time explanation, that the piece of gold actually is gold. It is difficult to see how, upon the descriptivist account of naming, somebody can be said to know what *gold* or *Hesperus mean*, without knowing that the terms apply to a specific substance, or heavenly body. Conversely, it also remains hard to explain, on the directly referential account, how people can have knowledge, or better, *fail to have knowledge*, of (the truth or falsity of) identity statements.

The observation that demonstratives and indexical pronouns figure like directly referential expressions has not, of course, misled Kaplan into neglecting their obviously context-dependent nature. However, the way in which context contributes to the meanings of these expressions is subtly different from the way in which most descriptive expressions contribute to the truth-conditional evaluation of sentences. Kaplan (1979, 1989b) and, in his marked footprints, Stalnaker (1978) acutely distinguished the two ways in which context interacts with interpretation.

First, a context sets the stage for any use of an expression and ideally settles questions like who is speaking to whom, what words he or she is actually uttering, at which time and location this happens, and so on. These features of the actual context of use are decisive for determining the interpretation of truly indexical expressions, most notably *I* or *me*, *you*, *now*, expressions that refer to the speaker, addressee, time, of the context of utterance. Besides some notorious exceptions, subject to sophisticated debates, such indexical interpretations are not affected by modifiers shifting time, location, or mode, expressions like *in 2031*, *in France*, or *according to Sheldon*. (Stalnaker, among others, includes facts about the reference of proper names among the facts relevant in this way in the context of use.) Second, this context of use may, but need not, play a further role in the determination of the extensional, descriptive, aspects of interpretation, eventually leading us to the truth-conditional evaluation of whole sentences. This truth-conditional evaluation can be stated in terms of the referents of terms and the extensions of predicates in circumstances of evaluation which can, but need not, be the contexts of use. Thus, the already-mentioned modifiers, but also various kinds of temporal and modal operators in general, may invoke a shift of evaluation from the actual contexts of use to other possible circumstances.

Thus, in a simple sentence like *You may at any time marry any available practitioner*, if used to indicate that circumstances are permitted in which you marry an available practitioner, it is a practitioner available in those circumstances that you are allowed to marry – not necessarily individuals that are available practitioners in the actual utterance situation; however, it is the person whom the sentence is directed at, so the addressee in the utterance situation, who is allowed to marry such practitioners – not necessarily the individual, if any, who is addressed in the permitted situations.

In the terminology of Kaplan, an expression has, originally, a *character*, which in a context of use delivers the expression's *meaning* in that context. The meaning, or intension, next delivers an *extension* in a context of evaluation. In the terminology of Stalnaker, the character of a sentence is a propositional concept, a function from contexts of use to propositions. The meaning of a sentence in a context, this proposition, itself is a function from contexts of evaluation, possible worlds, to truth values. As we said, the context of evaluation of an expression can also be its context of use – it is, by default – but it need not be, if the expression is explicitly modified.

By way of example, consider *At one of the evening lectures, the speaker was very tired*. On a most obvious interpretation, this expresses the proposition that at one of the evening lectures the person *holding that lecture* was very tired, so that it is true if for some evening x, the speaker on x was tired that evening x. If we were to replace the term *the speaker* in this sentence by the personal pronoun *I* (*At one of the evening lectures I was very tired*), we arrive at the *different* proposition that for some evening *x*, the speaker of this very utterance was tired that evening *x*.

Sometimes it happens that we lack relevant information about the context of use of a sentence, for instance when one overhears an utterance of *You are fired*, without knowing which person is addressed. In that case, one can resort to a so-called *diagonal* proposition, equating the possible contexts of use with the possible contexts of evaluation, settling on the proposition true in those worlds or situations in which the person addressed by the utterance in that situation is fired in that situation. Notice that such a diagonal interpretation may undo the rigid character of directly referential expressions, thus enabling a compromise between descriptive and directly referential (aspects or theories of) meaning.

Notice, finally, that from the way in which indexical expressions have been introduced in the literature, it can be concluded that there are no operators in language whose meaning it is to shift their interpretation. On the assumption that, indeed, no such operators exist, Kaplan has appropriately named such hypothetical operators “Monsters”. Interestingly, and as a matter of both theoretical and empirical debate, such monsters have been argued to exist after all. See, e.g., Schlenker (2003) and Anand (2006) for relevant discussion.

6.4 Speaker’s reference

6.4.1 Referential acts

Setting direct reference aside, Russell’s theory of descriptions, most particularly that of denoting, has been criticized from a quite different angle, that of the “ordinary language philosophers”, the most relevant spokesman in the context of this chapter being Peter F. Strawson (1950). The idea, adopted by many after but also before him, essentially is this. People mistakenly say the name “Aristotle” refers to Aristotle. One should, rather, say that the name is used to refer to Aristotle. Reference, thus conceived, is not something that an expression has or does, but it is a typical function of the *use* of expressions, in just the same way that “truth” and “falsity” are not predicates of sentences, but of typical uses of them in making true or false assertions. “ ‘Mentioning’, or ‘referring’, is not something an expression does; it is something that some one can use an expression to do” (Strawson, 1950, p. 326). Strawson employs the term *use* here to refer not to a particular use on a particular occasion but to a more generic, repeatable, use of an expression (or type of expression) on a particular type of occasions. Thus, people can make the same use of an expression on two different occasions, or on different (types of) occasions make a different use of the same expression.

Sentences and, likewise, their “referring” constituent parts are deemed significant, not because they say something true or false but because there are general directions of their use to say something true or false, as well as general directions governing the use of their constituent parts to mention individuals or refer to individuals, in order to subsequently predicate things of them.

> But one of the conventional functions of the definite article is to act as a *signal* that a unique reference is being made – a signal, not a disguised assertion . . . Now, whenever a man uses any expression, the presumption is that he thinks he is using it correctly: so when he uses the expression, "the such-and-such", in a uniquely referring way, the presumption is that he thinks both that there is *some* individual of that species, and that the context of use will sufficiently determine which one he has in mind. To use the word "the" in this way is then to imply (in the relevant sense of "imply") that the existential conditions described by Russell are fulfilled. But to use "the" in this way is not to *state* that those conditions are fulfilled. (Strawson, 1950, p. 331–332)

Quite an important consequence of Strawson's view is that, while expressions remain significant, their function shows in their use, and sometimes this use is infelicitous, or unsuccessful. Thus, where a definite description like *the present king of France* generally serves the purpose of identifying an individual – Russell's intended denotation – it may on occasion be unable to do so, because of the lack of a (unique) king of France. Russell, in such a case, would deem a simple sentence in which this description occurs simply false. Strawson opposes this. He says that the sentence, or rather that particular use of the sentence, fails to establish a referent to assert something about, and therefore no assertion is effectively made. The assertion as a whole is consequently deemed neither true nor false. (This actually complies with Frege's description of the situation, which Frege attributes to an unavoidable "Unvollkommenheit der Sprache", an imperfection of language.)

In a quite belated, because assumed obvious, reply, Russell (1957), not trying to hide his disconcern, claims that Strawson has merely rediscovered the context dependence of language. The shift in terminology, from speaking of a "true rather than false sentence" to "the use of a sentence to make a true rather than false assertion", he apparently considers unworthy of attention. He does acknowledge Strawson's proposal to distinguish, among Russell's own cases of falsity, genuine falsity from cases of presupposition (denotation) failure. Russell, however, considers the choice here a matter of "verbal convenience". The concluding paragraphs of both papers may be indicative of the difference in their interests.

> Neither Aristotelian nor Russellian rules give the exact logic of any expression of ordinary language; for ordinary language has no exact logic. (Strawson, 1950, p. 344)

> This brings me to a fundamental divergence between myself and many philosophers with whom Mr. Strawson appears to be in general

> agreement. They are persuaded that common speech is good enough not only for daily life, but also for philosophy. (Russell, 1957, p. 387)

The difference, not in opinion, but in perspective, is vast. Strawson wants to see how natural language works; Russell wants to see to what is good for logic and philosophy.

Notwithstanding the independent further development of logic (and, quite a bit later, of logical approaches to pragmatic matters), a concern with the use of language has become much more prominent in the study of language and linguistics in the last quarter of the twentieth century. On something of a side track, Wittgenstein had already qualified (or better *dis*-qualified) the abstract notion of reference as the, or one of the, primary semantic relations. Wittgenstein (1953) already argued that referring is not the simple and unanalyzable relation he had taken it to be in the *Tractatus* (1922), neither is it the sole and only thing we do with language. His *Philosophical Investigations* extensively illustrate to what extent reference is a *practice*, taking place in a linguistic community, and embedded in a host of other practices, many of which are appropriately deemed linguistic. The prototypical, representative (i.e., referential) use of language, as characterized (or caricaturized) by the picture in the introductory section above, stands in need of serious modification. The later Wittgenstein does not, and explicitly does not want to, replace the theory of reference by another theory, or a theory of something else. Rather, as already indicated by the title of his second main work, he was concerned with the investigation and clarification of various specific types of uses of language.

> Man kann für eine *große* Klasse von Fällen der Benützung des Wortes "Bedeutung" – wenn auch nicht für alle Fälle seiner Benützung – dieses Wort so erklären: Die Bedeutung eines Wortes ist sein Gebrauch in der Sprache. Und die *Bedeutung* eines Namens erklärt man manchmal dadurch, daß man auf seinen *Träger* zeigt.
> "For a *large* class of cases – even if not for all – one can clarify the application of the word 'Bedeutung' as follows: The 'Bedeutung' of a word is its use in the language. And one clarifies the *'Bedeutung'* of a name often by pointing at its *bearer*." (Wittgenstein, 1953, §43)

> Man könnte also sagen: Die hinweisende Definition erklärt den Gebrauch – die Bedeutung – des Wortes, wenn es schon klar ist, welche Rolle das Wort in der Sprache überhaupt spielen soll. Wenn ich also weiß, daß Einer mir ein Farbwort erklären will, so wird mir die hinweisende Erklärung "Das heißt 'Sepia' " zum Verständnis des Wortes verhelfen. – Und dies kann man sagen, wenn man nicht vergißt, daß sich nun allerlei Fragen an das Wort "wissen", oder "klar sein" anknüpfen. Man muß schon etwas wissen (oder können), um nach der Benennung fragen zu können. Aber was muß man wissen?

"So one could say: The ostensive definition clarifies the use – the meaning – of a word, when it is already clear which role the word has to play in language anyway. When I know, that someone wants to explain a color word to me, the ostensive clarification 'That is called "sepia" ' will help me understand the word. – And one can say this, as long as one does not forget, that the words 'to know', or 'to be clear' raise all kinds of questions. One already has to know something, or be able to do something, in order to be capable of asking for the name of a thing. But what does one have to know?" (Wittgenstein, 1953, §30)

6.4.2 Referential usage

Closer to the tradition of formal analysis and interpretation again, Keith Donnellan (1966, 1978) has come up with the famous distinction between what he called an "attributive" and a "referential" use of definite noun phrases. The proposal can be seen as an attempt to marry Russellian and Strawsonian insights on definite descriptions and correct both. When a definite description "the so-and-so" is used *attributively*, it serves in an assertion to state something about whoever or whatever may turn out to be the so-and-so. Typical examples are the uses of definite descriptions in statements of facts known, or believed, by description, not acquaintance, as Russell would call it. A typical example from Donnellan himself is a case in which the speaker states "The murderer of Smith is insane" in the presence of the dead body of Smith, who was, apparently, brutally murdered. The speaker may be completely unfamiliar with the person, if any, who murdered Smith and express his opinion that whoever caused the death of Smith, in this apparently brute manner, is insane. (Donnellan adds some qualifications about what is presupposed and asserted in some such cases, but these need not concern us here.)

More famous are Donnellan's examples of *referentially* used descriptions, upon which the descriptions serve to single out a specific person or thing to state something about. Indeed, this happens according to the picture Strawson has sketched, but with some qualifications. Thus, in a situation where we all think that a specific person killed Smith, for instance, because the suspect, when on trial, behaves in a particularly odd manner, then *The murderer of Smith is insane* can be used to assert that *that specific* suspect is insane. The description then can be taken to figure as a tool to focus on the suspect, firmly believed to be the murderer of Smith, and make an assertion about *him*.

Donnellan adds that upon its referential use, a definite description "the so-and-so" not only presupposes that there is someone who is the so-and-so, but more specifically that the particular individual referred to is the so-and-so (or a so-and-so), or at least that we firmly believe so. Cases in which our beliefs are mistaken, then, may serve to truth-conditionally distinguish the two uses of a description. For if our beliefs are correct, then "The murderer of Smith is insane", with the definite used referentially, serves to state about the person who murdered Smith that he is insane, which is true if, and only if, whoever murdered Smith – i.e., that person – is insane, which the attributive reading would give us. When, however, we are mistaken about the guilt of the suspect – something which the judge in the trial has to decide, of course – the two uses, and associated readings, depart. For then the referentially used description can still be seen to pick out the suspect in the trial, and make a claim about that person – who after all turns out not to be the murderer of Smith; when used attributively, however, the definite description still directs us to the person, if any, who did, actually, murder Smith, which turns out not to be the person put to trial. Upon the latter interpretation, the statement is true if the person who murdered Smith, whoever it is, but not the person on trial, is insane; upon the referential interpretation of the definite description, the statement says something true of the suspect if he, the person on trial, is insane.

A more mundane example that has become more famous in the literature, is a case in which someone at a cocktail-party, looking, even nodding, at a group of small-talkers, says, "The man with the martini is getting fired today." Upon the, more likely, referential use, the description "the man with the martini" serves to single out a person among the group looked at, who is most obviously holding a glass of martini, and say of *him* that he gets fired today. Upon its attributive use, the statement, rather unusually, perhaps, but not impossibly, can be seen to say that whoever (in that group) is holding a glass of martini will get fired today.

Kripke (1977) has raised the question of whether the phenomenon that Donnellan observed constitutes an ambiguity, and is hence worthy of a *semantic* analysis – or not, and hence is not an issue for a semantic theory. In addressing this point, he noticed that the same, or a similar, phenomenon can be observed with names. For two persons seeing Smith raking the leaves at a distance and mistaking him for Jones may observe *Jones is raking the leaves*. This may, of course, be literally false if Jones is not at that time raking the leaves, but people may agree that something true has been said – about Smith.

> "Jones," in the common language of both, is a proper name of Jones; it *never* names Smith. Yet, in some sense, on this occasion, clearly both participants in the dialogue have referred to Smith, and the second participant has said something true about the man he referred to if and only if Smith was raking the leaves (whether or not Jones was). (Kripke, 1977, p. 14)

Kripke assumes that one probably does not want to call *names* ambiguous, only because of this referential use of a name like *Jones*. But then if we can explain this case in, for instance, pragmatic terms, we may as well apply the analysis to the referential usage of descriptions and hence, do not need to postulate them to be ambiguous either.

Everybody seems to agree with the facts, or observations, that Donnellan and others have made. However, there is substantial disagreement about the proper description or characterization of them. A major question is whether the phenomenon is semantic or pragmatic, or better, whether it should be characterized semantically or pragmatically. Donnellan diplomatically labeled the difference in use a "pragmatic ambiguity" and deliberately side-stepped the issue, like many others do. Before him, Geach had already classified the phenomenon of speaker's reference "as of negligible importance for logic". (He mentions it "only to get it out of the way", [1962, p. 8].) Kripke (1977) acutely observed that only if the phenomena are classified as semantic can they count as possible objection to Russell's theory. If, as Kripke also argued, the phenomenon is properly explained pragmatically, it falls beyond the scope of Russell's theory, and the theory is immune to it. Whatever the outcomes of such methodological debates, it seems that any account of the interpretation or understanding of natural language ought to take this type of referential use eventually into account.

While Donnellan and Kripke focused on definite descriptions and discussed the referential use in a more logico-philosophical tradition, a closely related phenomenon concerning *indefinite descriptions* became an issue in more linguistically oriented circles. The classical paper is by Janet Fodor and Ivan Sag (1982), who make a distinction between what they call a "quantificational" and a "referential" interpretation of indefinites, the latter in the literature also known as a "specific use" of indefinites, or "specific indefinites" for short. The observations are quite analogous to those with definites, be it that they are mainly approached from an arguably more structurally linguistic angle. Classical examples include the following:

(8) A picture is missing from the gallery.

(9) Sue wants to marry a Swede.

Example (8) can be reported if the speaker has a certain specific picture in mind and has noticed that it is not, or is no longer, there in the gallery – a typically specific interpretation of "a picture". A quantificational interpretation results if the guard on watch has noticed that an alarm goes off whenever a picture gets removed from the gallery. Likewise, (9) can be used to report, upon a referential understanding of the indefinite, that there is a certain person whom Sue wants to marry, and who happens to be a Swede, or upon a quantificational reading, that Sue wants to marry whatever Swede.

The phenomenon of specificity has also been characterized in various ways, often depending on the line of analysis people tend to pursue. The specific use of an indefinite has been characterized pragmatically as a use by which the speaker has somebody or something in mind, a *speaker's referent*; alternatively, specific indefinites are taken to be terms which, although indefinite, behave like referential terms, syntactically, and/or semantically.

It is a matter of ongoing debate whether the contrast is or is not one of scope, whether it is of a pragmatic nature or governed by structural linguistic rules, and whether it is accidentally or universally marked in the grammar of sentences. Fodor and Sag, for instance, opted for a structural analysis.

> Our argument has been that the behavior of indefinites in complex sentences cannot be economically described, and certainly cannot be explained, unless a referential interpretation is assumed. It could be accounted for in pragmatic terms only if the whole theory of scope relations and of conditions on deletion could be eliminated from the semantics and incorporated into a purely pragmatic theory. But this seems unlikely. (Fodor and Sag, 1982, p. 392)

The quote makes clear, again, that the answer to the above questions is not purely empirical, but to a large extent methodological as well. The debate is open and significantly extends to current cross-linguistic investigations into the question of whether and to what extent specificity in various guises is lexically or grammatically marked in different languages.

6.4.3 Discourse reference

Along with the discussion of specific indefinites, and the referential usage of indefinite noun phrases that had already been observed in Strawson (1950), Chastain (1975), and Donnellan (1978), yet another type of reference, or *coreference*, made its way into the literature, actually mainly from computational linguistic sources. Lauri Karttunen (1968, 1976) introduced the concept of *discourse reference*, initially in order to model the phenomenon of pronominal (co-)reference, at the syntax–semantics interface.

> Let us say that the appearance of an indefinite noun phrase establishes a "discourse referent" just in case it justifies the occurrence of a coreferential pronoun or a definite noun phrase later in the text. (Karttunen, 1976, p. 5)

The notion of a discourse referent from then on has served as a theoretical tool to mediate between the syntactic representations of noun phrases in discourse and their semantic denotata. Bonnie Webber (1978a, 1978b) incorporated them in computational models of the interpretation of discourse and dialogue. A few years later she describes them as follows:

> discourse understanding involves the creation of a partial, mental model of the situation described through the discourse. Anaphoric pronouns are taken to refer to elements of that model (often called discourse referents or discourse entities) . . . (Webber, 1989, p. 2)

Discourse referents and the mental models that they inhabit have found a solid ground in the linguistic tradition in, for instance, Irene Heim's *File*

Change Semantics and Hans Kamp's *Discourse Representation Theory* (Heim, 1982; Kamp, 1981b, see Asher, Chapter 4).

In recent work in Discourse Representation Theory, the paradigm of discourse reference has been adapted to model the interpretation of paradigmatic directly referential terms like demonstratives and indexicals. The principal idea, in, e.g., Zeevat (1999), is this. Ordinary third-person pronouns invariably allow for demonstrative and anaphoric readings, and this potential of theirs seems to ask for a uniform treatment. The most likely *locus* for such a uniform treatment seems to be that of discourse reference, since demonstratively present individuals are most intuitively represented there, and since there seems to be no good motivation for assigning genuine discourse referents any ontological status. What holds for so-called demonstrative pronouns, then, naturally carries over to properly indexical terms.

Following up on the work of Kamp and Reyle (1993) and Kamp et al. (2011) on discourse representation theoretic anchoring, indexical terms, in particular, have then been associated with presuppositions that are employed to render them directly referential. Presuppositions here are represented as structured informational, representational, units that are required to be satisfied (bound, accommodated) in a context of interpretation by resolution mechanisms roughly along the lines of van der Sandt (1992) and Asher and Lascarides (1998c). Maier (2009) employs *layered discourse representation structures*, distinguishing *kk*-conditions and *fr*-conditions, partly induced by *kk*- and *fr*-presuppositions, respectively. (The first (*kk*) are named after Kripke and Kaplan, the second (*fr*) after Frege and Russell.) Thus, the first-person pronoun *I* and the definite description *The present speaker* can be associated with the *kk*-speaker and the *fr*-speaker, respectively. The two terms do not denote different entities but are interpreted along different *dimensions* (or *layers*); both, however, are handled by means of one presupposition resolution mechanism. In a similar vein, Hunter (2013) more uniformly employs designated discourse representation structures, K_0-*DRSs*, which are designed to present (information about) the extra-linguistic context.

The very status of a discourse referent, ontologically, conceptually, or even methodologically speaking, has not been a matter of discussion and remains somewhat underexposed. Karttunen, implicitly it seems, and Heim explicitly, conceived of them as a metaphor. Webber, and Kamp at least initially, presented the discourse representations as real, partial, models, suggesting discourse referents to be some *kind of* referents. Of course, hardly anybody would want to confuse discourse referents with real objects. They are often taken to stand in for real objects and are considered variables, "markers", or "conceptual hooks" to hang properties on. It does not seem to be inappropriate to think of a discourse referent as merely an encoding of the linguistic, (re)presentational, fact that a particular noun phrase has occurred in a discourse, or that a specific referent has been "mentioned" (Zimmermann, 1999b). Thus, discourse referents are representational by nature. However, one might object, then so would be all other things we refer and corefer to in discourse.

It appears, then, that at least to some extent we have to grant referents, be they discourse referents or actual ones, some kind of intended or intentional reality. Donnellan already mentioned the *intended reference* of referentially used noun phrases:

> the speaker need not expect nor intend his audience to recognize anyone as the subject of the story . . . I believe we can put the point more precisely in terms of what the speaker intends concerning the truth conditions of his utterances: that he intends that truth or falsity shall be a function, in part, of the properties of the person or thing he has in mind. (Donnellan, 1978, p. 61)

This position naturally raises the question of what the intended object is, and it suggests (or at least invites) some notion of an *intentional object*, conceivably similar to that of a discourse referent. Such intentional objects may not seem to show up in discourse per se, but they can be brought to bear on issues Peter Geach had discussed long before under the heading of *intentional identity*.

> We have intentional identity when a number of people, or one person on different occasions, have attitudes with a common focus, whether or not there actually is something at that focus. (Geach, 1967, p. 627)

> We very often take ourselves to know, when we hear the discourse of others, that they are meaning to refer to some one person or thing – and that, without ourselves being able to identify this person or thing, without our even being certain that there really is such a person or thing to identify. What we are claiming to know in such cases – let alone, whether the claim is justified – must remain obscure so long as intentional identity is obscure. (Geach, 1967, p. 631)

The phenomenon of intentional identity that Geach brought up has given rise to some, surely not mainstream, discussions about intentional identity conditions. Yet intentional reference also shows in fairly transparent uses of demonstratives. One of Geoffrey Nunberg's (1993, 1995) examples of *deferred reference* may constitute a case in point.

> A customer hands his key to an attendant at a parking lot and says . . . (1) "This is parked out back." . . . In (1), for example, we would be inclined to say that the subject refers not to the key that the speaker is holding, but to the car that the key goes with. And in fact all the linguistic evidence supports this analysis. (Nunberg, 1995, p. 110)

No matter how one analyzes the way in which the reference is brought about, "all the linguistic evidence supports" that the demonstrative is used to refer to a car that is not physically present. Some notion of intentional presence thus seems to be at issue, *even* in the case of demonstratives (Dekker, 2001). This point may be substantiated further by varying slightly on an example that David Kaplan used to demonstrate one of those "delightful anomalies" that may arise from direct demonstration.

> Suppose, without turning and looking I point to the place on my wall which has long been occupied by a picture of Rudolf Carnap and I say, "Dthat . . . is a picture of one of the greatest philosophers of the twentieth century". But unbeknownst to me someone has replaced my picture of Carnap with one of Spiro Agnew . . . I have said of a picture of Spiro Agnew that it pictures one of the greatest philosophers of the twentieth century. (Kaplan, 1978, p. 239)

Kaplan's point in the envisaged situation would have been made, more straightforwardly and unambiguously perhaps, if Kaplan had just said "Dthat is one of the greatest philosophers of the twentieth century." He then could have been taken to have said, unintentionally, of Spiro Agnew that he is one of the greatest philosophers of the twentieth century. Agnew, after all, would be the person who *is* intentionally present in the described situation. It may easily escape one's notice that, often, what is actually referred to, or actually pointed at, is not actually present itself, but rather, we venture to say, "intentionally present".

6.5 Conclusions

In this chapter we have discussed some of the prominent insights about the phenomenon of reference, and the angles from which it has been looked upon in philosophy of language. As we have seen, the issue transcends the borders, if any, between logic, semantics, and pragmatics, and even those, if any, with the neighboring areas of computation and cognition; it is also entrenched, deeply, in epistemology and (natural language, or "folk") metaphysics. We may have seen too that the characterization and analysis of the phenomenon depends not just on the perspective adopted but also, it seems, on the goals of the envisaged inquiry. Certain observations and insights may seem to be just right, or just misplaced, depending on whether one is engaged in philosophy and logic, or in the semantics of natural language, or in natural language interpretation and generation.

Selective glossary

Attributive description "A speaker who uses a definite description attributively in an assertion states something about whoever or whatever is the so-and-so." (Donnellan, 1966, p. 285)

***Bedeutung* (denotation, or reference) of a *Zeichen* (sign)** What the sign signifies ("bezeichnet"). (Frege, 1892b, p. 26)

Bezeichnen/Benennen "Am direktesten ist das Wort 'bezeichnen' vielleicht da angewandt, wo das Zeichen auf dem Gegenstand steht, den es bezeichnet . . . Etwas benennen, das ist etwas Ähnliches, wie einem Ding ein Namenstäfelchen anheften." (The word "signify" is perhaps used in the most straightforward way when the object signified is marked with the sign. . . . Naming something is like attaching a label to a thing.) (Wittgenstein, 1953, §15)

Demonstrative description "I will speak of a *demonstrative use* of a singular denoting phrase when the speaker intends that the object for which the phrase stands be designated by an associated demonstration." (Kaplan, 1978, p. 230)

Denotation "Thus if 'C' is a denoting phrase, it may happen that there is one entity *x* (. . .) for which the proposition '*x* is identical with C' is true (. . .). We may then say that the entity *x* is the denotation of the phrase 'C'." (Russell, 1905, p. 488)

Denoting phrase "By a 'denoting phrase' I mean a phrase such as any one of the following: a man, some man, any man, every man, all men, the present king of England, the present king of France . . . " (Russell, 1905, p. 479)

Direct reference "I intend to use '*directly referential*' for an expression . . . whose semantical *rules* provide *directly* that the referent in all possible circumstance is fixed to be the actual referent." "*The rules do not provide a complex which together with a circumstance of evaluation yields an object. They just provide an object.*" (Kaplan, 1989b, pp. 493–495)

Discourse referent "Informally, a discourse model may be described as the set of entities 'naturally evoked' by a discourse and linked together by the relations they participate in. These I will call discourse entities. (I can see no basic difference between what I am calling 'discourse entities' and what Karttunen (1976) has called 'discourse referents' . . .)" (Webber, 1978b, p. 21)

Referential description "A speaker who uses a definite description referentially in an assertion . . . uses the description to enable his audience to pick out whom or what he is talking about and states something about that person or thing." (Donnellan, 1966, p. 285)

Referential indefinite "Thus a referential indefinite can be regarded as an indexical phrase, where the function that determines its referent depends both on its descriptive content and on its context of use . . . ." (Fodor and Sag, 1982, p. 384)

Rigid designator "Let's call something a *rigid designator* if in every possible world it designates the same object." (Kripke, 1972, p. 48)

Semantic reference "If a speaker has a designator in his idiolect, certain conventions of his idiolect (given various facts about the world) determine the referent in the idiolect: that I call the *semantic referent* of the designator. (If the designator is ambiguous, or contains indexicals, demonstratives or the like, we must speak of the semantic referent on a given occasion . . .)" (Kripke, 1977, p. 263)

***Sinn* (meaning, or sense) of a *Zeichen* (sign)** A sign's mode of presentation of what it signifies ("Art des Gegebenseins des Bezeichneten"). (Frege, 1892b, p. 26)

Speaker's reference "we may tentatively define the speaker's referent of a designator to be that object which the speaker wishes to talk about, on a given occasion, and believes fulfills the conditions for being the semantic referent of the designator . . . The speaker's referent is the thing the speaker referred to by the designator, though it may not be the referent of the designator, in his idiolect." (Kripke, 1977, p. 264)

7

Generalized quantifiers

Dag Westerståhl

7.1 Thirty years of generalized quantifiers

It is now more than thirty years since the first serious applications of Generalized Quantifier (GQ) theory to natural language semantics were made: Barwise and Cooper (1981); Higginbotham and May (1981); Keenan and Stavi (1986). Richard Montague had in effect interpreted English NPs as (type $\langle 1 \rangle$) generalized quantifiers (see Montague, 1974),[1] but without referring to GQs in logic, where they had been introduced by Mostowski (1957) and, in final form, Lindström (1966). Logicians were interested in the properties of *logics* obtained by piecemeal additions to first-order logic (*FO*) by adding quantifiers like 'there exist uncountably many', but they made no connection to natural language.[2] Montague Grammar and related approaches had made

[1] In this chapter I use the classical terminology, but the reader is free to substitute everywhere "DP" for "NP", and "NP" for "N".

[2] Long before them, however, Frege had introduced quantifiers as second-order relations, and he did consider these for interpreting Dets like `all` and `some`, although his main interest was quantification in logic, where the unary $\forall$ was enough. But it was Montague's idea of interpreting NPs as type $\langle 1 \rangle$ generalized quantifiers that marked the real starting point for compositional model-theoretic semantics for natural languages.

clear the need for higher-type objects in natural language semantics. What Barwise, Cooper, and the others noticed was that generalized quantifiers are the natural interpretations not only of noun phrases but also in particular of *determiners* (henceforth Dets).[3]

This was no small insight, even if it may now seem obvious. Logicians had, without intending to, made available model-theoretic objects suitable for interpreting English definite and indefinite articles, the Aristotelian `all, no, some`, proportional Dets like `most, at least half, 10 percent of the, less than two-thirds of the`, numerical Dets such as `at least five, no more than ten, between six and nine, finitely many, an odd number of`, definite Dets like `the, the twelve`, possessives like `Mary's, few students', two of every professor's`, exception Dets like `no ... but John, every ... except Mary`, and Boolean combinations of all of the above. *All* of these can – if one wants! – be interpreted extensionally as the same type of second-order objects, namely (on each universe of discourse) *binary relations between sets*. Given the richness of this productive but seemingly heterogeneous class of expressions, a uniform interpretation scheme was a huge step. Further, the tools of logical GQ theory could be brought to bear on putative Det interpretations, which turned out to be a subclass of the class of all type $\langle 1, 1\rangle$ quantifiers with special traits. The three pioneer papers mentioned above offered numerous cases of novel description, and sometimes explanation, of characteristic features of language in terms of model-theoretic properties of the quantifiers involved.

This development has continued and still goes on. Many of the early results have reached the status of established facts in (most of) the linguistic community, and generalized quantifiers are by now standard items in the semanticist's toolbox. In the following sections I will, after a few preliminaries, indicate some of the most important achievements of GQ theory applied to natural language. Each will be presented in this format: first, a feature of language will be identified, and then we will see what GQ theory has to offer. In most cases I will only be able to outline the main issues and give references to more detailed accounts.

7.2 Definitions, examples, terminology

The 1 in "type $\langle 1, 1\rangle$" stands for 1-ary relation, i.e., set, so a type $\langle 1, 1\rangle$ quantifier (from now on I will often drop the word *generalized*) is (on each

[3] All languages appear to have rich means of expressing quantification. Some languages make scarce or no use of Dets but rely instead on "A quantification", where "A" stands for adverbs, auxiliaries, affixes, and argument structure adjusters; see Bach et al. (1995) for this terminology and many examples. But whatever words or morphemes are used, they can be interpreted, just like Dets, as type $\langle 1, 1\rangle$ quantifiers. It has been claimed that some languages lack NPs, or in general phrases interpretable as type $\langle 1\rangle$ quantifiers. But the point here is that $\langle 1, 1\rangle$ is the basic type of quantification in all natural languages; see Peters and Westerståhl (2006) for discussion.

universe) a relation between two sets, a type $\langle 1,1,1,1\rangle$ quantifier a relation between four sets, a type $\langle 1,2\rangle$ quantifier a relation between a set and a binary relation. In general, type $\langle n_1,\ldots,n_k\rangle$ signifies a relation between relations $R_1,\ldots,R_k$, where R_i is n_i-ary.

In model theory, a relation is always over a *universe*, which can be any non-empty set M. In a linguistic context we can think of M as a universe of discourse. So by definition, a *quantifier* Q of type $\langle n_1,\ldots,n_k\rangle$ is a function associating with each M a *quantifier* Q_M *on* M of that type, i.e., a k-ary relation between relations over M as above. For $R_i \subseteq M^{n_i}$, (1) means that the relation Q_M holds for the arguments $R_1,\ldots,R_k$.[4]

(1) $Q_M(R_1,\ldots,R_k)$

Q_M is often called a *local* quantifier (and Q a *global* one). In some applications, the universe can be held fixed, so a local perspective is adequate. However, in others, one needs to know how the *same* quantifier behaves in *different* universes. It is important to keep in mind that quantifiers are essentially global objects.[5]

As noted, the most important type in natural language contexts is $\langle 1,1\rangle$. Here are the interpretations of some of the Dets mentioned in the previous section (for all M and all $A, B \subseteq M$):

(2) $\mathit{all}_M(A,B) \Leftrightarrow A \subseteq B$
$\mathit{some}_M(A,B) \Leftrightarrow A \cap B \neq \varnothing$
$\mathit{no}_M(A,B) \Leftrightarrow A \cap B = \varnothing$
$\mathit{most}_M(A,B) \Leftrightarrow |A \cap B| > |A - B|$ ($|X|$ is the cardinality of X)
$\textit{less than two-thirds of the}_M(A,B) \Leftrightarrow |A \cap B| < 2/3 \cdot |A|$
$\textit{at least five}_M(A,B) \Leftrightarrow |A \cap B| \geq 5$
$\textit{between six and nine}_M(A,B) \Leftrightarrow 6 \leq |A \cap B| \leq 9$
$\textit{finitely many}_M(A,B) \Leftrightarrow A \cap B$ is finite
$\textit{an odd number of}_M(A,B) \Leftrightarrow |A \cap B|$ is odd
$\textit{the twelve}_M(A,B) \Leftrightarrow |A| = 12$ and $A \subseteq B$
$\textit{some students'}_M(A,B) \Leftrightarrow \textit{student} \cap \{a : A \cap \{b : \textit{has}(a,b)\} \subseteq B\} \neq \varnothing$
$\textit{every} \ldots \textit{except Mary}_M(A,B) \Leftrightarrow A - B = \{m\}$

The notation used in (1) and (2) is set-theoretic. Linguists often prefer lambda notation, from the *simply typed lambda calculus*. This is a *functional* framework, where everything, except primitive objects like individuals (type e) and truth values (type t), is a function. Sets of individuals are (characteristic) functions from individuals to truth values; thus of type $\langle e,t\rangle$. In general, $\langle \sigma,\tau\rangle$ is the

[4] We may define instead, as in Lindström (1966), Q as a *class of models* of type $\langle n_1,\ldots,n_k\rangle$. This is really just a notational variant; we have

$$(M, R_1,\ldots,R_k) \in Q \iff Q_M(R_1,\ldots,R_k)$$

[5] Couldn't we simply let a quantifier Q be a second-order relation over the class V of *all* sets, and then define Q_M as the restriction of Q to relations over M? This works for some quantifiers but not others (it works for Ext quantifiers; see Section 7.4). For example, the standard universal quantifier $\forall$ would then denote $\{V\}$, but the restriction to a set M is $\varnothing$, rather than $\{M\}$ as desired.

type of functions from objects of type σ to objects of type τ. Binary relations are of type $\langle e, \langle e, t\rangle\rangle$, type $\langle 1\rangle$ quantifiers now get the type $\langle\langle e, t\rangle, t\rangle$, and type $\langle 1, 1\rangle$ quantifiers are of type $\langle\langle e, t\rangle\langle\langle e, t\rangle, t\rangle\rangle$.

If *function application* is seen as the major operation that composes meanings (as Frege perhaps thought and Montague showed that one could assume in many, though not all, cases), then the functional notation serves a *compositional* account well. For example, while (3) is simply rendered as (3a) in *FO*, giving `likes` the type $\langle e, \langle e, t\rangle\rangle$ allows it to combine with the object first, as it should on a compositional analysis if `likes Sue` is a constituent of (3), and then with the subject, yielding (3b):

(3) Mary likes Sue.
  a. $like(m, s)$
  b. $like(s)(m)$

Similarly, (4) could be rendered as (4)′ (where *some, student, smoke* are constants of the appropriate types), reflecting the fact that `some students` is a constituent of (4).

(4) Some students smoke.

(4)′ $some(student)(smoke)$

So far there are no lambdas. But suppose *some* is not a constant but rather *defined* as $\lambda X \lambda Y \exists x(X(x) \wedge Y(x))$. Then (4) would be rendered as in (5):

(5) $\lambda X \lambda Y \exists x(X(x) \wedge Y(x))(student)(smoke)$

After two *lambda conversions* (5) becomes the following:

(5)′ $\exists x(student(x) \wedge smoke(x))$

This is the standard *FO* translation of (4), but now obtained compositionally. In this chapter I focus on succinct formulation of truth conditions of quantified sentences (not so much on their compositional derivation), and on model-theoretic properties of quantifiers, and then the relational set-theoretic notation seems simplest.

There is also a middle way: skip the lambdas but keep the functional rendering of quantifiers, using ordinary set-theoretic notation (as in e.g., Keenan and Stavi, 1986). This makes a type $\langle 1, 1\rangle$ quantifier a function mapping sets (N extensions) to type $\langle 1\rangle$ quantifiers (NP extensions), which is just how Dets work. In principle, one can choose the notation one prefers; it is usually straightforward to translate between them.[6]

[6] See, however, Keenan and Westerståhl (1997, pp. 876–877), for some additional advantages of the functional version.

7.3 Noun phrases

We already saw that quantified NPs, consisting of a determiner and a noun, are most naturally interpreted as type $\langle 1 \rangle$ quantifiers, i.e., on each universe M, as sets of subsets of M. For example, the extension of `three cats` is the set of subsets of M whose intersection with the set of cats has exactly three elements, and the extension of `no students but Mary` is the set of subsets of M whose intersection with the set of students is the unit set {Mary}. What happens is just that the first argument (the restriction argument) of the type $\langle 1, 1 \rangle$ quantifier Q that the Det denotes is fixed to a given set A. The operation is called restriction or *freezing*: Q and A yield a type $\langle 1 \rangle$ quantifier Q^A. Normally one has $A \subseteq M$, but in principle we should define the action of Q^A on any universe M. This is done as follows (for all M and all $B \subseteq M$):[7]

(6) $(Q^A)_M(B) \iff Q_{A\cup M}(A, B)$

Next, there is a class of quantified NPs that do not freeze to a noun with fixed extension like `cat`, but instead to a variable noun like `thing`, which can be taken to denote the universe. Some of these are lexicalized as words in English, but the interpretation mechanism is just as in (6), except that $A = M$. For example:

(7) $\mathit{everything}_M(B) \Leftrightarrow (\mathit{every}^{\mathit{thing}})_M(B) \Leftrightarrow (\mathit{every}^M)_M(B)$
$\Leftrightarrow \mathit{every}_M(M, B) \Leftrightarrow M \subseteq B \Leftrightarrow B = M$

Similarly, applying (6) we obtain the following:

(8) $\mathit{something}_M(B) \Leftrightarrow B \neq \varnothing$
$\mathit{nothing}_M(B) \Leftrightarrow B = \varnothing$
$\mathit{at\ least\ three\ things}_M(B) \Leftrightarrow |B| \geq 3$
$\mathit{most\ things}_M(B) \Leftrightarrow |B| > |M - B|$
etc.

Here we note that the first two are the standard universal and existential quantifiers of *FO*: $\forall$ and $\exists$. GQ theory started as generalizations of these: Mostowski (1957) considered type $\langle 1 \rangle$ quantifiers that place conditions on the cardinalities of B and $M - B$, as all the quantifiers listed above do. But the connection to the semantics of NPs was not then a motivation.

What about NPs that don't have Dets? A typical case are those denoting a single individual, in particular *proper names*. The most straightforward interpretation of a name is as an element of the universe: `Mary` denotes m. However, Montague devised a treatment of names as type $\langle 1 \rangle$ quantifiers too, partly for the reason that they are easily *conjoined* with quantified NPs, as in (9):

(9) Mary and three students went to the party.

[7] See Peters and Westerståhl (2006, Chapter 4.5.5) for arguments why this is the correct definition, rather than, say, $(Q^A)_M(B) \Leftrightarrow A \subseteq M \,\&\, Q_M(A, B)$.

Thus, for each individual a, the type $\langle 1\rangle$ quantifier I_a is defined as follows for all M and all $B \subseteq M$:

(10) $(I_a)_M(B) \iff a \in B$

Here we have not required that $a \in M$; if not, $(I_a)_M$ is simply empty,[8] but if $a \in M$, $(I_a)_M$ is the principal filter (over M) generated by a.

The quantifiers I_a are called *Montagovian individuals*. (9) also illustrates that *Boolean combinations* of quantifiers (of the same type) work smoothly and as expected in the type $\langle 1\rangle$ case:

(11) $(Q \wedge Q')_M(B) \iff Q_M(B)$ and $Q'_M(B)$
$(Q \vee Q')_M(B) \iff Q_M(B)$ or $Q'_M(B)$
$(\neg Q)_M(B) \iff$ not $Q_M(B)$

So in (9), `Mary and three students` is conjoined from the NPs `Mary` and `three students`, each interpretable as a type $\langle 1\rangle$ quantifier, and the interpretation of the conjoined NP is the conjunction of these two. Similarly, we get the obvious interpretations of NPs like `John and Mary`, `Fred or Mary, but not Sue`. Summing up, interpreting names as Montagovian individuals provides us with interpretations of conjoined NPs that would otherwise not be easily available: Boolean operations are defined on quantifiers but not on elements of the universe.

This takes care of a vast majority of English NPs. A kind not mentioned so far are *bare plurals*, but these can be (roughly) treated as if they had a null (universal or existential) Det:

Firemen wear helmets $\approx$ All firemen wear helmets
Firemen are available $\approx$ Some firemen are available

However, what about the following?

(12) Only firemen wear black helmets.

(13) Only John smokes.

If we allow that `John` denotes the singleton $\{j\}$, it might *seem* that these two sentences have the same form, namely, *only A are B*, and that `only` is a Det whose interpretation is $only_M(A, B) \Leftrightarrow \varnothing \neq B \subseteq A$. However, several things speak against this idea. First, we can agree that (12) and (13) have the same form, but that the form is rather only *Q are B*, where Q is an NP. After all, `John` is an NP, and `firemen` too, if taken as a bare plural. Other NPs work as well:

(14) Only the three boys were rescued.

[8] So on this analysis, if Mary is not in the universe of discourse, all positive claims about her (that she has a certain property) are false. Note that requiring that $a \in M$ changes nothing: for all a, all M, and all $B \subseteq M$, $a \in B \Leftrightarrow a \in M \,\&\, a \in B$.

In this case, however, `only` modifies an NP and is not a Det, and the interpretation of `[only NP]` is not obtained along the lines of (6).[9] In the next section, we will see another reason why `only` cannot be a Det.

Let me also mention that there are NPs formed by Dets applying to more than one N argument, as in (15):

(15) More men than women smoke.

This is quite naturally seen as a type $\langle 1, 1, 1\rangle$ quantifier *more_than* applied to two noun denotations, yielding – along lines generalizing (6) – a type $\langle 1\rangle$ quantifier interpreting the NP `more men than women`:

$$\mathit{more\_than}_M(A, B, C) \iff |A \cap C| > |B \cap C|$$

I will not deal further with such Dets here; see Keenan and Westerståhl (1997, section 19.2.3) for more examples and discussion.

7.4 Domain restriction

Sentences like (16) have a perfectly clear constituent structure, i.e., (16)′

(16) Most students smoke.

(16)′ $[_S\ [_{NP}\ [_{Det}$ most$]\ [_N$ students$]]\ [_{VP}$ smoke$]]$

This may also be rendered schematically, as in (16)″

(16)″ $[QA]B$

So it is obvious that the *restriction* argument A of Q plays a very different syntactic role from the *nuclear scope* argument B. Is there a semantic counterpart to this?

Indeed there is, and this is the most characteristic trait of type $\langle 1, 1\rangle$ quantifiers that interpret natural language Dets. Intuitively, the domain of quantification is restricted to A. Technically, this can be described via the model-theoretic notion of relativization. For any Q of type $\langle n_1, \ldots, n_k\rangle$, the

[9] What do these NPs mean, i.e., which type $\langle 1\rangle$ quantifiers interpret them? Try the following:

(i) $(\mathit{only}\ Q^A)_M(B) \iff Q_M(A, B)$ & $B \subseteq A$

This actually gives correct truth conditions for (12)–(14), provided we (a) use the *decomposition* of I_a as $\mathit{some}^{\{a\}}$, i.e. we use the fact that $I_a = \mathit{some}^{\{a\}}$; (b) similarly decompose the existential reading of bare plurals. (If that reading is given by the quantifier $(C^{e,pl})_M(B) \Leftrightarrow C \cap B \neq \varnothing$, so $C = \mathit{firemen}$ in our example, then we have $C^{e,pl} = \mathit{some}^C$.) However, this is complicated by the fact that such decomposition is not unique (see Westerståhl, 2008, for more about decomposition) and also that `only` has other uses, as in (ii), for example:

(ii) Only ten boys were rescued.

Besides the reading given by (i), this has the reading (with focus on `boys`) that exactly ten boys were rescued, but that others (e.g., girls) might also have been rescued. Then it is truth-conditionally equivalent to `Ten boys were rescued`, and `only` is rather a pragmatic addition that this number is remarkable in some way. Indeed, the complex semantics of `only` and `even` is crucially tied to focus phenomena, which are partly pragmatic; see Rooth (1996) for a survey.

relativization of Q is the quantifier Q^{rel} of type $\langle 1, n_1, \ldots, n_k \rangle$ defined by the following:

$$(Q^{rel})_M(A, R_1, \ldots, R_k) \iff Q_A(R_1 \cap A^{n_1}, \ldots, R_k \cap A^{n_k})$$

In particular, for Q of type $\langle 1 \rangle$, Q^{rel} has type $\langle 1, 1 \rangle$ and the following holds:

(17) $(Q^{rel})_M(A, B) \iff Q_A(A \cap B)$

What Q^{rel} does is to take its first argument as a universe and describe the action of Q on that universe. That is, $Q^{rel}(A, \ldots)$ "simulates" Q with A as its domain of quantification. This means that, for a type $\langle 1, 1 \rangle$ Det interpretation Q, the idea that the first argument of Q provides the domain of quantification can be expressed as follows: *Q is the relativization of some type $\langle 1 \rangle$ quantifier.*

Historically, this crucial property of Det interpretations was approached in a different way. It was noticed early on (Barwise and Cooper, 1981; Higginbotham and May, 1981; Keenan, 1981) that these quantifiers have the property of *conservativity* for all M and all $A, B \subseteq M$:

(Conserv) $Q_M(A, B) \iff Q_M(A, A \cap B)$

This can be easily checked in each case; for example, the following sentence pairs are not only equivalent but trivially so, in that the second sentence contains an obvious redundancy.

(18) a. Most students smoke.
b. Most students are students who smoke.

(19) a. All but five teams were disqualified.
b. All but five teams are teams that were disqualified.

(20) a. Q *As* are B
b. Q *As* are *As* that are B

Conserv rules out many type $\langle 1, 1 \rangle$ quantifiers that are quite natural from a logical or mathematical point of view but cannot serve as interpretations of English determiners as shown, for example, in (21):

(21) $more_M(A, B) \Leftrightarrow |A| > |B|$
$I_M(A, B) \Leftrightarrow |A| = |B|$ (the equicardinality or Härtig quantifier)

It also rules out `only` as a Det: interpreted as suggested in the previous section it would not be Conserv. Note that all these quantifiers are easily expressed in English; for example, $more_M(A, B)$ says `There are more As than Bs`, and $only_M(A, B)$ would say `There are Bs and all Bs are As`. However, the point is that they do not interpret English *determiners*.

Conserv contains part of the idea of domain restriction, since it says in effect that the elements of $B - A$ do not matter for the truth value of $Q_M(A, B)$. But it says nothing about elements of the universe that are outside both A and B, i.e., in $M - (A \cup B)$. For example, it does not rule out a quantifier *unex* that behaves as *every* on universes with at most 100 elements, and as *some* on larger universes.

Although a quantifier Q may associate any local quantifier Q_M on a universe M, it seems reasonable to say that *unex*, even though it is CONSERV (and definable in first-order logic), is not the *same* on all universes, or that it is not *uniform*. The following property, introduced in van Benthem (1984) under the name of *extension*, goes a long way to capture the idea of sameness or uniformity over universes. It applies to quantifiers of all types; here is the type $\langle 1, 1\rangle$ case:

(EXT) If $A, B \subseteq M \subseteq M'$, then $Q_M(A, B) \Leftrightarrow Q_{M'}(A, B)$.

In other words, what the universe is like outside the arguments A and B doesn't matter. This rules out quantifiers like *unex*. But all the other type $\langle 1, 1\rangle$ quantifiers shown so far are EXT. And it is easy to see that relativized quantifiers are always EXT. Among the type $\langle 1\rangle$ quantifiers looked at so far, all are EXT *except* $\forall$ (*everything*) and *most things*. Significantly, the last two involve a noun *thing* that refers to the universe, and in these cases (as opposed to *something* or *nothing*), whether $Q_M(B)$ holds or not depends also on the *complement* $M - B$. For example, $\forall_M(B)$ says that $M - B$ is empty, and so EXT fails.

For Det interpretations, EXT should be part of the idea of domain restriction, even if the rationale for EXT goes far beyond that. If the truth value of $Q_M(A, B)$ could change when the universe M is extended, we could hardly say that A was the domain of quantification. Now it turns out that CONSERV and EXT together exactly capture domain restriction. The following fact is essentially trivial but basic, so I will give the proof.

Fact 7.4.1 *A type $\langle 1, 1\rangle$ quantifier is* CONSERV *and* EXT *if and only if it is the relativization of a type $\langle 1\rangle$ quantifier.*

Proof If Q is of type $\langle 1\rangle$ it is straightforward to check that Q^{rel} is CONSERV and EXT. Conversely, suppose the type $\langle 1, 1\rangle$ quantifier Q' is CONSERV and EXT. Define Q of type $\langle 1\rangle$ by

$$Q_M(B) \Leftrightarrow Q'_M(M, B)$$

Then we have, for all M and all $A, B \subseteq M$,

$$\begin{aligned}
Q^{rel})_M(A, B) &\Leftrightarrow Q_A(A \cap B) && \text{(def. of } Q^{rel}\text{)}\\
&\Leftrightarrow Q'_A(A, A \cap B) && \text{(def. of } Q\text{)}\\
&\Leftrightarrow Q'_M(A, A \cap B) && \text{(EXT)}\\
&\Leftrightarrow Q'_M(A, B) && \text{(CONSERV)}
\end{aligned}$$

That is, $Q' = Q^{rel}$. □

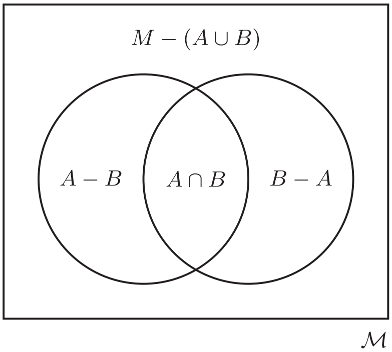

Figure 7.1 *A model of type* $\langle 1, 1\rangle$

So we have a clear model-theoretic characterization of the special semantic role of the restriction argument of Dets. A model $\mathcal{M} = (M, A, B)$ can be depicted as in Figure 7.1.

Conserv says that $B-A$ doesn't matter for whether $Q_M(A, B)$ holds or not. Ext says that $M-(A\cup B)$ doesn't matter. The only sets that matter are $A-B$ and $A\cap B$, both subsets of A. That is what it means that Q restricts the domain of quantification to its first argument.

In addition, it seems that Ext is a kind of semantic universal: All 'reasonable' quantifiers, *except* some of those that involve a predicate like *thing*, satisfy it. Ext also lets us simplify notation and write $Q(A, B)$ instead of $Q_M(A, B)$; a practice I will follow whenever feasible.

7.5 Quantity

You would think quantifiers had something to do with quantities, and indeed we see directly that most of the Det interpretations in (2) are perfectly good answers to the question posed in (22).

(22) How many As are B?

So it is the *number of elements* in the concerned sets that matter, not the elements themselves. Formally, if we have two models as in Figure 7.2 the requirement is as follows:

(Isom) If the corresponding four sets in Figure 7.2 have the same cardinality, then $Q_M(A, B) \Leftrightarrow Q_{M'}(A', B')$.

This property is called *isomorphism closure* in model theory, since the antecedent amounts to the existence of an isomorphism from $\mathcal{M}$ to $\mathcal{M}'$. The notion of isomorphism applies to models of any type, and hence so does Isom.

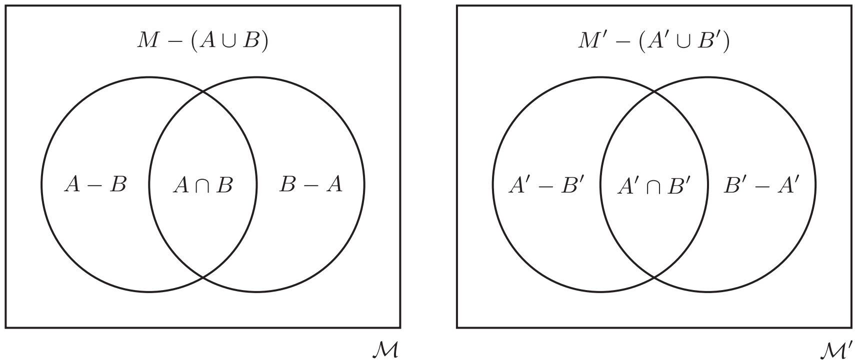

Figure 7.2 *Two models of type* $\langle 1, 1 \rangle$

In the case of a type $\langle 1, 1 \rangle$ quantifier satisfying Conserv and Ext, Isom amounts to the following:

(23) If $|A - B| = |A' - B'|$ and $|A \cap B| = |A' \cap B'|$ then $Q(A, B) \Leftrightarrow Q(A', B')$.

This is why $Q(A, B)$, for Conserv, Ext, and Isom Q, answers question (22). It means that these quantifiers can be seen as *binary relations between* numbers; in the case of finite models between natural numbers. This is a huge simplification; recall that by definition quantifiers are operators that with each universe (non-empty set) associate a second-order relation on that set. Now this is reduced to a (first-order) relation between numbers, with no mention of universes. For example, with $|A - B| = m$ and $|A \cap B| = n$,

all $(m, n) \Leftrightarrow m = 0$
some $(m, n) \Leftrightarrow n > 0$
most $(m, n) \Leftrightarrow n > m$
an odd number of $(m, n) \Leftrightarrow n$ is odd

This also simplifies the model-theoretic study of the expressive power of quantifiers. It follows from Fact 7.4.1 that, under Isom, Q and Q^{rel} define the same binary relation between numbers (where Q has type $\langle 1 \rangle$), and it is much easier to obtain results for type $\langle 1 \rangle$ quantifiers than for any other types.

A weaker version of Isom, called Perm, has the same definition except that $M' = M$. This is closure under *automorphisms* or, equivalently, under *permutations* (since every permutation of the universe M induces an automorphism on $\mathcal{M}$). If one is working with a fixed universe of discourse, Perm is the natural choice. One easily construes artificial examples of quantifiers that are Perm but not Isom. (E.g., let a be a fixed object, and let $Q_M = some_M$ if $a \in M$ and $Q_M = every_M$ otherwise.) In the presence of Ext, however, the difference disappears; one can show that the following holds for Q of any type.

Fact 7.5.1 *If Q is* Ext *and* Perm, *then Q is* Isom.

However, some of the Det interpretations in (2) are not Isom (not even Perm): `Henry's`, `some students'`, `every_except Mary`, and likewise the Montagovian individuals I_a. This makes perfect sense: all of these depend on a fixed property like being a student, or a fixed individual like Mary. Permuting the elements of the universe may map *student* to *cat*, or Mary to Henry. Also, these quantifiers occur less naturally as answers to (22); cf. (24):

(24) a. How many dogs are in the pen?
 b. At least three/no/more than half of the dogs are in the pen.
 c. ? Henry's dogs are in the pen.

From a logical point of view, one might then prefer to generalize these second-order relations by taking the additional set or individual as extra arguments. Then, *some students'* would be of type $\langle 1, 1, 1\rangle$, and *every_except Mary* of type $\langle 1, 1, 0\rangle$, where 0 now stands for an individual. These quantifiers would all be Isom. Logicians usually look at model-theoretic objects "up to isomorphism", and indeed closure under isomorphism was part of Mostowski's and Lindström's original definition of a generalized quantifier. But from a linguistic perspective, the type should correspond to the syntactic category of the relevant expression. As long as there are independent reasons to think of `Henry's`, `some students'`, `every_except Mary`, etc. as Dets, one would want to interpret them as type $\langle 1, 1\rangle$ quantifiers.

7.6 Negation

The most common occurrence of negation in English is not the logician's sentential negation, "it is not the case that", but VP negation. (25b) can be true when (25a) is false.

(25) Two-thirds of the students smoke.
 a. Two-thirds of the students don't smoke.
 b. It is not the case that two-thirds of the students smoke.

VP negation corresponds to a natural Boolean operation on type $\langle 1\rangle$ quantifiers. In addition to (11), we have (26):

(26) $(Q\neg)_M(B) \iff Q_M(M - B)$

This operation is called *inner negation* or, in Keenan's terminology, *postcomplement*. Like the other Boolean operations, it applies also to Conserv and Ext type $\langle 1, 1\rangle$ quantifiers, and combined with normal (*outer*) negation it yields a natural notion of a *dual* quantifier; below is the type $\langle 1, 1\rangle$ case:

(27) $(Q\neg)(A, B) \iff Q(A, A - B)$

(28) $Q^d = \neg(Q\neg) = (\neg Q)\neg$

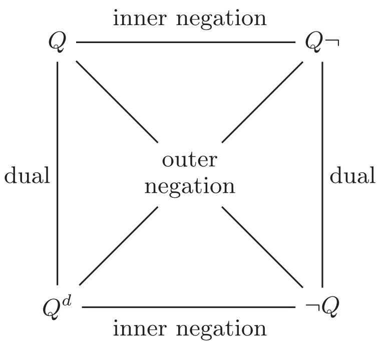

Figure 7.3 *square*(Q)

For example, *no* is the inner negation of *all*, *some* is the dual, and *not all* is the outer negation. Medieval Aristotle scholars noticed early on that these four quantifiers can be geometrically displayed in a *square of opposition*. In fact, we can now see that every CONSERV and EXT type $\langle 1, 1\rangle$ quantifier Q spans a square of opposition *square*(Q) $= \{Q, Q\neg, Q^d, \neg Q\}$; see Figure 7.3.[10]

Outer and inner negation and dual all satisfy double negation elimination: $Q = \neg\neg Q = Q\neg\neg = Q^{dd}$. They interact with $\wedge$ and $\vee$ as follows:

(29) a. $\neg(Q \wedge Q') = \neg Q \vee \neg Q'$ and $\neg(Q \vee Q') = \neg Q \wedge \neg Q'$
(de Morgan laws)
b. $(Q \wedge Q')\neg = Q\neg \wedge Q'\neg$ and $(Q \vee Q')\neg = Q\neg \vee Q'\neg$
c. $(Q \wedge Q')^d = Q^d \vee Q'^d$ and $(Q \vee Q')^d = Q^d \wedge Q'^d$

Using these facts, it is easy to verify that every quantifier in *square*(Q) spans the same square (so two squares are either disjoint or identical), which always has either four or two members.

Inner negations and duals of English Dets are often expressible as other Dets, without using explicit Boolean connectives. For example, one checks that (*all*)^d = *some*, (*at most three*)$\neg$ = *all but at most three*, (*the ten*)$\neg$ = *none of the ten*, (*at least two-thirds of the*)^d = *more than one-third of the*, (*all_except Mary*)$\neg$ = *no_except Mary*, (*exactly half the*)$\neg$ = *exactly half the*. In short, the square of opposition is a very useful tool for understanding the relations between the various forms of negation occurring in natural languages.

As the last example in the previous paragraph shows, we can have $Q = Q\neg$ for naturally occurring quantifiers (and so *square*(Q) has two members). Keenan has observed that there are also many less obvious examples; the equivalence of the following pair requires a small calculation:

[10] This is not quite an Aristotelian-type square, which instead of inner negation along the top side has the relation of *contrariety* (Q and Q' are contraries if $Q(A, B)$ and $Q'(A, B)$ can never both be true), and in fact differs along all the sides of the square; only the diagonals are the same. For a comparison between the two kinds of square, and the properties of several examples of (modern) squares of generalized quantifiers, see Westerståhl (2012).

(30) a. Between 10 and 90 percent of the students left.
b. Between 10 and 90 percent of the students didn't leave.

That is, (*between 10 and 90 percent of the*)$\neg$ = *between 10 and 90 percent of the*.

Can the vertical sides of the square also be collapsed, i.e., can we have $Q = Q^d$, or equivalently, $\neg Q = Q\neg$? Such quantifiers are called *self-dual* in Barwise and Cooper (1981). The answer to this question reveals an interesting difference between global and local quantifiers. For in contrast with the collapse $Q = Q\neg$, which as we saw does occur for certain common global quantifiers, *there are no interesting self-dual global quantifiers*. The next fact provides evidence for this (somewhat vague) claim. I formulate it here for a type $\langle 1\rangle$ quantifier Q.

Fact 7.6.1 *If Q is either (i)* Isom, *or (ii) a Montagovian individual I_a, or (iii) of the form $(Q_1)^A$ for some* Conserv *type $\langle 1, 1\rangle$ Q_1, then Q is not self-dual.*[11]

Thus, most (all?) common NP interpretations are not globally self-dual. This may seem surprising, since precisely in case (ii), self-duality has been cited as a significant property of Montagovian individuals! The explanation is that a *local* quantifier $(I_a)_M$ is self-dual if $a \in M$, for then we have: $(\neg I_a)_M(B) \Leftrightarrow a \notin B \Leftrightarrow a \in M - B \Leftrightarrow (I_a\neg)_M(B)$. As Barwise and Cooper note, this corresponds to the fact that *names lack scope with regard to negation*: in contrast with (25), the following sentences are equivalent:

(31) a. Ruth doesn't smoke.
b. It is not the case that Ruth smokes.

In fact, the interpretation of names as Montagovian individuals is also easily seen to explain why they lack scope with regard to all Boolean operations; cf. the equivalence of the sentences in (32):

(32) a. Bill or John smokes.
b. Bill smokes or John smokes.

Frans Zwarts has shown that lacking scope with regard to Boolean operators holds for *exactly* the Montagovian individuals.[12]

So here we have another case of a linguistically significant phenomenon with a clear model-theoretic counterpart. But this time the property is local, not global.

[11] *Outline of proof*: For (i), choose M and $B \subseteq M$ s.t. $|B| = |M - B|$. Then $Q_M(B) \Leftrightarrow Q_M(M - B)$ by Isom, which contradicts $Q_M = (Q^d)_M$. (As Keenan (2005) observes, this argument works for any local Perm quantifier Q_M, as long as $|M|$ is either even or infinite.) For (ii), choose M s.t. $a \notin M$. Then $(I_a)_M$ is the trivially false quantifier on M, but $(I_a)^d_M$ is the trivially true quantifier on M. For (iii), choose M s.t. $A \cap M = \varnothing$. Then an easy calculation, using the conservativity of Q_1, shows that $Q_M = (Q\neg)_M$, contradicting self-duality.

[12] Van Benthem (1989) and Zimmermann (1993) have further discussion and results about scopelessness.

7.7 Polarity and monotonicity

Natural languages have expressions – called *negative polarity items* (NPIs) – that seem to occur only (with a particular sense) in negative contexts and, as it were, make the negative claim as strong as possible. Two prime English examples are `ever` and `yet`:

(33) a. Susan hasn't ever been to NYC.
b. *Susan has ever been to NYC.

(34) a. Henry hasn't read the morning paper yet.
b. *Henry has read the morning paper yet.

Other examples include `any`, and various idioms such as `give a damn` and `budge an inch`. An obvious linguistic concern is to identify (a) the class of NPIs, and (b) the positions in which they occur. It is with (b) that model-theoretic semantics, and in particular GQ theory, turns out to be useful.[13]

It is well known that NPIs also occur in certain positions not in the scope of an explicit negation:

(35) a. Less than half of my friends have ever been to NYC.
b. *At least half of my friends have ever been to NYC.

(36) a. No one here has read the morning paper yet.
b. *Someone here has read the morning paper yet.

So what is "negative" about `less than half`? The proper generalization appears to turn on the concept of *monotonicity*.[14]

A function f from an ordered set $(X, \leq_1)$ to an ordered set $(Y, \leq_2)$ is

increasing if $x \leq_1 y$ implies $f(x) \leq_2 f(y)$;
decreasing if $x \leq_1 y$ implies $f(y) \leq_2 f(x)$.

Sometimes *monotone* is used synonymously with "(monotone) increasing"; here it will mean "either increasing or decreasing". Now negation is a prime example of a decreasing function; then $X = Y$ is a class of propositions and $\leq_1 = \leq_2$ is implication. (Alternatively, $X = Y$ is the set of truth values $\{0, 1\}$ and $\leq_1 = \leq_2$ is the usual non-strict order among them.) Moreover, most

[13] There are also *positive* polarity items, with a behavior partly symmetric to NPIs, such as `already`:

(i) a. Bill has already heard the news.
b. *Bill hasn't already heard the news.

I can only scratch the surface of the complex issues surrounding NPIs and PPIs (positive polarity items) here; see Ladusaw (1996) and Peters and Westerståhl (2006, ch. 5.9) for surveys and relevant references.

[14] NPIs also occur in questions, comparatives, antecedents of conditionals, and complements of phrases like `it is surprising that`. Here I focus on their occurrence in quantified contexts.

quantifiers interpreting NPs or Dets are monotone in some respect. More precisely, an Ext type ⟨1, 1⟩ quantifier Q is

right increasing if for all A, B, B', $Q(A, B)$ & $B \subseteq B'$ implies $Q(A, B')$,

and similarly for *right decreasing*, *left increasing*, *left decreasing*, and correspondingly for type ⟨1⟩ quantifiers (without the "right" and "left").[15]

For example, `every` is left decreasing and right increasing, `at least five` is left and right increasing, `most` is right increasing but not left monotone, and the same holds for *the ten*. Numerical quantifiers like *exactly five*, *between two and seven*, *either at least three or no* are not themselves monotone but Boolean combinations of monotone (in fact right and left increasing) quantifiers. To find thoroughly non-monotone Det denotations, we need to look at examples like *an even number of*.

The monotonicity behavior of an NP of the form [Det N] is determined by that of the Det, not by that of the N. This fact has a straightforward semantic explanation (cf. Section 7.4): a type ⟨1⟩ quantifier Q is increasing (decreasing) iff Q^{rel} is right increasing (decreasing). Also note that the behavior of Q determines exactly the behavior of the other quantifiers in *square*(Q). For example, if Q (type ⟨1, 1⟩) is right decreasing and left increasing, then Q^d is right and left increasing; the reader can easily figure out the other correspondences that hold.

Now, what is characteristic of NPIs seems to be that they occur in *decreasing* contexts, and as we saw in (35a) this can happen without there being any explicit negation: `less than half of my friends` is decreasing but not `at least half of my friends`. So to the extent this is correct, we again have a model-theoretic property that explains or at least systematizes a linguistic phenomenon.

In fact, much more can (and should) be said about polarity. For just one example, there is a difference between `ever` and `yet`: the former is fine in all decreasing contexts, but not the latter:

(37) a. None of my friends have seen *Alien* yet.
b. *At most three of my friends have seen *Alien* yet.

Zwarts argued that `yet` requires the stronger property of anti-additivity. An Ext type ⟨1⟩ quantifier Q is

anti-additive if for all B, C, $Q(B)$ & $Q(C)$ iff $Q(B \cup C)$.

This is equivalent to Q^{rel} being *right anti-additive*: $Q^{rel}(A, B)$ & $Q^{rel}(A, C)$ iff $Q^{rel}(A, B \cup C)$. It is clear that being (right) anti-additive implies being (right) decreasing, but the converse fails. In fact, Peters and Westerståhl (2006, ch. 5.9.4) show that over finite universes, very few Isom quantifiers Q^{rel} are right anti-additive: essentially only *no*, *none of the k (or more)*, and disjunctions

[15] So here $\leq_1$ is $\subseteq$, but $\leq_2$ is still the implication order.

of these. Model-theoretic results like this make it feasible to empirically test various hypotheses about the distribution of NPIs, but I shall leave the topic of NPIs here.

Monotonicity is relevant to natural language semantics far beyond establishing the distribution of NPIs. Most conspicuously, it pervades much of everyday *reasoning*. Aristotle's syllogisms express various kinds of monotonicity. Consider the following, for example:

$$\frac{\text{all } BC \qquad \text{all } AB}{\text{all } AC} \qquad\qquad \frac{\text{no } BC \qquad \text{all } AB}{\text{no } AC}$$

These two syllogisms say that *all* is right increasing and *no* is left decreasing, respectively. If the syllogistics is seen as a logic calculus for monadic predicates, it is poor in expressive power. But, as van Benthem (2008) points out, if we instead see it as recipes for *one-step monotonicity reasoning* (allowing A, B, C to be complex predicates), it takes on a new flavor. This is a leading idea in the program of *natural logic*: making inferences directly on natural language forms, without first translating them into some formal language.[16]

For monotonicity reasoning, one can systematically, during a syntactic analysis, mark certain predicate occurrences as increasing (+) or decreasing (−), allowing the corresponding inferences at those positions. For example, we would write the following (leaving out the simple structural analysis):

(38) a. All students$^-$ jog$^+$.
b. Most professors smoke$^+$.

Here (38a) indicates that we may infer, for example, `All graduate students jog`, or `All students jog or swim`. There is no marking on `professors` in (38b), since *most* is not left monotone, but since it is right increasing, there is a + on `smoke`.

Direct monotonicity inferences are simple, but combination with other natural modes of reasoning can give quite intricate results. The following example is adapted from Pratt-Hartmann and Moss (2009):

(39) a. All skunks are mammals
b. *Hence*: All people who fear all who respect all skunks fear all biologists who respect all mammals

To see that the conclusion really follows, start with the logical truth:

(40) All biologists$^-$ who respect$^-$ all skunks$^+$ respect$^+$ all skunks$^-$

Note that relation occurrences too can have signs. For example, changing the first occurrence of `respect` to `respect and admire` preserves

[16] For example, Sommers (1982), Sanchez Valencia (1991). Van Benthem (2008) gives a good overview.

validity. However, this is not used in (39). Instead we use the + on the first occurrence of `skunks` to obtain the following:

(41) a. All skunks are mammals
b. *Hence*: All biologists who respect all mammals respect all skunks

(41) is valid, and validity is preserved under appropriate replacement of predicates. So replace `skunks` by `biologists who respect all mammals`, replace `mammals` by `(individuals who) respect all skunks`, replace `biologists` by `people`, and replace `respect` by `fear`. The result is (42).

(42) a. All biologists who respect all mammals respect all skunks
b. *Hence*: All people who fear all who respect all skunks fear all biologists who respect all mammals

Thus, using, besides monotonicity, *substitution* and *transitivity* of consequence, we obtain (39).

However, isn't this *logic* rather than *semantics*? Actually the dividing line is not so clear, and many semanticists take the meaning of an expression to be essentially tied to the valid inferences containing it. The point here is just that these inferences can often be "read off" more or less directly from surface structure, without translation into a formal language like first-order logic or intensional type theory.[17]

Finally, consider the sentences in (43):

(43) a. More than 90 percent of the students passed the exam
b. At least 10 percent of the students play tennis
c. *Hence*: Some student who plays tennis passed the exam

This doesn't quite look like monotonicity reasoning of the previous kind. Why does the conclusion follow from the premises? The first pertinent observation is that *at least 10 percent of the* is the dual of *more than 90 percent of the*. So the pattern is that in (44).

(44) a. $Q(A, B)$
b. $Q^d(A, C)$
c. *Hence*: $some(A \cap C, B)$

Now, Barwise and Cooper (1981, Appendix C) noted that if Q is right increasing, this pattern is always valid, and *more than 90 percent of the* is indeed right increasing. Further, Peters and Westerståhl (2006, ch. 5.8) showed that the pattern actually *characterizes* that property: A CONSERV quantifier Q is right

[17] But one can also make a logical study of syllogistic languages, extended with names, transitive verbs, adjectives, etc. In a series of papers Larry Moss has pursued this (see, e.g., Pratt-Hartmann and Moss, 2009; Moss, 2010), with particular attention to formats for (complete) axiomatization, and how far these fragments of first-order logic can remain *decidable*, unlike *FO* itself. (39) is a variant of an example mentioned in Pratt-Hartmann and Moss (2009); this form of reasoning is treated in detail in Moss (2010).

increasing iff it validates (44). So (43) too turns out to essentially involve monotonicity, but in addition also inner and outer negation.

For determiners, right monotonicity is much more common than the left variant. Indeed, Westerståhl (1989) showed that over finite universes, each left monotone CONSERV, EXT, and ISOM quantifier is first-order definable, which entails that there are countably many such quantifiers, whereas there are uncountably many right monotone quantifiers with the same properties. And van Benthem (1984) showed that under these conditions plus a natural non-triviality requirement, the only *doubly* (both left and right) monotone quantifiers are the four ones in *square*(*all*). Moreover, Barwise and Cooper (1981) proposed as one of their *monotonicity universals* that every Det denotation which is left monotone is also right monotone, a generalization which seems to be borne out by the facts.

There is another monotonicity observation worth mentioning. Almost all right increasing Det denotations in fact have a stronger property, called *smoothness*.[18]

It is actually a combination of two weaker *left* monotonicity properties, one increasing and one decreasing. Recall that Q is left decreasing when $Q(A, B)$ is preserved if A is decreased. The weaker property is: $Q(A, B)$ is preserved if A is decreased *outside* B. That is, if $A' \subseteq A$ but $A \cap B = A' \cap B$, then $Q(A', B)$. For lack of a better name, I will say that Q is *left outside decreasing*. Likewise, while Q being left increasing means that $Q(A, B)$ is preserved if A is increased, the weaker property of being *left inside increasing* is that $Q(A, B)$ is preserved if A is increased *inside* B, i.e., so that $A - B = A' - B$. Q is *smooth* iff it is left outside decreasing *and* left inside increasing. It is fairly straightforward to show that if a CONSERV Q is smooth, it is right increasing, but the converse is far from true. However, most common right increasing Det denotations are in fact smooth; for example, right increasing numerical quantifiers (Boolean combinations of *at least n*), right increasing proportional quantifiers (such as *at least m/nths of the*), and right increasing possessive quantifiers (see Section 7.10).[19]

The following inference illustrates the property of being left outside decreasing (given that only men can join the men's soccer team), without being left monotone:

(45) a. At least one-third of the students joined the men's soccer team
b. *Hence*: At least one-third of the male students joined the men's soccer team

From a logical point of view, the two right monotonicity properties, plus the two properties constituting smoothness, plus two obvious variants of these – *left outside increasing*, and *left inside decreasing*, respectively – are the

[18] In Peters and Westerståhl (2006). It was first identified under the name of *continuity* in van Benthem (1986).

[19] Most but not all: quantifiers requiring that $|A|$ is not decreased, like those of the form *at least k of the n (or more)*, are exceptions.

basic six monotonicity properties: all others, like smoothness and left monotonicity, are combinations of these. Furthermore, properties that one would have thought have nothing to do with monotonicity result from combining them. I end this section with the following slightly surprising fact (the proof is not difficult; see Peters and Westerståhl, 2006, ch. 5.5):

Fact 7.7.1 *A* CONSERV *quantifier Q is symmetric (i.e., $Q_M(A, B)$ implies $Q_M(B, A)$ for all M and all $A, B \subseteq M$) if and only if it is both left outside decreasing and left outside increasing.*

Already Aristotle noted that *some* and *no* are symmetric ("convertible"), in contrast with *all* and *not all*. However, inferences illustrating this, such as in (46), were not part of the syllogistic, which as we saw dealt with right and left monotonicity.

(46) No fish are mammals
―――――――――――
No mammals are fish

7.8 Symmetry and existential there sentences

Many Dets besides `some` and `no` denote symmetric (SYMM) quantifiers, for example, `at least five`, `no more than seven`, `between three and nine`, `finitely many`, `an odd number of`, `no ... but Mary`. And many others are *co-symmetric*, meaning that their inner negation is symmetric; `every`, `all but five`, `all ... except John`. (Co-)symmetry is preserved under conjunction and disjunction, and if Q is symmetric, so is $\neg Q$, whereas $Q\neg$ and Q^d are co-symmetric. Quantifiers that are neither symmetric nor co-symmetric are, for example, proportionals like *most*, *fewer than one-third of the*, definites like *the ten*, and possessives like *Mary's* and *some student's*.

Another formulation of symmetry is the following (Keenan): Q is *intersective* if the truth value of $Q_M(A, B)$ depends only on the set $A \cap B$, that is (assuming EXT in what follows, for simplicity),

(INT) If $A \cap B = A' \cap B'$, then $Q(A, B) \Leftrightarrow Q(A', B')$.

We have the following fact:

Fact 7.8.1 *If Q is* CONSERV, *the following are equivalent:*

a. *Q is symmetric.*
b. *Q is intersective.*
c. $Q(A, B) \Leftrightarrow Q(A \cap B, A \cap B)$[20]

[20] *Proof*: $a \Rightarrow c$: Suppressing the universe M for simplicity, we have: $Q(A, B) \Leftrightarrow Q(A, A \cap B)$ (CONSERV) $\Leftrightarrow Q(A \cap B, A)$ (SYMM) $\Leftrightarrow Q(A \cap B, A \cap B)$ (CONSERV). $c \Rightarrow b$: Immediate. $b \Rightarrow a$: Since $A \cap B = B \cap A$ it follows by INT (with $A' = B$ and $B' = A$) that $Q(A, B) \Rightarrow Q(B, A)$.

In fact, all the above examples of symmetric/intersective quantifiers, except *no ... but Mary*, have the stronger property of being what Keenan calls *cardinal*: $Q(A, B)$ depends only on the number of elements in $A \cap B$, i.e., only on $|A \cap B|$.

One reason to be interested in symmetry is that it seems to be tied to the analysis of so-called *existential there* sentences. Compare the following.

(47) a. There is a cat here.
b. *There are most cats here.
c. There are no signatures on these documents.
d. *There are the signatures on these documents.
e. There are over a hundred religions.
f. *There are more than 75 percent of the religions.
g. There are ten people coming.
h. *There are the ten people coming.

The form is given in (48).

(48) `there be` [pivot NP] ([coda])

In more semantic terms, the form is as follows:

(49) `there be` $Q\,A\,(B)$

In (47), the optional *coda* is present in (47a), (47b) and (47g), (47h). But not all the sentences are well-formed. A classical issue in linguistics is to characterize the ones that are. An early idea is that *definite* NPs (or Dets) are ruled out. The notion of definiteness is another can of worms (see Section 7.9), but one can see that it cannot provide the whole explanation, since `most cats` and `more than 75 percent of the religions` are in no sense definite. Milsark (1977) concluded that the acceptable pivot NPs were not quantifiers but "cardinality words", and that putting genuinely quantified NPs there would result in a "double quantification", since `there be` already expresses quantification, which would be uninterpretable.

This was an attempt at a *semantic* explanation of existential there acceptability, though not in terms of precise truth conditions. Keenan (1987) gave a precise compositional account, inspired by some of Milsark's insights, but rejecting both the idea that acceptable pivot NPs are not quantified and that `there be` expresses quantification. Instead, acceptability turns, according to Keenan, on a model-theoretic *property* of quantifiers.

In fact, Keenan's analysis was proposed as an alternative to another celebrated semantic (and pragmatic) account of existential acceptability: the one in Barwise and Cooper (1981) in terms of so-called *weak* and *strong* quantifiers. (These terms were used by Milsark, but Barwise and Cooper redefined them.) A detailed comparison of the two approaches, in theoretical as well as empirical respects, is given in Peters and Westerståhl (2006, ch. 6.3). Here I will only outline the main points in Keenan's proposal.

The natural meaning of a sentence of the form (48) or (49) *without* a coda, like (47c) and (47e), is

$$Q_M(A, M)$$

This can be read as "Q^A exist". So existence is not quantification but the predicate *exist*, whose extension is the universe M. When a coda is present, as in (47a) and (47g), it is equally clear that the reading is as in (50).

(50) $Q_M(A \cap B, M)$

This is the intended *existential reading* of (acceptable) existential there sentences. Now, *prima facie* it is not trivial to obtain this reading by a compositional analysis of (48). Keenan's idea is that the compositional analysis always yields the following:

(51) $(Q^A)_M(B)$, i.e., $Q_M(A, B)$

Then he stipulates that the acceptable quantifiers are exactly those for which these two are equivalent:

(52) $Q_M(A, B) \Leftrightarrow Q_M(A \cap B, M)$

It readily follows from Fact 7.8.1, however, that under Conserv, Q satisfies (52) if and only if Q is symmetric (intersective). So it is *symmetry*, according to this proposal, that characterizes the Dets of the quantified pivot NPs that can appear in existential there sentences. Furthermore, this is not just a generalization from empirical data. It comes out of a natural compositional analysis, with the result that exactly for symmetric quantifiers do we obtain the intended existential reading.

Note that Milsark's "cardinality words" denote cardinal quantifiers, which are all symmetric, but a non-Isom symmetric quantifier like *no . . . except Mary* is also acceptable:

(53) There is no graduate student except Mary present.

On the other hand, proportional quantifiers like *most*, co-symmetric quantifiers like *every* and *all but seven*, and definites like *the ten* are all ruled out, as they should be. In general, it is rather striking how well this simple model-theoretic criterion fits our intuitions about the meaning of existential there sentences.[21]

[21] Which is not to say that the analysis is unproblematic. Peters and Westerståhl (2006) discuss the following problems with Keenan's proposal: (i) It gives wrong predictions for proportional readings of `many` and `few`, which seem to be fine in existential there sentences; (ii) It assigns meanings to existential there sentences with non-symmetric Dets that these sentences do not have; (iii) If not emended, it gives wrong results for complex pivot NPs like `at least two of the five supervisors`, `several people's ideas`, which, although not symmetric, actually do occur (with the existential reading) in existential there sentences.

7.9 Definites

I have already used the common label *definite* for Dets like `the ten` (and correspondingly NPs like `the ten boys`). So what is definiteness? This is something linguists still debate, and overviews such as Abbott (2004) will present proposals, counter-examples, new proposals, and so on but no final definition. As Barbara Abbott concludes her survey paper: "As so frequently seems to be the case, grammar is willfully resistant to attempts at tidy categorization." My aim in this brief section is not to offer a new proposal, only to see to what extent GQ theory may help.

The above quote indicates that definiteness is a morphosyntactic category. Even so there might be a semantic and even model-theoretic *correlate*. But if there is no definition of morphosyntactic definiteness, it is hard to even start looking for such a correlate. There are clear cases – `John, the ten boys` are definite, `a tall man` is indefinite – but no definition. The most common *criterion* used is, in fact, unacceptability in existential there sentences. Could we use that as a definition? Then, assuming Keenan's analysis of these sentences to be largely correct, we *would* have a nice model-theoretic counterpart: non-symmetry.

However, presumably no semanticist would accept that as a definition. For example, it would make the Det `most` definite, which few think it is. The criterion only works in some cases. Moreover, it is hardly syntactic. Consider the sentence in (54):

(54) There is the problem of cockroaches escaping.

This is fine as a follow-up to `Housing cockroaches in captivity poses two main problems`, only *not in its existential reading*. So to get the right result – that `the problem of cockroaches escaping` is definite – we need to appeal to meaning after all.

Even if there is a fairly robust concept of purely *morphosyntactic definiteness* – one syntacticians recognize when they see it – there are also notions of definiteness that rely on the *meanings* of Dets and NPs. Most commonly, these are expressed in terms of *familiarity* and *uniqueness*. Familiarity is the idea that definite NPs refer back to something already existing in the discourse, whereas indefinites introduce new referents. Uniqueness is that there is a unique thing (in some sense) referred to by definite NPs.

Familiarity is a problematic criterion. To identify the things that are *available*, or *salient*, in the discourse universe is notoriously a pragmatic affair. Consider the variants in the sentences in (55).

(55) A woman came into the room and sat down. A cat jumped up in her lap/?on her books/??on her car.

We can easily see which variants are more easily interpretable, even if only the woman herself was explicitly introduced in the discourse, but what are the precise conditions?

Uniqueness seems more promising – if we drop the restriction to singular NPs and allow reference to sets or groups as well. Suppose you ask whether `most cats` is definite or not. We cannot even begin to apply the familiarity criterion, since there is no reasonable sense in which this NP introduces anything. But precisely for that reason, it fails to satisfy uniqueness.

Even if we grant a notion of, say, *pragmatic definiteness*, it seems clear that we also want a *semantic* notion. After all, none of the three variants of (55) is ungrammatical or meaningless. There is no semantic difference between `her lap`, `her books`, and `her car`, with respect to definiteness; all differences come from the surrounding discourse. So what is it about these three NPs that makes them (semantically) definite, in contrast with `most cats`? The answer seems simple: They are *referring expressions*.

Recall that we interpret NPs, on a given universe, as sets of subsets of that universe. In what way can we get *reference* out of such a set of subsets? If we include plural reference, that is, reference to a collection or set of individuals, then GQ theory has a precise proposal, first made in Barwise and Cooper (1981):

> A type $\langle 1, 1\rangle$ quantifier Q is (semantically) *definite* iff for each M and each $A \subseteq M$, either $(Q^A)_M$ is empty,[22] or there is a non-empty set $X \subseteq M$ such that $(Q^A)_M$ is the filter generated by X, i.e. $(Q^A)_M = \{B \subseteq M : X \subseteq B\}$.

Accordingly, a Det is (semantically) definite if it denotes a definite quantifier, in which case also NPs of the form [Det N], and their denotations, are definite. And we can extend the definition in an obvious way to non-quantified NP denotations, allowing us to call, for example, Montagovian individuals definite.

Note first that the definition has a local character: in principle it would allow different generator sets X on different universes. However, Peters and Westerståhl (2006, Proposition 4.10) prove that if Q is Conserv, Ext, and definite, then $(Q^A)_M$ is generated by the *same* set whenever it is non-empty. And this is what allows us to regard Q^A as referring: if it refers at all, it refers to that generator. Put differently, when $(Q^A)_M$ refers, it refers to $\cap(Q^A)_M$.

For example, `the ten` is definite. If $|A| \neq 10$, $(\textit{the ten}^A)_M$ is empty, i.e., $\textit{the ten}_M(A, B)$ is false for all $B \subseteq M$. If there are just five boys (in the discourse universe), then `the ten boys` doesn't refer to anything. But if $|A| = 10$, $(\textit{the ten}^A)_M$ is generated by A. A definite NP doesn't always refer, but it is *able*

[22] Barwise and Cooper instead treat $(Q^A)_M$ as *undefined* in this case, in order to capture the idea that the existence of a generator is a *presupposition*. This plays a role in their account of existential *there*-sentences, but not for what I will have to say here about definiteness. (See Peters and Westerståhl, 2006, chapters 4.6 and 6.3, for discussion.)

to refer under the right circumstances. `Mary's books` is definite (on the universal interpretation; see the next section): it refers whenever Mary "possesses" at least one book, and then it refers to the set of books she "possesses". We get reference to single objects as reference to singletons: I_a is definite, and if $a \in M$, $(I_a)_M$ is generated by $\{a\}$.

However, `every`, `all` are not definite, which seems according to intuition: `all students` doesn't refer to the set of students any more than `three students` or `most students` does. The reason is that $all(\varnothing, B)$ is true for every B, so for $A = \varnothing$, there is no *non-empty* set generating $(Q^A)_M = \mathcal{P}(M)$.[23]

If we distinguish different notions of definiteness, we should expect them to overlap but not coincide. For example, some NPs are semantically indefinite but morphosyntactically definite:

(56) the inventor of a new drug, the manuscripts of some professors

(These are sometimes called *weak definites*; see Poesio, 1994). The difference between pragmatic and semantic definiteness seems to run deeper, in that it involves the very notion of meaning appealed to. If one thinks that the meaning of `the ten boys` or `Mary's books` *in itself* carries a familiarity condition (as one does in *dynamic semantics*; see, e.g., Asher, Chapter 4 and Dekker, 2012; Yalcin, 2012b for overviews), then that is not captured in the GQ account of Dets and NPs. But the semantic notion is unique in that it has (a) a clear intuitive content in terms of reference, and (b) a precise model-theoretic counterpart.[24]

7.10 Possessives

I end by considering how GQ theory can be applied to the semantics of the rich and productive class of *possessive NPs*, as exemplified in (57).

[23] If we define *all with existential import* as the quantifier $all_{ei}(A, B)$ iff $\varnothing \neq A \subseteq B$, then all_{ei} is definite. Many linguists seem to think that `all` means all_{ei} in English; I prefer to regard the fact that it is often *odd to say* `All A are B`, when (we know that) A is empty, as pragmatic rather than semantic. And the conclusion that `all A` is definite, in the semantic sense of referring to A, seems rather unwelcome.

[24] So one would think that the semantic notion would be fairly undisputed, but in fact it is often criticized by linguists (see, e.g., Abbott, 2004). Most of this criticism, however, concerns Barwise and Cooper's treatment of existential *there*-sentences in terms of their notions of strong and weak Dets. That treatment can indeed be disputed, as Keenan (1987) did, but is an entirely different matter (Keenan had no objections to their concept of definiteness). We already found reasons to doubt that unacceptability in existential *there*-sentences amounts to definiteness. For example, most theorists regard `all A` as non-definite, in any of the senses we have mentioned, but it is unacceptable in such sentences. Indeed, `all A` is strong in Barwise and Cooper's sense, but not semantically definite. A more pertinent criticism concerns the fact (recognized by Barwise and Cooper) that `both` and `the two` denote the same generalized quantifier, but only `the two` can occur in partitives: `one of the two/*both men`. Ladusaw (1982) concludes that `both` is not definite, arguing that it does not refer to a unique group. In any case, this single example apart, Barwise and Cooper's definition covers a vast number of Dets (and NPs) that are indisputably semantically definite.

(57) a. Mary's books, my sisters
b. several students' bicycles, each woman's parents
c. most of Mary's books, none of my sisters
d. two of most students' term papers, exactly one of each woman's parents[25]

Here (57a) and (57b) consist of a *possessor NP* + `'s` followed by a noun, so we can take [NP 's] to be a *possessive determiner*, interpretable as a (Conserv and Ext, but not Isom) type ⟨1, 1⟩ quantifier. Possessive NPs denote type ⟨1⟩ quantifiers, just as other NPs. In (57c) and (57d) they are preceded by [Det of], and the whole phrase can be seen as a possessive NP.[26]

However, there is no standard application of GQs to the semantics of possessives. The vast linguistic literature on possessives mostly focuses on a small portion of the full class of possessive NPs, like those in (58).

(58) Mary's brother, John's portrait, my book, the table's leg, *the leg's table, God's love

Here the possessor NP is a proper name or a pronoun or a simple singular definite, and where the noun is in the singular.[27]

For these, one might think, GQ theory is of little relevance. But, (a) if possible, a uniform semantics for the whole spectrum of possessive Dets and NPs would surely be preferable, and (b) the study of the various quantified cases turns out to shed light also on the simpler ones. GQ theory does have good things to offer the analysis of possessives, only they are not yet in the semanticist's standard toolbox.

"Possessiveness" is here taken to consist in a certain syntactic form with a certain kind of meaning. This may seem somewhat stipulative, but in fact the class thus delineated is quite natural. It means, however, that some things often called "possessive" are not included. One example is constructions with `have`, `belong`, `own`:

(59) a. Many paintings that John has are quite valuable.
b. Three books belonging to Mary are lying on the sideboard.

These are quite ordinary constructions, with a transitive verb that happens to indicate ownership or some similar relation. Apart from that, they are not different from, say, the following sentences:

[25] This section sketches parts of the account of the semantics of possessive in Peters and Westerståhl (2013).

[26] Many theorists would not call the expressions in (57c) and (57d) possessive but *partitive*. But given that the NP in a partitive of the form [Det of NP] is supposed to be definite (cf. footnote 24), we see directly that the NPs in (57d) are not partitive. Still, they are perfectly meaningful, and their meaning is given by the semantics for possessive NPs sketched here.

[27] The main exceptions are Keenan and Stavi (1986) and Barker (1995). Keenan and Stavi were the first to emphasize the wide variety of possessive Dets. Barker gave a systematic treatment of a subclass (those of the form exemplified in (57a) and (57b)), related to but distinct from the semantics proposed here.

(60) a. Many paintings that John bought are quite valuable.
b. Three books written by Mary are lying on the sideboard.

Possessive NPs always involve a *possessive relation*, holding between *possessors* and *possessions*. But not much hangs on which particular relation it happens to be. In particular, it need not have anything to do with ownership or possession. For example, `Mary's books` can be the books she owns, or bought, or read, or wrote, or designed, or is standing on to reach the upper shelf. Often the possessive relation comes from a relational noun, as in `Henry's sisters`, `my students`, `Susan's enemies`; again nothing to do with possession in the literal sense. But in (59) the characteristic syntax of possessives is missing. Note, by the way, that in this case there are logically equivalent sentences which do involve possessive NPs:

(61) a. Many of John's paintings are quite valuable.
b. Three of Mary's books are lying on the sideboard.

However, that does not make (59) possessive.

Freedom of the possessive relation is one of the characteristic features of possessives. The freedom involved in cases like `Mary's books` is well known, but the possessive relation is free also with relational nouns. That is, although it often comes from the relational noun (as the *inverse* of the relation expressed by the noun), it does not have to. `Henry's sisters` can be the sisters (of someone else) that he was selected to escort. `Ruth's mothers` usually *has to* involve a relation other than the inverse of "mother-of". The point is, however common a default selection of the possessive relation might be, there are *always* circumstances under which a different relation, coming from the context and unrelated to the linguistic co-text, is chosen.[28]

Perhaps the most important characteristic of possessives is that they always *quantify over possessions*. Often the quantification is universal, but it can also be existential. Consider the sentences below.

(62) a. The teacher confiscated three children's paint sprayers.
b. The teacher confiscated three children's paint sprayers hidden around in bushes near the school.

(63) a. Mary's dogs escaped.
b. When Mary's dogs escape, her neighbors usually bring them back.

The most natural reading of (62a) has the teacher confiscating *every* paint sprayer of each of the three children. But in (62b) the most plausible reading is existential. There are three children who had paint sprayers and for whom the teacher discovered at least *some* of the child's paint sprayers in

[28] This criterion allows us to distinguish gerundive nominals, as in (i), from possessives:

(i) John's not remembering her name annoyed Mary.

Here the relation is completely fixed.

the bushes. Similarly for the sentences in (63). Other sentences, such as in (64), are ambiguous:

(64) Most cars' tires were slashed.

This has a reading where there is a set with more than half of the (salient) cars such that every car in this set has all its tires slashed, and another, perhaps more natural, where each of these cars had some tire slashed.

Now, these readings can be made explicit as follows:

(65) a. All of Mary's dogs escaped.
b. When some of Mary's dogs escape, her neighbors usually bring them back.

Furthermore, when the quantification over possessions is explicit, it can be (almost) *any* quantifier:

(66) a. Most of Mary's dogs escaped.
b. When two of Mary's dogs escape, her neighbors usually bring them back.

These contain possessive NPs as in (57c) and (57d). Whether implicit or explicit, quantification over possessions is always there.

Since possessor NPs can also be quantified, many possessive NPs (perhaps all, if, e.g., you treat proper names as quantifiers) are *doubly quantified*. This has several consequences that GQ theory helps illuminate. To state some of them, it is convenient to spell out uniform truth conditions for sentences involving possessive NPs. In the most general case, such a sentence has the form in (67).

(67) (Q_2 of) Q_1 C's A are B

Here Q_2 quantifies over possessions; it may be implicit but Q_2 is always part of the semantics. Q_1 quantifies over possessors. We define an operation *Poss*, taking two type $\langle 1, 1\rangle$ quantifiers, a set C, and a binary relation R (the possessive relation) as arguments, and returning a type $\langle 1, 1\rangle$ quantifier as value. To state the definition, the following abbreviations are convenient. First, for any a,

$$R_a = \{b : R(a, b)\}$$

is the set of things "possessed" by a. Second, for any set A,

$$\mathrm{Dom}_A(R) = \{a : A \cap R_a \neq \varnothing\}$$

is the set of a which "possess" things in A. Now we can define *Poss* as follows:[29]

[29] I suppress the universe M; this is harmless, since one can show that if Q_1 and Q_2 are Conserv and Ext, so is $Poss(Q_1, C, Q_2, R)$.

(68) $Poss(Q_1,C,Q_2,R)(A,B) \Leftrightarrow Q_1(C \cap \mathrm{Dom}_A(R), \{a : Q_2(A \cap R_a,B)\})$

The right-hand side of (68) expresses the truth conditions of (67).[30]

Indeed, in a compositional analysis, one may take *Poss* to be the denotation of the possessive morpheme `'s`, and $Poss(Q_1,C,Q_2,R)^A$ as the denotation of the possessive NP. When Q_2 is implicit, it has to be provided by the context. Moreover, the idea of freedom entails that for all sentences of the form (67), there are situations where R has to be supplied by context, even if A comes from a relational noun.[31] For example, consider (69):

(69) Some of at least three students' library books are overdue.

Applying (68) to this example yields the interpretation that at least three (Q_1) students (C) who borrowed (R, the most natural possessive relation here) library books (A) are such that at least one (Q_2) of the library books they had borrowed is overdue (B). This seems correct.

Notice that the phrase `who borrowed library books`, which comes from the restriction of C to $\mathrm{Dom}_A(R)$ in (68), is unnecessary: the truth conditions in this case are as follows:

$$|\{a \in C : A \cap R_a \cap B \neq \varnothing\}| \geq 3$$

Whether (69) quantifies over students who borrowed library books or students in general is therefore irrelevant. But this is not always the case. Consider the sentence in (70)

(70) Most people's grandchildren love them.

This is probably true, but note that most people in the world don't have any grandchildren (they are too young for that). But this fact has nothing to do with the truth value of (70). The quantifier *most* (Q_1) indeed quantifies only over "possessors", i.e. over people who have grandchildren, saying that most of *these* are such that their grandchildren love them. This is why (68) in general *narrows* C to $\mathrm{Dom}_A(R)$.

The term *narrowing* is from Barker (1995), who argued that narrowing is always in place. I tend to agree, though counter-examples have been suggested. It can be shown that for *symmetric* Q_1, as in (69), narrowing has no effect, which explains why its presence is often not felt. But for non-symmetric Dets like `every` and `most`, it has a clear semantic effect. For

[30] We also have to account for the semantics of non-quantified possessive Dets such as `Mary's`. This can be done by decomposing the quantifier I_m as $all_{ei}^{\{m\}}$ and then applying (68). This gives the right truth conditions (for the universal reading), but one problem is that the decomposition is not unique: we also have $I_m = all^{\{m\}}$, and this decomposition gives `Mary's friends are nice` rather odd truth conditions: either Mary has no friends or all of her friends are nice. It also raises the question of whether all non-quantified possessive NPs are decomposable. Both issues are dealt with at length in Peters and Westerståhl (2013).

[31] If A comes from, say, `parent`, A is the set of parents, i.e., the set of individuals standing in the parent-of relation to something, and R is the *inverse* of the parent-of relation.

example, without narrowing, (70), would be made trivially false (with $Q_2 =$ *all*) by the fact that most people have no grandchildren.[32]

Here is an application of the uniform truth conditions. In the literature, possessiveness is usually tied to *definiteness*. As Abbott (2004) says, "Possessive determiners ... are almost universally held to be definite" (p. 123). A more nuanced view, originating with Jackendoff, is put forth in Barker (2011): possessive NPs *inherit* definiteness from their possessor NPs. Since we have precise truth conditions for possessives as well as definites (Section 7.9), we can find out what the facts are. Peters and Westerståhl (2006, ch. 7.11) prove the following.

Fact 7.10.1 *If Q_1 is semantically definite and Q_2 is universal, then, for all C and R, $Poss(Q_1,C,Q_2,R)$ is semantically definite. Also, in practically all cases when Q_1 is not definite, or Q_2 is not universal, $Poss(Q_1,C,Q_2,R)$ is not definite.*

So we see that in general, there is no reason to expect possessive Dets or NPs to be semantically definite. Even a simple phrase like `Mary's dogs` is only definite under the universal reading. Further, Fact 7.10.1 shows what is right about the Jackendoff/Barker inheritance claim, but also what is wrong: the definiteness of the possessor NP is not inherited when quantification over possessions is not universal. Consider (63b) again

(63b) When Mary's dogs escape, her neighbors usually bring them back.

Here `Mary's dogs` is not semantically definite: the possessive NP does not refer to any particular set of dogs.

Another illustration of the potential of model-theoretic semantics to clarify important issues concerning the semantics of possessives is afforded by the monotonicity behavior of possessive Dets and NPs. This behavior is quite interesting, but to study it one needs precise truth conditions like those in (68) (see Peters and Westerståhl, 2006, ch. 7.12). I will end, however, with a different illustration: the meaning of *negated* sentences with possessive NPs.

To begin, inner and outer negation (Section 7.6) applies to possessive Dets just as to all other Dets, and it is easy to check that the following holds:

Fact 7.10.2

(a) $\neg Poss(Q_1, C, Q_2, R) = Poss(\neg Q_1, C, Q_2, R)$
(b) $Poss(Q_1, C, Q_2, R)\neg = Poss(Q_1, C, Q_2\neg, R)$
(c) $Poss(Q_1\neg, C, \neg Q_2, R) = Poss(Q_1, C, Q_2, R)$

[32] Peters and Westerståhl (2013) show that the only reasonable non-narrowed version of the truth conditions is as follows:

(i) $Poss^{w}(Q_1,C,Q_2,R)(A,B) \Leftrightarrow Q_1(C, \{a : A \cap R_a \neq \varnothing \;\&\; Q_2(A \cap R_a, B)\})$

So if most $a \in C$ are such that $A \cap R_a$ is empty, (i) makes (70) false with $Q_1 = most$ and $Q_2 = all$.

For example:

(71) Not everyone's needs can be satisfied with standard products.

This seems to be a case of outer negation: it says that at least someone's needs cannot be thus satisfied. On the other hand, consider the sentence below:

(72) Mary's sisters didn't show up at the reception.

Here Q_2 is naturally taken as universal, and the sentence says that none of the sisters showed up; this is inner negation ($all\neg = no$).

However, if we make Q_2 explicit, as in (73), there is another interpretation, which is neither outer nor inner negation.

(73) All of Mary's sisters didn't show up at the reception.

That is, not all the sisters showed up (but some of them may have). This possibility is not covered in Fact 7.10.2. But given that we have *two* quantifiers and *two* types of negation, the combination is natural enough. Let us call it *middle negation*:

$$\neg^m Poss(Q_1, C, Q_2, R) =_{\mathsf{def}} Poss(Q_1, C, \neg Q_2, R)$$

It follows from Fact 7.10.2(c) that $\neg^m Poss(Q_1, C, Q_2, R)$ is also equal to $Poss(Q_1\neg, C, Q_2, R)$. Westerståhl (2012) shows that possessive Dets, in view of these three types of negation, span a *cube*, rather than a square, of opposition. There is much more to say on this subject, but I leave it here, noting only that the study of how negation interacts with possessives would hardly have been possible without the GQ tools at our disposal.

7.11 Conclusions

The purpose of this chapter has been to illustrate how tools from generalized quantifiers in model theory can contribute to our understanding of the semantics of quantification in natural languages, which in English is carried out mostly by means of determiners and noun phrases. I have chosen, except perhaps in the preceding section, tools that are by now more or less standard in formal semantics. There are many applications of GQ theory to natural language quantification I did not touch upon, most notably the use of polyadic quantifiers, for example in reciprocal sentences, and questions concerning the logical expressive power of various quantifiers. And I said nothing about processing quantified expressions.

Note also that I have not been trying to convey the impression that GQ theory can account for every feature of natural language quantification. So far it has little to say, for example, about the inner composition of determiners (treating, e.g., `more than two-thirds of the` as an unanalyzed Det), or about meaning distinctions "below" the level of generalized quantifiers.[33] However, I hope that the illustrations given here provide some feeling for the amazing ease with which the tools of GQ theory, invented for mathematical logic purposes, can be used for the semantics of ordinary language.

[33] Such as the distinction between `both` and `the two` (footnote 24), or between `at least two` and `more than one`: cf. Hackl (2000):

(i) a. At least two men shook hands.
    b. #More than one man shook hands.

Szabolcsi (2010) presents a number of such challenges for GQ theory, or for going beyond (without abandoning) GQ theory in the linguistic analysis of quantification.

8

Indefinites

Adrian Brasoveanu and Donka F. Farkas

8.1 Introduction

Work on the semantics and pragmatics of indefinite nominals has grown in the last thirty years to form a subfield of its own within the already focused field of nominal semantics. In this area of study, clearly circumscribing the domain of inquiry amounts to giving a theory of its object. Defining indefinites, therefore, cannot be a first step in a chapter like the present one, whose aim is to provide an overview of some of the solutions developed to the semantic and pragmatic problems they raise. Instead of attempting a definition of indefinites, then, we begin with a quick empirical tour of the type of nominals that are uncontroversially or arguably indefinite, after which we outline the issues the rest of the chapter focuses on.

As a first step, we can divide determiner phrases (DPs) into definite and indefinite based on whether they are headed by a definite or an indefinite D(eterminer). In English then, the expressions in (1) count as indefinite while those in (2) count as definite.

(1) Mary visited *a garden, some garden(s), some of the gardens, a certain garden*.

(2) Maurice visited *the / this garden, these gardens / the capital of Albania / the largest museum in the world*.

Within formal semantics, rooted in Aristotelian logic, the italicized DPs in these examples share the interpretive property of being existential, a property that distinguishes them from universal DPs such as *every garden* or *each garden*. Definite existentials are distinguished from their indefinite sisters in that their referent is supposed to be uniquely identified somehow, either because it is familiar or unique in context, or because it is inherently unique.

Classifying further types of nominals as definite or indefinite is intimately connected with analytic choices. Staying again with English, the italicized nominals below are uncontroversially accepted among the indefinite group even though *this* is a definite D and the plural in (4) is bare.

(3) We visited *this splendid garden in Suzhou* that was offered to a Chinese scholar by his disciples.

(4) Muriel visited *gardens* when she traveled to France this summer.

This classification is based on the fact that these DPs share the interpretive properties characteristic of uncontroversial indefinites in (1). Thus, the referent of the DP in (3) is assumed to be novel relative to the interlocutor and thus not uniquely identifiable in context. Similarly, in (4), the interpretation of the bare plural is existential and its referent is not uniquely identifiable.[1]

Next, note that the class of uncontroversial indefinites is heterogeneous. We illustrate with some differences in distribution. What we refer to here as an u(nmarked)-indefinite, i.e., a DP whose D is *a(n)*, may occur in an argument position with an ordinary existential interpretation, as in (5), or with a generic interpretation, as in (6), or it may occur in a predicative position, as in (7):

(5) Susan visited *a garden*.

(6) *A madrigal* is polyphonic.

(7) This is *a madrigal*.

Bare plurals in English have predicative and generic-like uses as well, as exemplified in (8) below, but the other indefinite DPs in (1) do not, as shown in (9) and (10), where the stars mark attempted readings in which the italicized DP is generic or predicative.

(8) *Madrigals* are polyphonic. / These are *madrigals*.

(9) **A certain* / **Some madrigal* is polyphonic.

(10) *These are *some madrigals*.

We briefly mention two controversial cases of DPs that are sometimes, but not always, treated as indefinites: DPs headed by the "free choice" determiner *any* and DPs headed by the negative determiner *no*.

[1] For the earliest work on indefinite *this*, see Prince (1981a) and for a more recent approach Ionin (2006). The classic work on bare plurals is Carlson (1977a,b); see also Carlson and Pelletier (1995).

(11) Max can describe *any garden* in this city.

(12) Pauline visited *no garden* during her trip.

The analytical choice here is between a treatment of the relevant DPs as indefinite existentials interpreted within the scope of a quantificational operator or simply as quantificational DPs. Thus, *any garden* can be treated as an indefinite existential interpreted within the scope of the modal *can* or as a wide-scope universal that must have a modal in its scope. Similarly, *no garden* can be treated as an existential within the scope of an implicit sentential negation operator or as a negative quantifier. The choice between analyses is guided by a complex web of theoretical considerations and empirical concerns having to do with accounting for distributional restrictions as well as for cross-linguistic patterns.

We will focus here on the uncontroversial indefinites in (1). In the rest of this section we attempt to put in perspective some of the general problems indefinite nominals raise and then turn to the particular concerns we focus on in the rest of the chapter.

The semantic and pragmatic properties of indefinites have driven much of the theorizing in the field in the last thirty years. Consequently, giving a balanced and comprehensive review of the problems they raise is well beyond the scope of this section, or indeed this chapter. Instead, we mention here just some of the issues that have been at the forefront of research in this area.

Indefinites were first systematically studied in formal semantics as a subtype of generalized quantifiers – an approach to nominal semantics rooted in Montague's work and developed in Barwise and Cooper (1981); Keenan and Stavi (1986) (among many others). This approach was successful in capturing the compositional properties common to the syntactic constituents known as NPs (or DPs), such as all the italicized nominals above, as well as *bona fide* quantificational DPs such as *every student* or *most students*. In the generalized quantifier view of DP denotation, the quantifier (or D) expresses a relation between sets, and different quantifiers differ with respect to the (type of) relation they express.

This approach was somewhat less successful, however, in capturing the fine and less fine grained distinctions between types of DPs in such a way as to delineate linguistically natural classes. To differentiate so-called "weak" quantifiers, which arguably form the *indefinite* group, from "strong" ones, one had to resort to properties such as "existential import" and "presupposition" that are not naturally connected to formal properties of generalized quantifiers.

A different line of inquiry is found in Kamp (1981b), Heim (1982), and Kamp and Reyle (1993) – the works that initiated the "dynamic turn" in formal semantics. The starting point of this line of research is the insight in Karttunen (1976) that the main job of indefinite DPs (when in argument position, e.g., *A student left early*) is to introduce a new "discourse referent", while the job of a definite DP is to refer back to an already introduced or otherwise familiar discourse referent. Discourse referents, in this view, are to be understood as theoretical constructs mediating between linguistic expressions and entities in the world.

Early work in dynamic semantics draws a sharp distinction between "existential" DPs and *bona fide* quantificational DPs. In Kamp's work, as well as in Heim (1982, ch. 3), existential DPs (whether definite or indefinite) are treated as free variables and existential force per se is contributed by the interpretive process. Thus, the interpretive effect of existential DPs is simply to update the input assignment function on the variable they introduce.[2]

Bona fide quantificational DPs, on the other hand, have a more complex interpretive effect: they update the input assignment function repeatedly on the variable they introduce by looping through the set of individuals denoted by the sister of the D. For each individual in this set, the assignment resulting from updating the input assignment function with that individual is then used as the input assignment for the interpretation of the remainder of the sentence, that is, for the interpretation of the nuclear scope of the quantificational DP.

Within the tradition of dynamic semantics then, there is a fundamental distinction between definite and indefinite existential DPs on the one hand, and *bona fide* quantificational DPs on the other, with the former being essentially simpler semantically than the latter. This fundamental insight is preserved in much of current work in nominal semantics, in one way or another, and will be assumed in this chapter as well.

Within the class of "existentials", the characterization of the difference between definite and indefinite DPs has wavered between novelty/familiarity theories and uniqueness accounts of various types. Semantically based classifications should treat as definite not only DPs headed by a definite article but also proper names and definite pronouns.[3] We come back to the definite/indefinite divide in Section 8.2 below.

The focus of early work in dynamic semantics was to capture well-known differences between existentials and *bona fide* quantificational DPs, differences that involve scope in various ways. Thus, as exemplified below, (in)definites may have discourse scope, that is, they may serve as antecedents to a definite pronoun in discourse. In contrast, the scope of *bona fide* quantifiers, at least when the anaphoric pronoun is morphologically singular, does not normally extend into the discourse.

(13) A_x *woman* walked in. She_x sat down.

(14) $Every_x$ *woman* in the room stood up. $She_{*x/\checkmark y}$ walked out.

[2] Henceforth, we take the terms *variable* and *discourse referent* to be synonymous.

[3] Note, however, that the existence of weak definites, e.g., Poesio (1994) among others, and various analyses of proper names (see, e.g., Kamp and Reyle, 1993) cast doubt on a clear-cut categorization as definites for certain uses of some DPs on the definite branch.

Another issue that involves scope at the sentential level is the ability of indefinite DPs to bind a pronoun outside the domain that delimits the binding potential of *bona fide* quantifiers. This is exemplified by "donkey sentences" such as (15), discussed by philosophers since medieval times:

(15) Every farmer who owns a_x *donkey* feeds it_x.

Given the configurational properties of (15), the indefinite *a donkey* should not be able to bind the pronoun *it*, and yet this is exactly what happens in the most natural interpretation of this sentence. That *bona fide* quantificational expressions do not have this ability is exemplified in (16), which does not allow an interpretation in which the universal binds the pronoun:

(16) A reporter who liked $every_x$ *actress in this movie* interviewed $her_{*x/\checkmark y}$.

Various versions of dynamic semantics developed over the last thirty years have provided solutions to this pair of problems rooted precisely in the non-quantificational/quantificational distinction mentioned above.

Indefinite DPs have attracted a lot of attention due to another intrasentential scopal property, namely that of being able to take scope freely over operators no matter how deeply embedded under such operators the indefinite might be. Thus, consider the contrast between the two examples below:

(17) Joan wrote to every senator who voted on an important bill.

(18) Joan wrote to a senator who voted on every important bill.

In (17), the indefinite can be interpreted within the scope of the universal, in which case the sentence would be true iff Joan wrote to every senator such that there was an important bill the senator voted for. Here, then, the reference of the indefinite is allowed to covary with the values given to the variable bound by the universal. Example (17) also has an interpretation in which the indefinite scopes outside the universal, in which case the sentence claims that there is some important bill and Joan wrote to every senator who voted for it. Under this interpretation, the reference of the indefinite is fixed relative to that of the universal.

In contrast, (18) is unambiguous: the only possible interpretation it has is one where the indefinite scopes over the universal, and thus where the referent of the indefinite does not covary with that of the universal. Crucially missing is an interpretation where the universal outscopes the indefinite and where such covariation would be allowed. Indefinites, then, have free "upward" scope in their sentence, while the "upward" scope of *bona fide* quantifiers is clause bound.[4]

A popular solution to this problem in static semantics is to treat indefinites as non-quantificational expressions just as in dynamic semantics.

[4] By *upward scope* we mean the ability of an expression e_1 to scope over an expression e_2 in a configuration where e_2 occupies a structurally higher position than e_1.

Their semantics is assumed to involve a choice function which itself is either freely bound by an existential or contextually provided. Early dynamic solutions to this problem are essentially configurational, allowing indefinites to introduce a variable at any level of the discourse representation, a type of freedom not enjoyed by *bona fide* quantifiers. We return to this issue in Section 8.3.

Work on indefinites in the twenty-first century has focused on the differentiation of indefinite DPs within a single language as well as cross-linguistically. Staying within the confines of singular indefinite DPs in English, we should distinguish the versatile u(nmarked)-indefinite, *a garden*, from the motley class of marked indefinites such as *a certain garden*, *some garden*, the use of *this garden* exemplified in (3), *some of these gardens* and arguably *any garden* and *no garden*. If one leaves the confines of English, the variety of indefinite DPs becomes bewildering. It also becomes clear, however, that there are systematic properties that differentiate further subtypes of indefinites.

The following two related questions arise with some urgency from this perspective:

(i) what are the basic parameters that underlie the rich variety of indefinites we find within a language as well as cross-linguistically?
(ii) what is the fine semantics of each subtype of DP?

Answering them should shed light not only on the typology of indefinites but also on the definite/indefinite divide and thus provide a basis for an account of the distribution and interpretation of various subtypes of existentials. While these questions are at the heart of the whole discussion that follows, they are addressed more specifically in Section 8.4. In Section 8.5 we conclude by reviewing some questions that have been answered as well as some that are still open.

8.2 The definite/indefinite divide

In the rest of this chapter we follow the tradition of treating indefinites as a subtype of existential expressions and follow the dynamic tradition in assuming that existential interpretation is essentially different from the interpretive procedure triggered by *bona fide* quantifiers.

Common to all existential DPs (whether definite or not) is that they have existential force. If the existential DP is headed by a D, we assume that the nominal sister of this D denotes a set that functions as the domain from which witnesses are to be found, that is, the domain of possible values for the variable introduced by the DP.[5] Working with First Order Logic (FOL)

[5] Whether the existential force involved is due to the contribution of the D or to default interpretation of free variables is a matter we will not discuss here. Nor do we go into the details of the interaction of indefinites and genericity, since that would require a chapter of its own.

with restricted quantification for the sake of simplicity, the translation of (19) is as in (20), with the restrictor in square brackets and the nuclear scope in round brackets:

(19) A_x woman left.

(20) $\exists x[woman'(x)]\ (leave'(x))$

The variable bound by the existential quantifier is the discourse referent introduced by the D. The interpretation of the expression in the restrictor delimits the domain from which witnesses/values for the variable bound by the quantifier may be chosen. In a dynamic approach, the existential force comes from the definition of truth in a model rather than an explicit existential quantifier.

In the rest of this section, we briefly consider approaches that distinguish definite DPs from indefinites. In doing so, we will concentrate on setting up two parameters across which DPs can differ and which will form the background for the discussion of indefinite DPs in the sections that follow.

Even this minimal setup allows us to distinguish the following two theoretically valuable parameters along which existential expressions can be further refined: (i) further constraints on how the witness is chosen (*witness-choice constraints*) and (ii) further constraints on properties of the domain of the existential (*domain constraints*). Witness-choice constraints have already been invoked when distinguishing existential from *bona fide* quantificational expressions, but further refinements within each type are to be expected. Domain constraints, on the other hand, may target DPs with descriptive content and thus cut across existential and *bona fide* quantificational DPs.

The two main contenders for the property distinguishing definite DPs from indefinite ones exemplify each of these parameters. We will briefly discuss each in turn, but first note that under either view, one can have a symmetric or an asymmetric account of the definite/indefinite contrast. Under the symmetric account, both definites and indefinites are required to obey a constraint – uniqueness/familiarity for definites, non-uniqueness/novelty for indefinites. Under the asymmetric account, definites are required to obey a constraint (uniqueness or familiarity), while indefinites, or at least u-indefinites (unmarked, "ordinary" indefinites like *a garden*), are not constrained in any particular way. We assume here an asymmetric approach, where definites have a special requirement while u-indefinites are, as their name suggests, unmarked.[6] U-indefinites differ from their definite and marked indefinite sisters in that these last two subclasses are indeed subject to further witness choice or domain constraints.

The uniqueness approach to definites is rooted in Russell's work. In essence, it reduces to the requirement that the set denoted by the restrictor

[6] See Farkas (2006) and Abbott and Horn (2012).

of definite descriptions be a singleton for singular definites and maximal for plural ones. Under this view, the DPs in (2), repeated below, are definite because their domain is a singleton either in absolute terms or because of assumed contextual restrictions.

(21) Maurice visited *the / this garden, these gardens / the capital of Albania / the largest museum in the world*.

How to extend this constraint to cover proper names and definite pronouns as well is not obvious given that these DP types do not have a clear domain that can be restricted. Discussing this issue would take us too far afield into the realm of definite DPs, so we simply note that formulated this way, the uniqueness requirement is quite transparently a domain constraint.

The other popular approach to the definite/indefinite distinction is to require the variable introduced by the definite to be familiar relative to its input context. This view, advocated in early dynamic approaches (Karttunen, 1976; Kamp, 1981b; Heim, 1982), can be seen as a witness-choice constraint because it amounts to constraining the way one chooses the value given to the variable introduced by the DP. The familiarity approach is quite natural for definite pronouns and proper names as well as for anaphoric uses of definite descriptions but is problematic when it comes to definite DPs that are unique in virtue of their descriptive content. These DPs are felicitous even in contexts where their referent is not familiar or easily accommodated. In (22), for instance, the definite is appropriate even in a context that does not entail that there is or will be someone who will prove the Riemann hypothesis.

(22) The first person to prove the Riemann hypothesis will be justly famous.

Dynamic semantics allows us to characterize uniqueness in such a way that we can capture the advantages of both approaches sketched above. It rests on a view of context as a set of world-assignment function pairs that satisfy whatever constraints are placed on them by the information contributed by the previous part of the discourse, and by background assumptions. Under this view, the class of definite DPs as a whole can be characterized as imposing the requirement that at the time the input context is updated with the variable introduced by the definite, the set of allowable choices be a singleton. As a result, in the output context, the set of world-assignment function pairs will agree on the value they give to the variable in question.[7]

This version of the uniqueness theory of definites promises to be able to account both for what is common across the class of definite DPs and for capturing finer-grained distinctions between them. Thus, ordinary definite

[7] This constraint can be conceptualized as a "determined reference" constraint requiring there to be no choice with respect to the value of the relevant variable as one goes from the input context to the output context (see Kadmon, 1990; Farkas, 2002b).

descriptions achieve dynamic uniqueness if their domain is singleton relative to the input context. This condition can be met either because the content of the description assures it, as in (22), or, as in most cases, because the context provides a singleton salient domain. In the case of definite pronouns, on the other hand, the constraint is met because of the essential anaphoric requirement on witness choice in their case. Proper names, whether treated as descriptions or as a special type of DP, would fulfill the determined reference requirement in virtue of their semantics.

We will assume, then, that definite DPs require determined reference while u-indefinites do not, and leave open the possibility that special, marked indefinites impose further constraints on their domain or on their witness choice, constraints that may require variation of values across particular sets of world-assignment pairs. We also assume that domain and witness-choice constraints may be part of the non-at-issue meaning of indefinite Ds, just as they are usually taken to be part of non-at-issue meaning for definite Ds. But unlike for definites, where these constraints are usually taken to be presuppositional, the status of the same constraints on indefinites is less clear – it could be presuppositional (e.g., Geurts, 2000), appositive/parenthetical-like (e.g., Wang et al., 2005), and/or postsuppositional (e.g., Farkas, 2002c; Brasoveanu, 2013).

While definites are marked for determined reference, u-indefinites obey no special restrictions. U-indefinites are semantically unmarked because they have the widest distribution and lend themselves to the widest scale of interpretations. The basic property of u-indefinite Ds, then, is that they impose no special interpretive constraint, and as a result DPs headed by them enjoy the widest freedom of scope and interpretation among indefinite DPs. Other languages that are like English in that they rely heavily on articles and exhibit a robust definite/indefinite contrast also have unmarked indefinite determiners: the determiner *egy* in Hungarian, *uno/una* in Spanish and Italian, *un/une* in French, and *un/o* in Romanian. The semantics of u-indefinites may differ in finer details, partly due to differences in the whole D system of each language, but they are always freer in distribution and interpretation than other indefinite Ds the language may have.

The lesson we draw from this brief discussion of the issue is that under the view of definites as marked for determined reference, definiteness is treated as a witness-choice constraint requiring fixed reference. This is a crucial observation for us because in our view, a fundamental distinguishing factor between semantic types of nominals in general and subtypes of indefinites in particular concerns precisely the question of stability vs. variation of values across particular components of the (local) context of semantic evaluation. We will suggest in Section 8.4 that requirements of constancy/stability across particular such sets are essential when it comes to distinguishing among various subtypes of indefinites.

Before discussing marked indefinites, however, we turn in the next section to the problem of the freedom of scope exhibited by u-indefinites. We will see that there too, the issue of stability vs. variation of witness choice across sets of assignment functions plays a crucial role.

8.3 The free scope of indefinites

This section is devoted to the problem of the unlimited upwards scope of indefinites introduced in Section 8.1, a problem that has been at the center of work on indefinites since the early eighties (see Farkas, 1981; Fodor and Sag, 1982; Abusch, 1994a, among many others). We first briefly characterize the problem and then outline two classes of proposed solutions.

8.3.1 The problem of too much freedom

Matters of scope always involve two expressions, e_1 and e_2; e_2 is said to be within the semantic scope of e_1 if the interpretation of e_2 is affected by the semantic contribution of e_1; e_2 is said to be outside the semantic scope of e_1 if its interpretation is unaffected by the semantic contribution of e_1. (See Westerståhl, 1989; Peters and Westerståhl, 2006; Szabolcsi, 2010; Steedman, 2012, for extensive discussion.)

A worthwhile goal to pursue is to attempt to predict scopal relations from independently needed constraints on the semantics of the two expressions involved and the syntactic configuration they occur in. This is what the present section focuses on with respect to u-indefinites in English which, we assume, carry no special extra constraints of any sort and therefore have the freest distribution, scope, and interpretive possibilities. The extent to which other types of existentials behave in a parallel fashion depends on the specific interpretive constraints they impose in addition to the existential force associated with u-indefinites; we will return to this in the following section.

The issue we turn to now, in a nutshell, is that u-indefinites can take scope over any operator in their sentence, independently of what semantic or syntactic material intervenes between the indefinite and that operator – in particular, independently of intervening clausal and even syntactic island boundaries. This unlimited freedom contrasts with the constrained scopal freedom of quantificational Ds such as *every*, *each*, and *most*, the "upward" scope of which is limited to their own clause. The contrast is illustrated below, where determiners are subscripted with the variable they introduce:

(23) a. Amanda bought every$_x$ album that was praised by a$_y$ famous Hungarian photographer.
b. $\forall x[album'(x) \wedge \exists y[fHph'(y)]\ (praise'(y, x))]\ (buy'(a, x))$
c. $\exists y[fHph'(y)]\ (\forall x[album'(x) \wedge praise'(y, x)]\ (buy'(a, x)))$

(24) a. Amanda bought an$_x$ album that was praised by every$_y$ famous Hungarian photographer.
b. $\exists x[album'(x) \wedge \forall y[fHph'(y)]\ (praise'(y, x))]\ (buy'(a, x))$
c. $^*\forall y[fHph'(y)]\ (\exists x[album'(x) \wedge praise'(y, x)]\ (buy'(a, x)))$

In (23a), the indefinite a_y *famous Hungarian photographer* may be inside or outside the scope of *every*$_x$ *album*. If outside, the sentence claims that there is a famous Hungarian photographer (say, Lucien Hervé) such that Amanda bought every album he praised. In this case there is no possible covariation between values given to x and values given to y, and thus the interpretation of the indefinite is not affected by the universal.

If the indefinite is inside the scope of the universal, the sentence claims that Amanda bought every album that has the property that a famous Hungarian photographer or other praised it. Under this reading, covariation between values given to x and values given to y is possible, and Amanda is claimed to have bought a large number of albums – all the albums praised by Kertész, all the albums praised by Moholy-Nagy, all the albums praised by Brassaï, and so on. In this case, the interpretation of the indefinite is affected by the interpretation of the universal: variation in values of the indefinite is made possible precisely because of the presence of the universal.

In contrast, (24a) is scopally unambiguous: its only interpretation is the one that mirrors the surface order of the quantifiers, that is, this sentence can only be interpreted as claiming that there is an album Amanda bought such that every Hungarian photographer praised it. The missing interpretation is the one where the universal were to scope over the indefinite, in which case the sentence would be interpreted as claiming that for every famous Hungarian photographer, there is an album that he/she praised and that Amanda bought.[8] The FOL formulas representing the relevant readings for both examples are given above, with the unavailable interpretation marked by * and with complex nominal restrictions abbreviated.

The fact that universals can take inverse scope over a preceding and c-commanding u-indefinite as long as the two are clause-mates is shown by (25) below. This sentence has two possible interpretations: if the universal takes scope over the indefinite, covariation between representatives and meetings is possible; if the indefinite is outside the scope of the universal, such covariation is ruled out.

(25) A$_x$ representative of our group attended every$_y$ caucus meeting.

The special upward scoping properties illustrated for indefinites in (23a) above carry over to definite DPs such as *the book*, as well as to plural DPs (*the books, some books, three books*), as long as these plurals are interpreted collectively rather than distributively.

[8] The example in (23a) was chosen so that its surface, wide-scope-universal reading entails its inverse, narrow-scope-universal reading – in opposition to the case below:

(i) Every$_x$ student read a$_y$ paper.

The point is to show that an indefinite taking inverse scope over a universal does not always yield a stronger reading, i.e., that it is not possible to maintain that all sentences in which an indefinite occurs in the syntactic scope of a universal have only one semantic/logical form representation, namely the one that is associated with their surface form.

(26) Amanda bought every album that was praised by the famous Hungarian photographer I visited yesterday.

(27) Amanda bought every album that was praised by three/some famous Hungarian photographers.

In the definite case, the conditions imposed on definite DPs amount to requiring non-covariation between albums and photographers, that is, the definite is normally taken to have wide scope. Narrow scope readings are, however, possible in special contexts that allow uniqueness to be relativized to values given to the universal, as in the simple case in (28):

(28) Every participant was given a cookie and an apple. Every participant ate the cookie first.

If the plural indefinites in (27) have a collective interpretation, the sentence is scopally ambiguous: the indefinite plural can take both narrow and wide scope relative to the universal. However, if the plural DPs are distributively interpreted, their scope is restricted to their own clause just as in the case of universals.[9]

There are two interconnected questions that arise at this point:

(29) *Existentials vs. universals*: Why do indefinites (and existentials more generally) contrast with distributive quantifiers with respect to upward scope?

(30) *Upward scopal freedom*: What accounts for the freedom of scope of existentials, and in particular, for their disregard of the syntactic structure intervening between the existential and the higher quantifier(s) the existential may scope over?

The upward scopal freedom that existentials enjoy is problematic for syntax-based accounts of semantic scope because such accounts assume that an expression e_1 takes semantic scope over an expression e_2 iff e_1 c-commands e_2. Inverse scope, that is, cases where surface c-command does not match semantic scope, are dealt with by assuming covert quantifier raising, which results in configurations where c-command and semantic scope match. The problem, then, is that existentials have to be allowed to raise freely and exceptionally (given that syntactic islands are otherwise barriers for movement), leading to the question in (30). At the same time, the raising of universals and other distributively interpreted DPs is clause-bounded, a contrast that leads to the question in (29).

The following two subsections review some of the answers to these questions grouping them depending on whether they take the apparent upward scopal freedom of indefinites to be a manifestation of scopal behavior or not.

[9] For discussion of this latter point, see Ruys (1992).

8.3.2 Exceptional upward scope is an illusion

Most approaches to the problem of exceptional upward scope of indefinites treat it as an illusion, that is, not as an instance of true scopal behavior. They differ with respect to where exactly the source of the illusion is located: lexical ambiguity (Fodor and Sag, 1982), the special lexical meaning of indefinites, which are taken to contribute choice functions (Reinhart, 1997; Winter, 1997; Kratzer, 1998b, among many others) or, finally, pragmatic contextual restrictions that narrow the restrictor set of indefinites to a singleton (Schwarzschild, 2002b). We summarize these approaches in turn.

An early and influential answer to both questions posed in (29) and (30) above is given in Fodor and Sag (1982). The starting point is the claim that indefinites on their own are lexically ambiguous between a "referential" and a "quantificational" (or existential) interpretation. Under the referential reading of (31), the indefinite is a deictic-like expression whose value is some particular individual the speaker has in mind.

(31) A_x student in Semantics 1 cheated in the exam.

The interpretation of a referential indefinite, just like that of a deictic expression or a proper name, is fixed and therefore such expressions remain unaffected by operators that c-command them. On the other hand, under their existential interpretation, indefinites are quantificational just like universals, and they are given scope in the same way and subject to the same constraints as universal DPs.

Under this account, the contrast in scopal restrictions described in (29) above is an illusion: indefinites, when quantificational, are clause-bounded in their upward scope just like universals. The illusion rests on their possible referential reading, which is equivalent to a "widest scope" existential interpretation simply because the reference of referential indefinites is fixed and therefore independent of any other variable. Thus, the "wide scope" interpretation of the indefinite in (23a) above is due to *a famous Hungarian photographer* being interpreted as a referential expression, rather than to the existential taking exceptional wide scope.

This solution answers (30) above as well: referential expressions do not "scope over" any material; they are interpreted *in situ*, but their interpretation is independently fixed and thus immune to covariation, giving the illusion of "widest scope" interpretation. The only relevant difference between indefinites and universals, then, is that the former are ambiguous between a quantificational and a referential reading, while the latter have only the quantificational interpretation.

There are two issues this otherwise attractive proposal raises. First, u-indefinites are claimed to be lexically ambiguous. This conjecture is theoretically problematic in view of the cross-linguistic persistence of this ambiguity and of the fact that other indefinite expressions, such as *three candidates*, *some candidate(s)*, and *a certain candidate* would have to be analyzed as exhibiting a parallel ambiguity because they too are susceptible to exceptional wide scope as well as to covarying interpretations, as we will see below.

The second problem is empirical. Since referential indefinites are treated on a par with deictic expressions and quantificational indefinites are treated on a par with universals, the account predicts that *intermediate* exceptional scope readings for indefinites are not possible, as Fodor and Sag note. The problematic scope configuration is schematized in (32) and illustrated in (33):

(32) $\mathbf{Q}_1 x \ldots \mathbf{Q}_2 y \ldots [_S \ldots \exists z \ldots]$,
where $\exists z$ takes semantic scope between $\mathbf{Q}_1 x$ and $\mathbf{Q}_2 y$.

(33) Every$_x$ committee member read every$_y$ paper that a$_z$ job candidate submitted.

Fodor and Sag (1982) predict that the indefinite *a$_z$ job candidate* is either quantificational, in which case it must have narrowest scope, covarying with both y and x, or referential, in which case it would give the illusion of widest scope because no covariation whatsoever between z and either x or y is possible.

The reading predicted not to exist is the intermediate scope reading in which the values of z covary with x but are fixed relative to y. In this case, for each committee member, there is some job candidate such that the committee member read every paper submitted by that candidate. This reading is ruled out because the interpretation of the indefinite covaries with x, so we have to be dealing with a quantificational rather than a referential indefinite. But then the indefinite should also covary with y given that it should be scopally trapped within the restrictive relative clause.

Farkas (1981) and Abusch (1994a), among others, argue that such intermediate readings do in fact exist and once these readings are accepted, we are left with a questionable ambiguity and without clear answers to our two questions.[10]

Fodor and Sag's ambiguity hypothesis was subsequently picked up by Reinhart (1997), which relies on the notion of *choice function*, introduced in the linguistic literature on indefinites by Egli (1991). For Reinhart, indefinites are lexically ambiguous between a quantificational (existential) interpretation and a choice functional (rather than referential) interpretation. When quantificational, the scope of indefinites is the same as that of universals. When choice functional, the indefinite introduces a choice function variable *in situ* whose argument is the restrictor of the existential; the

[10] However, Fodor and Sag's analysis of referential indefinites could be the right analysis for *this*-indefinites (Prince, 1981a), exemplified in (i) below (from (Prince, 1981a, p. 233). *This*-indefinites have a demonstrative form and flavor, but they are still indefinites in that they introduce a new but highly topical discourse referent.

(i) I work in electronic and auto shows. Companies hire me to stay in their booth and talk about products. I have this speech to tell.

variable is then bound by an existential quantifier that can be freely inserted at any point in the interpretation process.

We obtain the widest scope interpretation of (33) if the choice function variable is bound by an existential inserted at the highest point in the structure of the sentence. The intermediate interpretation is obtained by inserting such an existential between the two universal quantifiers.[11]

This account rests on the "unselective binding" proposal in Heim (1982, Chapter 2), where existentials are treated as free variables unselectively bound by an existential quantifier with scope over the entire sentence or only over the nuclear scope of quantifiers. In Heim's proposal, existentials are bound by the first c-commanding quantifier in the structure in which they occur, an assumption that leaves the problem of the special scope of indefinites open. Reinhart solves it by assuming an unprecedented freedom of binding choice-functional variables at any distance by existential quantifiers inserted for the sole purpose of binding them.

In Reinhart (1997), then, the answer to the first question above is that indefinites but not universals can be (and for Winter, 1997, must be) treated as choice functional. The answer to the second question is that choice-functional variables can be bound by existential closure operators inserted at any point in the structure. The major drawback of this approach is that the exceptional scope potential of choice-functional expressions remains a stipulation.

Kratzer (1998b) and Matthewson (1999) solve this problem by assuming that the value of the choice-functional and variable is a unique, contextually provided choice function, thus reviving the essence of Fodor and Sag's referential account of indefinites. They account for widest scope readings of indefinites in examples like (33) above or (34) below without the need for wide scope existential operators of any sort.

(34) Every$_x$ linguist that studied every$_y$ solution that *some problem* might have has become famous.

In order to account for intermediate scope readings, Kratzer enriches choice functions with implicit arguments so that under the intermediate scope interpretation of (34), *some problem* is interpreted by the contextual choice function f implicitly relativized to the variable x (effectively changing f into a Skolem function), which results in possible covariation between values assigned to x and the value that the x-parametrized choice function gives when applied to the interpretation of *problem*. We now can have different problems relative to different linguists.[12]

In sum, the choice-function-based family of solutions to the problem of the exceptional upward scope possibilities of unmarked indefinites rests

[11] In Winter (1997) the ambiguity part of this proposal is given up: indefinites and existentials more generally are uniformly treated as expressions introducing choice functions.

[12] See Chierchia (2001) and Schwarz (2001) for more discussion of the problems faced by the approach in Kratzer (1998b), particularly when indefinites occur in downward entailing contexts.

on the insight that existential quantification is essentially different from universal quantification. A Kratzer-style choice-functional approach is in principle superior to its predecessors because it does not posit an unmotivated ambiguity characterizing indefinite expressions, nor does it assume special binding properties of the choice-functional variable that effectively stipulate its special scope properties. However, such an approach rests on assuming a special device, namely choice functions, introduced for the sole purpose of accounting for existentials. In addition, choice functions are assumed to sometimes have implicit arguments (which partly brings back the ambiguity problem), an assumption needed to capture intermediate scope interpretations.

Fodor and Sag's idea that the exceptional scopal properties of existentials are an illusion is picked up by Schwarzschild (2002b). The proposal is radically simple: existentials are unambiguously quantificational and their scopal properties are the same as those of universals or other distributive quantifiers. The illusion of exceptional wide scope is due to the pragmatics of the context, which narrows down the denotation of the restrictor of the existential to a singleton. In (35), for instance, the existential is interpreted *in situ*, but the illusion of widest scope is due to the restrictor set of the indefinite being interpreted as a singleton.

(35) Every$_x$ student had read most$_y$ of the reviews that were written about *a$_z$ movie that Phil said was his favorite*.

Because we assume there is only one movie that Phil said was his favorite, there is no possible covariation between reviews and movies or students (and reviews) and movies, which results in the neutralization of the contrast between narrow and wide scope readings. For intermediate scope cases, one has to assume that the restrictor set is singleton relative to varying values of some other variable. The insight here is the reduction of semantic scope to possibility/impossibility of covariation independently of the syntactic position of the existential.

Leaving the whole work up to the assumed pragmatics of the situation seems, however, unjustified given that widest and intermediate scope interpretations are possible even in the absence of pragmatic pressure toward a singleton restrictor. In (36), the indefinite can be interpreted as having widest or intermediate scope (within *decide* but outside *every*) even in contexts where it has been established that there are many famous Hungarian photographers.

(36) Tom has decided to buy every album that *some famous Hungarian photographer praised*.

It is true that once a widest or intermediate scope reading is assumed, the restrictor of the existential can be pragmatically narrowed down to an absolute or relative singleton set precisely because such readings involve a choice of witness whose value is fixed absolutely (in the case of widest scope) or relative to each world that conforms to Tom's decision, in the case of intermediate scope.[13]

8.3.3 Exceptional upward scope is real

We turn now to approaches that take the exceptional semantic behavior of indefinites (and existentials more generally) to truly be a scopal matter and thus be an effect of the different ways semantic evaluation can unfold in sentences that contain both indefinites and *bona fide* quantifiers.

There are two main classes of approaches. One of them, pursued most clearly in Abusch (1994a), is to attribute the exceptional scopal behavior of indefinites to the free way they can enter semantic composition. Abusch offers an account of exceptional scope that uses a quantifier (Cooper) storage mechanism allowing for the delayed interpretation of indefinites. Therefore, semantic composition does not need to mirror syntactic structure, and thus there is no need for exceptional covert movement of existentials. This account leaves open, however, the question of why existentials scope differently from other quantifiers since the delayed interpretation mechanism is not tied to any particular semantic property of existentials.

The other class of approaches attributes exceptional scope to the ability of indefinites to control the way semantic interpretation unfolds. This ability is tied to their existential meaning, i.e., to the fact that unlike *bona fide* quantifiers, their semantic contribution is characterized as witness choice. (In)Dependence Friendly Logics (Hintikka, 1973, 1986; Sandu, 1993; Hintikka and Sandu, 1997; Hodges, 1997; Väänänen, 2007) develop a logical framework that expresses this basic difference directly. The account in Brasoveanu and Farkas (2011) relies on it to propose an analysis of the unbounded upward scope of u-indefinites that answers our two questions without relying on ambiguity or special devices to derive intermediate scope readings.

The earliest proposal along these lines on the linguistic side is Farkas (1997b), where the semantic scope of existentials is determined by what evaluation indices c-commanding expressions have introduced up to the point when the existential is interpreted. An existential, then, is free to choose any evaluation parameter, including the initial one, which results in freedom of upward scope. A problem with this account is that the relevant evaluation parameters are assignment functions. Wide scope readings of existentials are not compositional as a result: to obtain them, one has to backtrack and "rewind" the semantic evaluation to an earlier assignment function.

In Brasoveanu and Farkas (2011), this problem is solved by making reference directly to constraints on variation/stability of reference relative

[13] For another pragmatic account, see Geurts (2000) who suggests that existentials contribute a presupposition that can be accommodated globally (for widest scope interpretations) or more locally (for intermediate or narrow scope interpretations). The presuppositional nature of indefinites that this account rests on has not been sufficiently motivated, however.

to previously introduced variables. The reader is referred to this work for discussion of its antecedents within the tradition of Independence Friendly Logic and within linguistic semantics, as well as for a full formal account. We outline it here as an approach that takes variation vs. stability of witness choice as a primary notion rather than one derived from configurational properties. This notion is at the heart of the typology of indefinites to which we turn in the next section.

(In)Dependence Friendly Logic analyzes scopal relations directly as relations among variables. Recall that in essence, $\exists y$ is in the semantic scope of $\forall x$ if the values for y are allowed to covary with those of x, and outside the scope of $\forall x$ if they are not. Such dependence/independence relations between variables are captured directly without the intermediary of configuration. For Brasoveanu and Farkas (2011), syntactic configuration is relevant only in deciding which potential variables an existential could in principle covary with. The essence of the proposal is that in a sentence like (37) the indefinite is interpreted *in situ* but because it is in the syntactic scope of two universals, it can be interpreted in three different ways depending on its relation with the variables x and y bound by the universals.

(37) Every$_x$ professor recommended every$_y$ paper to a$_z$ student.

One possible choice for the indefinite is to be interpreted independently of these two variables, in which case its values are fixed relative to them, resulting in the widest scope interpretation. The second possibility is for the indefinite to be interpreted as covarying with x but as being fixed relative to y, resulting in the intermediate scope interpretation. The third possibility is for the indefinite to be interpreted as covarying with both x and y, resulting in the narrowest scope reading. Syntax provides the variables with which an indefinite may in principle covary, and the indefinite chooses whether to avail itself of these possibilities or not.

To formalize this account, Brasoveanu and Farkas (2011) enrich classical FOL semantics in two ways. First, formulas are evaluated relative to *sets* of assignments $G, G', \ldots$ instead of single assignments $g, g', \ldots$ (see Hodges, 1997; Väänänen, 2007, among others). This is needed in order to be able to talk about *varying* values of x relative to the values of y.

The second formal innovation is that the index of evaluation for a quantifier is taken to contain the set $\mathcal{V}$ of variables introduced by the previously evaluated, that is, syntactically higher, quantifiers or operators. Thus, the interpretation function has the form $[\![\cdot]\!]^{\mathfrak{M},G,\mathcal{V}}$. (From now on we leave the model $\mathfrak{M}$ implicit.) This is needed to capture the syntactic side of scopal relations, namely the fact that an existential may only covary with the previously introduced variables.

When an indefinite is interpreted, a subset $\mathcal{V}'$ of the set $\mathcal{V}$ of previously introduced variables is chosen, as shown below. The members of $\mathcal{V}'$ are variables relative to which the values of the witness for the existential may covary. The choice of witness for the existential has to be fixed relative to the other variables in $\mathcal{V}$, that is, relative to the complement set of variables $\mathcal{V} \setminus \mathcal{V}'$.

(38) Existential quantification:
$[\![\exists^{\mathcal{V}'} x[\phi]\ (\psi)]\!]^{G,\mathcal{V}} = \mathbb{T}$ iff $\mathcal{V}' \subseteq \mathcal{V}$ and $[\![\psi]\!]^{G',\mathcal{V}\cup\{x\}} = \mathbb{T}$, for some G' such that
a. $G'[x]G$; intuitively, the new set of assignments G' differs from the old one at most with respect to the values assigned to x
b. $[\![\phi]\!]^{G',\mathcal{V}'\cup\{x\}} = \mathbb{T}$; intuitively, all the values of x in the new set of assignments G' satisfy the restrictor formula ϕ
c. $g(x) = g'(x)$, for all $g, g' \in G'$ that are $\mathcal{V}'$-identical (g and g' are $\mathcal{V}'$-identical iff for all variables $\nu \in \mathcal{V}'$, $g(\nu) = g'(\nu)$)

The crux of the matter with respect to (non-)covariation is the final clause (38c). Intuitively, this clause requires the choice of witness for the variable x contributed by the existential to be fixed relative to the variables in $\mathcal{V} \setminus \mathcal{V}'$. In contrast, the subset $\mathcal{V}'$ contains the variables relative to which the values of the witness for the existential may covary.

To connect this intuition and the formal characterization in (38c), consider the case in which $\mathcal{V}' = \varnothing$, that is, when the existential does not covary with any of the previously introduced variables stored in $\mathcal{V}$. Then, any two assignments $g, g' \in G'$ are vacuously $\mathcal{V}'$-identical, so condition (38c) effectively requires $g(x) = g'(x)$ for all $g, g' \in G'$. That is, it requires the value of x to be fixed in absolute terms.

Formally then, an existential that is in the syntactic scope of a quantifier binding a variable x is also in its semantic scope iff x is in $\mathcal{V}'$. If $\mathcal{V}' = \varnothing$, the variable introduced by the existential is fixed absolutely, resulting in the widest scope reading. If $\mathcal{V}' = \mathcal{V}$, the variable introduced by the existential can covary with all the previous variables, resulting in the narrowest scope reading. Choices intermediate between $\varnothing$ and $\mathcal{V}$ result in intermediate scope readings. Thus, in the absence of additional constraints, u-indefinites are predicted to occur freely within or outside the semantic scope of any quantifier that has syntactic scope over them. This accounts for their freedom of distribution and interpretation.

For concreteness, consider the example in (39) and its semantic representation in (40).[14]

(39) Every$_x$ student read every$_y$ paper that a$_z$ professor recommended.

(40) $\forall x[\mathit{student}'(x)](\forall y[\mathit{paper}'(y) \wedge$
$\exists^{\varnothing/\{x\}/\{x,y\}} z[\mathit{professor}'(z)]\mathit{recommend}'(z, y))](\mathit{read}'(x, y)))$

The existential has three possible choices for $\mathcal{V}'$, that is, for the set of variables with which it can covary: $\varnothing$, $\{x\}$, and $\{x, y\}$.

The choice $\mathcal{V}' = \varnothing$ results in the widest scope interpretation of the indefinite, where the values of z do not covary with either x or y, that is, there

14 For the semantic clause for universals and for other details of the formal system, see Brasoveanu and Farkas (2011).

must be some professor such that every student read every paper recommended by that professor. The choice $\mathcal{V}' = \{x\}$ results in the intermediate scope reading, where the values of z covary with x but not with y, that is, for each student x we choose a professor z and require x to have read every paper that z recommended. Finally, the choice $\mathcal{V}' = \{x, y\}$ results in the narrowest scope interpretation, where professors covary with both students and papers, and therefore the students read every paper such that some professor or other recommended it.

In this approach, existentials are not ambiguous and are interpreted *in situ*. Moreover, there is no need to introduce choice functions or to further assume that choice functions may have implicit arguments. But just like in approaches based on choice (or Skolem) functions, the non-configurational approach sketched above treats the difference in scope potential between existentials and universals in terms of an essential difference in interpretive procedure: existentials, but not universals, require the choice of a witness at a particular point in the interpretation and the existential is free to choose this witness relative to previously introduced interpretive parameters.

It is this fundamental difference between existentials and *bona fide* quantifiers, that is, witness choice vs. relations between sets of entities, that is responsible for the difference in their scope-taking potentials – and this is the answer Brasoveanu and Farkas (2011) provide to question (29) above. Unlike choice-functional approaches, however, Brasoveanu and Farkas (2011) build witness choice and the fact that it can be freely parametrized – i.e., their answer to question (30) above – into the very process of semantic interpretation and into the way indefinites can take advantage of richly structured semantic evaluation contexts.

This non-configurational, independence-friendly framework allows us to impose fixed or variable reference requirements directly without the intermediary of syntactic configuration while at the same time capturing the sensitivity of variable reference to syntactic factors. In the next section, we turn to marked indefinites and show how this framework can account for marked indefinites that add constraints to the very free witness-choice semantics associated with u-indefinites.

8.4 Toward a typology of indefinites

In this section we pick up the thread of indefinite classification from the end of Section 8.2 to discuss some of the parameters along which marked indefinites vary. The approach will rely heavily on the notion of variation/stability of values across a set of assignments at the core of the non-configurational approach to free upward scope of u-indefinites that we just discussed.

8.4.1 Two types of marked indefinites

From the discussion so far, we expect marked indefinites to impose either domain restrictions or witness-choice restrictions. Furthermore, these restrictions may result in either stability or variation of values assigned to the relevant variable across a set of assignment functions. Stability requirements are associated with specificity, while variation requirements are associated with non-specificity. (See Farkas, 2002b, for discussion.) To render these considerations concrete, consider partitives (whether implicit or explicit), exemplified below:

(41) Some children ran into the room. *A child* / *Some of the children* was/were dressed up.

What distinguishes partitive indefinites from u-indefinites is a domain constraint requiring their restrictor to be discourse familiar. This constraint results in an anti-variation requirement relative to u-indefinites since the domain of the partitive is necessarily restricted while that of a u-indefinite doesn't have to be. This domain constraint, however, is compatible with any semantic scope configuration, and thus we correctly predict that with respect to scopal properties, partitives will behave like u-indefinites.

On the other side of the variation/stability divide, domain constraints have been invoked in work on free choice DPs by Kadmon and Landman (1993) for instance, who impose a widening constraint on the domain of such items. This constraint can be reformulated as a witness-choice constraint requiring each element of the domain to be a value for the variable in question under the relevant set of assignment functions. Either way, the result is that possible variation of values of the variable in question is maximized, and thus it amounts to a pro-variation requirement. The scopal requirements that free choice items are subject to should, ideally, follow from the details of the variation constraint they introduce.

At the highest level of generality, then, we propose that a fundamental parameter along which marked indefinites differ is as in (42) below:

(42) a. *Pro-variation* marked indefinites obey a constraint that leads to (relative) variability of values for the variable introduced by the DP.
b. *Anti-variation* marked indefinites obey a constraint that leads to (relative) stability of values for the variable introduced by the DP.

In these terms, all definite DPs obey a strong anti-variation constraint while u-indefinites are neutral. Assuming that the property of stability vs. variability of reference underlies the many versions of specificity, pro-variation DPs will count as non-specific and anti-variation DPs will count as specific. What subtype of specificity is involved in each case depends on the details of the special constraint the DP imposes. In the case of indefinites, special, often morphologically complex Ds are responsible for introducing such provariation or anti-variation requirements. We assume that variation vs. stability of reference targets values given to the relevant variable across a set of assignments, or alternatives. Further distinctions can be drawn within pro- and anti-variation DPs depending on the details of the constraints they contribute.

Within the group of Ds marked for anti-variation are overt partitives, *a certain* indefinites in English and their close, though not quite identical, relatives in other Indo-European languages, such as German *ein gewiss/bestimmt*, Romanian (*un NP anume*), or French (*un NP particulier*), as well as *this* indefinites in English. Such anti-variation Ds within a language and across languages differ with respect to where and how (relative) stability of reference is required. Thus, for partitives, relative stability of reference results from circumscribing their domain to a discourse familiar set. They allow variation within this set (which is what makes them indefinite), but this variation is limited to the subset in question and therefore all possible witnesses share the property of being members of this subset. In the case of *a certain* and its relatives, the parameter involves identifiability of the witness, a matter that we turn back to in Section 8.4.3.

Within the group of pro-variation Ds, we can distinguish *internal* and *external* pro-variation inducing Ds. The former require variability of reference relative to alternatives introduced within the sentence the DP occurs in. External pro-variation Ds require variability of reference relative to contextual alternatives. Internal pro-variation Ds have to occur within the semantic reach of the item that introduces the relevant alternatives, while external pro-variation Ds will simply have to occur within general contexts compatible with their requirement. Examples of internal pro-variation Ds are the group of dependent or distributive indefinite DPs in Hungarian, Romanian and many other languages, as well as the Romanian "epistemic" *vreun* indefinites (Farkas, 1997a; Fălăuş, 2015). Negative indefinites and free choice indefinites fall under internal pro-variation Ds as well (on negative indefinites, see de Swart, Chapter 16; on free choice indefinites, see Dayal, 1998; Sæbø, 2001b; Giannakidou, 2001; Jayez and Tovena, 2005; Menéndez-Benito, 2010; Chierchia, 2013, among others). The particular constraints these Ds impose differ across Ds and across languages but the common denominator is that the result requires variation of values assigned to the variable introduced by the DP across assignments that serve as input to the DP in question. External pro-variation Ds are exemplified by English singular *some* (Farkas, 2002c) and Spanish *algún* indefinites (Alonso-Ovalle and Menéndez-Benito, 2010), and arguably German *irgend* indefinites (cf. Kratzer and Shimoyama, 2002; Kratzer, 2005; Aloni and Port, 2011; Aloni and Roelofsen, 2014, among others). Again, the details of the constraints may vary but their common denominator will involve a requirement of variation of values that can be met across contextual alternatives.

When it comes to anti-variation Ds, then, the relevant question to ask is what particular stability requirement they involve and what variation they tolerate. When it comes to pro-variation D, one has to establish what the crucial variability parameter is and what stability of reference variability parameters are compatible with. Answers to these questions should predict what scopal properties these special indefinites have. In the next two subsections, we exemplify with one D from each subtype.

8.4.2 Pro-variation Ds: the case of dependent indefinites

Recall that pro-variation indefinites are marked indefinites that impose further conditions requiring variation of chosen witness values across a particular set of alternatives. In this subsection we turn to a class of pro-variation DPs, namely *dependent indefinites* (Farkas, 1997a, 2007). This class of indefinites is marked by special morphology signaling a requirement of covariation with a licensor. The licensor is an individual or event/situation variable that must also vary across its domain, in the simplest case because it is contributed by a *bona fide* quantifier.

We exemplify below with Hungarian (43), where dependent indefinites are marked by reduplication, and with Romanian (44), where they are marked by the special morpheme *cîte*:

(43) Minden vonás **egy-egy** emlék.
every feature *a-a* memory
'Every feature is a memory.'

(44) *Fiecare băiat* a recitat **cîte** un poem.
every boy has recited *cîte* a poem.
'Every boy recited a poem.'

In (43), the reduplicated indefinite must covary with the variable bound by the licensor of the dependent indefinite, namely the universal determiner *minden* "every". The variable bound by the universal ranges over a non-singleton set of features, and each such feature must be associated with a memorable event. The reduplicated indefinite article *egy-egy* requires that there be some variation across these memories and thus rules out a situation in which each feature is associated with the same memory. Similarly, the addition of the morpheme *cîte* to the simple indefinite *un* in (44) imposes the requirement that there be covariation between boys and the poems they recited.

In both languages, such sentences contrast with sentences that are identical except for the replacement of the dependent indefinite by a simple one (the non-reduplicated u-indefinite article *egy* in Hungarian and the u-indefinite article *un/o* in Romanian). While the witnesses of the dependent indefinite have to covary with those of the licensor, the simple indefinite allows both a covariation and a wide scope/fixed-value interpretation, just like their English translations.

We now sketch how the account in Brasoveanu and Farkas (2011) extends to dependent indefinites. Recall that the independence-friendly account of u-indefinites has two crucial ingredients: (i) the superscript on the existential that stores the set of parameters relative to which the indefinite may covary, and (ii) the fixed-value constraint that makes use of this superscript and that constrains the values of the indefinite stored in the resulting "output" set of variable assignments. We therefore expect the existence of special indefinites that target the same superscript and enforce further constraints on the "output" set of assignments.

Dependent indefinites can be seen as doing exactly this: while u-indefinites contribute a fixed-value condition relativized to their superscript, dependent indefinites add a non-fixed-value condition relativized to the same superscript. The interpretation rule for dependent indefinites is provided in (45) below. It is identical to the interpretation rule for u-indefinites in (38) above except for the last clause in (45d), which is contributed by the dependent morphology.

(45) $[\![\mathbf{dep}\text{-}\exists^{\mathcal{V}'}x[\phi]\ (\psi)]\!]^{G,\mathcal{V}} = \mathbb{T}$ iff $\mathcal{V}' \subseteq \mathcal{V}$ and $[\![\psi]\!]^{G',\mathcal{V}\cup\{x\}} = \mathbb{T}$, for some G' such that

a. $G'[x]G$

b. $[\![\phi]\!]^{G',\mathcal{V}'\cup\{x\}} = \mathbb{T}$

c. $g(x) = g'(x)$, for all $g, g' \in G'$ that are $\mathcal{V}'$-identical

d. $g(x) \neq g'(x)$, for at least two $g, g' \in G$ that are not $\mathcal{V}'$-identical

The clause in (45d) requires covariation because it requires the set of variables $\mathcal{V}'$ that contains parameters of possible covariation to be non-empty: there have to be at least two assignments $g, g' \in G'$ that are not $\mathcal{V}'$-identical, which means that $\mathcal{V}'$ must be non-empty. Furthermore, there has to be at least one variable $v \in \mathcal{V}'$ such that $g(v) \neq g'(v)$. This ensures that the licensor of the dependent indefinites has to introduce multiple values for the same variable.

The example in (44) is represented as shown in (46) below, where we indicate that the empty set $\varnothing$ is not a possible superscript for the existential by starring it, and that the singleton set $\{x\}$ is a possible superscript for the existential by adding a check mark.

(46) $\forall x[boy'(x)]\ (\mathbf{dep}\text{-}\exists^{*\varnothing\,/\,\checkmark\{x\}}y[poem'(y)]\ (recite'(x,y)))$

The evaluation proceeds as follows. First, the restrictor of the universal introduces the set of all students and stores it in the variable *x*. We then evaluate the dependent existential. If the existential is superscripted with the empty set $\varnothing$, we fail to satisfy the variation condition (45d) contributed by the morpheme *câte*: the variable *y* introduced by the existential has a unique value, which makes any variation or covariation impossible; moreover, any two assignments $g, g' \in G$ are (vacuously) $\varnothing$-identical. Hence the dependent existential can only have the superscript $\{x\}$. This makes it *possible* for the variable *y* introduced by the existential to covary with the variable *x* introduced by the universal. The variation condition (45d) contributed by *câte* requires this covariation to *actually* be realized.[15] Finally, the nuclear scope of the indefinite checks that each *x*-student read the corresponding *y*-paper.

[15] It might be possible to weaken (45d) and simply require that there should be at least two $g, g' \in G$ that are not $\mathcal{V}'$-identical. The extra requirement that $g(x) \neq g'(x)$ might simply be a (default) pragmatic inference. This would account for the example in (i) below from Brasoveanu (2011), which is felicitous and true in a

8.4.3 Anti-variation Ds: the case of *a certain* indefinites

In this final section, we turn to the class of anti-variation indefinites, that is, indefinites that impose conditions restricting variation in witness choice. We exemplify with English *a certain* indefinites.

Consider the examples in (47) and (48) below based on Hintikka (1986) (for reasons of space, we examine only extensional cases). As Hintikka observes, *a certain* indefinites take wide scope (forced by the continuation *the Queen* in (47)), or if they take narrow scope, they tend to have a functional interpretation (forced by the continuation *his mother*; see Schwarz, 2011a, for a recent overview and discussion).

(47) Every Englishman adores a certain woman – the Queen / his mother.

(48) A certain sum of money will be paid for each quantity of this commodity.

Kratzer (1998b), Chierchia (2001), and Schwarz (2011a) note that the functional interpretation of these indefinites must have widest scope. To see this, consider example (49) below from Schwarz (2011a) under the reading in which *his* is bound by *no boy*, forcing the *a certain* indefinite to take narrow scope.

(49) No boy talked with a certain female relative of his about girls.

The indefinite has narrow scope, but it does not have a regular "narrow-scope existential" interpretation: (49) cannot be interpreted as saying that no boy talked with any female relative of his about girls. Under the narrow-scope functional interpretation, sentence (49) is true if no boy talked about girls with his mother, for example, even if there are boys who talked about girls with their aunties.

Schwarz (2011a, pp. 890–891) compares two kinds of analyses of such functional readings, namely a free Skolem function variable analysis along the lines of Kratzer (1998b) and an existentially bound choice-functional variable analysis along the lines of Winter (1997), and argues that a free variable approach is empirically more adequate. Furthermore, a free variable approach is theoretically and formally simpler, so we will follow its main insight and capture the specifier nature of *a certain* indefinites by means of the semantic clause in (50) below. The only difference between this and the

situation in which there are several marbles in the bag that are indistinguishable from each other, and Linus happens to take the same marble out of the bag, over and over again.

(i) Din cînd în cînd, Linus scotea **cîte** o bilă din pungă, se uita la ea cu
from when to when, Linus take.out.IMPF.3.SG *cîte* a marble out bag, REFL look.IMPF.3.SG at it with
atenție, după care o punea la loc.
care, after which it put.IMPF.3.SG at place.
'Every now and then, Linus would take out a marble from the bag, look at it carefully, then put it back.'

clause for u-indefinites in (38) above is (50c), which strengthens the clause in (38c) by further constraining/specifying the kinds of witnesses the indefinite can choose.

(50) $[\![\textbf{certain} - \exists^{\mathcal{V}'}x[\phi]\ (\psi)]\!]^{G,\mathcal{V}} = \mathbb{T}$ iff $\mathcal{V}' \subseteq \mathcal{V}$ and $[\![\psi]\!]^{G',\mathcal{V}\cup\{x\}} = \mathbb{T}$, for some G' such that

a. $G'[x]G$

b. $[\![\phi]\!]^{G',\mathcal{V}'\cup\{x\}} = \mathbb{T}$

c. $g(x) = g'(x) = \mathcal{F}(g(\mathcal{V}'))$, for all $g, g' \in G'$ that are $\mathcal{V}'$-equivalent with respect to some suitable function $\mathcal{F}$

(51) Two assignments g and g' are $\mathcal{V}'$-equivalent with respect to a suitable function $\mathcal{F}$ iff $\mathcal{F}(g(\mathcal{V}')) = \mathcal{F}(g'(\mathcal{V}'))$.[16,17]

Under this account **certain-∃** is an anti-variation determiner because it imposes a restriction that requires a particular type of identity of value across assignments. It does that by invoking a suitable function $\mathcal{F}$ and using it relative to the same two semantic ingredients that are crucial for our analysis of u-indefinites: the superscript $\mathcal{V}'$ and the fixed-value condition $g(x) = g'(x)$. In particular, the function $\mathcal{F}$ specifies the witness that has to be chosen relative to the values of the variables in the set $\mathcal{V}'$.

For example, consider the two scopal possibilities for the indefinite in Example (47) above, represented in (52).

(52) $\forall x[englishman'(x)]\ (\textbf{certain-}\exists^{\varnothing\,/\,\{x\}}y[woman'(y)]\ (adore'(x, y)))$

If the superscript is $\varnothing$, then the indefinite has wide scope, that is, we choose one absolutely fixed witness, and in addition we have to have a suitable function $\mathcal{F}$ whose only value is that witness. "Suitable" means that the domain of $\mathcal{F}$ consists of sets of n individuals, where n is the cardinality of the set of variables superscripted on the existential. Since the superscripted set has cardinality 0 in this case, the suitable function $\mathcal{F}$ is simply an individual (a "degenerate" function), for example, the Queen.

If the superscript is $\{x\}$, then the indefinite has narrow scope, which means that we can choose possibly different values for the variable y if the corresponding x-values are different. But the values for y are highly constrained: we have to have a suitable function $\mathcal{F}$ that provides these values (in this case, "suitable" means that $\mathcal{F}$ is a function from singleton sets of individuals to individuals). That is, for any given value α for the variable x,

[16] For a set of n variables $\mathcal{V}' = \{v_1, \ldots, v_n\}$, a variable assignment g and a function $\mathcal{F}$ from sets of n individuals to individuals: $\mathcal{F}(g(\mathcal{V}')) := \mathcal{F}(\{g(v_1), \ldots, g(v_n)\})$.

[17] To show that clause (50c) entails clause (38c), assume that G' satisfies clause (50c), in particular, that $g(x) = g'(x)$, for any two assignments $g, g' \in G'$ that are $\mathcal{V}'$-equivalent with respect to $\mathcal{F}$. Now take two arbitrary $g, g' \in G'$ that are $\mathcal{V}'$-identical. In order to show that G' satisfies clause (38c), we have to show that $g(x) = g'(x)$. By definition, $g, g' \in G'$ are $\mathcal{V}'$-identical iff for all variables $v \in \mathcal{V}'$, $g(v) = g'(v)$. Therefore, we have that $\mathcal{F}(g(\mathcal{V}')) = \mathcal{F}(g'(\mathcal{V}'))$. But then by the definition in (51), g and g' are $\mathcal{V}'$-equivalent with respect to $\mathcal{F}$, and given our hypothesis that G' satisfies clause (50c), we have that $g(x) = g'(x)$.

the corresponding value for the variable y has to be $\mathcal{F}(\{\alpha\})$. For example, $\mathcal{F}$ could be the $\texttt{mother}$ function: given (the singleton set whose only member is) an individual, this function returns the mother of that individual as its value.

Thus, the narrow scope reading for the *a certain* indefinites in Example (47) is more *specific* than the narrow scope reading for a u-indefinite, e.g., *Every Englishman adores a woman*. The u-indefinite places a milder constraint on the set of assignments G': any two assignments $g, g' \in G'$ that assign the same value to x, e.g., $g(x) = g'(x) =$ Bob, have to assign the same value to y, e.g., $g(y) = g'(y) =$ Jane. But if we have an assignment g'' that assigns a different value to x, e.g., $g''(x) =$ Tom, the corresponding value of y can be the same, e.g., $g''(y) =$ Jane, or it can be different, e.g., $g''(y) =$ Mary.

The anti-variation *a certain* indefinite places stricter constraints on the set of assignments G': for any assignment $g \in G'$, $g(y) = \texttt{mother}(g(x))$. In particular, if we have two assignments $g, g' \in G'$ such that $g(x) = g'(x) =$ Bob and Bob's mother is Jane, then we have to have $g(y) = g'(y) = \texttt{mother}(\text{Bob}) =$ Jane. If in addition we have a third assignment g'' such that $g''(x) =$ Tom and it so happens that Tom is Bob's (maternal) brother, then the specifier indefinite requires that $g''(y) =$ Jane even if Tom also adores Mary.

The formalization above captures the idea that *a certain* indefinites are anti-variation Ds, that is, they constrain witness choice by means of a functional dependency, but it glosses over certain details that would need to be captured in a fuller account. First, instead of being contextually provided, the constraining functional dependency $\mathcal{F}$ should be introduced by the indefinite itself (possibly by the adjective *certain*) and made available for further specification in subsequent discourse. This is what happens in Hintikka's example in (47) as well as in (53) below. The role of the context is to constrain the domain of functions thus introduced, in much the same way that the context restricts quantificational domains in general.

(53) Every man forgot a certain date. Matt the birthday of his wife, Bert the birthday of his daughter and Sam his wedding anniversary.

Second, note that explicitly invoking a functional dependency $\mathcal{F}$, as *a certain* indefinites do, is not a necessary requirement to capture functional readings in general. In this framework, all indefinites – u-indefinites included – implicitly have functional readings whenever their superscript is non-empty. That this is correct is shown by *Every Englishman adores a woman – his mother*.

The role of the functional dependency for *a certain* indefinites is to require the chosen witness to be in principle identifiable in the sense of Farkas (2002c). That is, since the functional dependency is introduced in discourse, it is implicated that it is non-trivial. Furthermore, subsequent conversation may further elaborate on it and zoom in on a particular witness identification procedure (which the function $\mathcal{F}$ is intended to encode) but does not have to.

It has often been noted in the literature that the functional dependency introduced by *a certain* indefinites has a doxastic flavor (see Kamp and Bende-Farkas, 2006, among others). This is predicted by the above account since this dependency is intended to act as a witness identification procedure: $g(x) = g'(x) = \mathcal{F}(g(\mathcal{V}'))$. But nothing in the account requires the speaker, or anyone else for that matter, to be able to fully provide the identifying information, which is a welcome result. Finally, note that *a certain* indefinites are predicted to be as free in taking upward scope as u-indefinites are. Their ability to scope under particular operators will depend on whether such narrow scope remains compatible with the special constraint they introduce or not.

8.5 Conclusions

We hope to have shown in this chapter that indefinite DPs raise a rich and varied array of empirical challenges that have inspired major theoretical proposals. We have argued that within nominal semantics, what is common to all DPs is that they introduce a variable, or discourse referent, and restrict the way values for this variable are to be chosen. Existential DPs as a class are essentially simpler than *bona fide* quantificational DPs because their effect on the input state is the simplest possible effect, namely an update of the input assignment function on the variable they introduce. Within existentials, u-indefinites are the simplest, which accounts for their versatility.

The rich variety of indefinites we find within a language as well as cross-linguistically is due to the possibility of further constraints that marked indefinites are subject to. These constraints can target their domain (domain constraints) or the way the values are chosen (witness-choice constraints).

A common type of witness-choice constraint targets variation vs. stability of values for the variable contributed by the indefinite across a particular set of assignment functions. We have argued here that this is an underlying parameter relative to which existential DPs differ. There is hope that the major as well as the minor variations we find in the complex scopal patterns exhibited by various subtypes of indefinites will follow from an adequate characterization of the domain and witness-choice constraints they impose, coupled with the right account of the operators they interact with.

In this respect, work on the semantics of indefinites is in its infancy. There are two major open avenues of research: (i) on the empirical side, we have to better understand the parameters of variation across subtypes of marked indefinites, within a language as well as cross-linguistically; (ii) on the theoretical side, we have to match these with the appropriate formal semantics framework. Based on current research, a significant number of subtypes of indefinites we find across languages are sensitive to whether their values are stable or vary across particular sets of assignment functions. The open issue is to characterize the relevant sets and understand how they interact with semantic composition.

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9

Plurality

Rick Nouwen

9.1 Introduction

Although there is striking variation across languages (and even within a single language) in how the plural is formally expressed, it is relatively easy to indicate what plurality is from a morphological point of view: the plural is one of the instances of the inflectional category of number. From a semantic point of view, however, the concept of plurality is much more diffuse. To start with, the general folk linguistic intuition that being plural expresses being *more than one* is inaccurate. For example, while (1a) suggests that there are multiple stains on the carpet, (1b) does not suggest that only the carrying of *multiple* guns is illegal, nor does (1c) suggest it might be the case that there has been a solitary alien walking the earth.

(1) a. There are stains on the carpet.
    b. Carrying guns is illegal in Illinois.
    c. No aliens have ever walked the earth.

Furthermore, plurality may emerge from sentences that lack any plural morphology, such as the first sentence in (2). Despite the morphologically singular *a picture*, this sentence expresses that a multitude of pictures was drawn, each by one of the boys. This emergent plurality becomes apparent in the second sentence in which a plural pronoun refers to the pictures that the boys drew.

(2) Each boy drew a picture. They are hanging on the wall.

It is often said that in languages like English (and indeed Indo-European languages, generally) plurality is an essentially nominal phenomenon. Corbett (2000), for instance, uses (3) to point out that the plural verbal form must be an uninterpreted agreement reflex triggered by the (unmarked) plurality of the noun. We cannot, for instance, use (3) to express that a single sheep drinks from the stream more than once. It has to mean that there were multiple sheep.

(3) The sheep drink from the stream. (Corbett, 2000)

In other languages verbal number marking does have semantic substance. For instance, (4), an example from Hausa (from Součková, 2011), is incompatible with there being a single kick to the table and typically expresses a quick repetition of kicks. This interpretation is triggered by plural morphology, namely. partial reduplication of the verb stem.

(4) Yaa shùs-shùuri teebùr̂
3SG.MASC REDUP-kick table
'He kicked the table repeatedly.'

Plurality involving the multiplicity of events via some kind of verbal morphological marking is often referred to as *pluractionality* (Newman, 1980).[1] In this chapter, I will ignore the phenomenon of pluractionality and focus instead on the kind of nominal plurality as found in English. The observation that, in English, plural morphology has obvious semantic effects in the nominal, but not in the verbal domain, should not, however, be mistaken for a deeper semantic conclusion, namely that there is nothing to study beyond plural reference.[2] In fact, it turns out that the most puzzling data involving plurality concern exactly the interaction between plural arguments and verbs. This can be illustrated by the following observation: predicates differ with respect to the entailment patterns they display for plural arguments. Take the *distributivity* entailment pattern in (5).

(5) A predicate 'VP' is *distributive* if and only if 'X and Y VP' entails 'X VP' and 'Y VP'

Being wounded is an example of a predicate that clearly supports the entailment scheme in (5), for (6a) entails both (6b) and (6c).

(6) a. Bob and Carl are wounded.
b. Bob is wounded.
c. Carl is wounded.

[1] See Wood (2007) for a general discussion of the notion. One difficult question concerning pluractionality is how (or whether, Corbett, 2000) it differs from aspectual marking or Aktionsart.

[2] Also, see Beck and von Stechow (2007) for a discussion of English adverbials that can be analysed as having a pluractional function.

For other predicates, the pattern in (5) does not hold. Consider the following examples.

(7) a. Bob and Carl carried a piano up the stairs.
b. Bob carried a piano up the stairs.
c. Carl carried a piano up the stairs.

In a situation in which both (7b) and (7c) are true, (7a) is true too. However, (7a) is also true in a situation in which Bob and Carl jointly carried the piano up. In that case, it would be false to say (7b) or (7c). It turns out, then, that while *to carry a piano up the stairs* is not distributive, it does have the inverse property:

(8) A predicate 'VP' is *cumulative* if and only if 'X VP' and 'Y VP' entails 'X and Y VP'

Note that *being wounded*, besides being distributive, is cumulative, too. It follows from (6b) and (6c) that (6a). Yet other predicates are neither distributive nor cumulative:

(9) a. Bob and Carl are a couple.
b. *Bob is a couple.
c. *Carl is a couple.

In sum, the kind of entailment patterns we can observe for plural arguments depends on the predicate (among other things such as the presence of certain adverbs, floated quantifiers, some of which will be discussed below). Plurality will therefore need to be studied in a compositional context. It is this interaction between plural arguments and predicates that is the focus of this chapter. The structure is as follows. In Section 9.2, I will introduce the most commonly assumed complication that plurality brings to the logical language, namely the inclusion of individual constants that are not atomic but *sums*. Using such plural individuals, in Section 9.3 I turn to distributive entailments, as well as to distributive *readings* of sentences. Section 9.4 turns to a special class of interpretations for sentences with plurality, namely cumulative readings, and the relation this bears to distributivity. Section 9.5 looks at dependency phenomena involving plurals. Finally, in Section 9.6, I conclude by briefly touching upon some other issues in the semantics of plurality.

9.2 Sums

Let us consider the simple statement in (10) again.

(10) Bob and Carl are wounded.

Given the observed distributivity entailment of *being wounded*, it is tempting to analyse (10) as (11). Not only does (11) yield the intuitively correct truth-conditions, it does so without complicating the predicate-logical language. That is, plurality in natural language is *distributed* over several conjuncts of essentially singular predications.

(11) $wounded(b) \wedge wounded(c)$

The discussion on entailment patterns above, however, shows that this kind of analysis is not very promising, for it would fail on predicates that lack distributive entailments. For instance, analysing (12a) as (12b) incorrectly predicts that (12a) is false on a scenario where Bob and Carl collectively carry a piano up the stairs.

(12) a. Bob and Carl carried a piano up the stairs.
b. $[\![$carried a piano up the stairs$]\!](b) \wedge$
$[\![$carried a piano up the stairs$]\!](c)$

The common solution is to assume that the phrase *Bob and Carl* refers to a plural individual and that this individual is, as a single collective individual, the argument of the predicate. It would not do, however, to just assume that the conjunction Bob and Carl is a name for some plural individual. There must be some connection between the plural individual that *Bob and Carl* refers to and the individual entities Bob and Carl. This is because, ultimately, we want an account of how certain predicates allow for distributivity and/or cumulativity entailments that link statements involving plural arguments to statements involving the singular parts. Here we can just assume that pluralities are to singularities what sets are to their members. That is, if D_e is the set of singular entities, then the set of plural individuals will be the powerset of this domain with the empty set removed: $\wp(D_e) \setminus \varnothing$. We can now say that *Bob and Carl* refers to the smallest set that has Bob and Carl as members. So, for (12a) we get (13).

(13) $[\![$carried a piano up the stairs$]\!]$ $(\{b, c\})$

While analyses along this line exist (Hoeksema, 1983; Gillon, 1987; Schwarzschild, 1996; Winter, 2002), a more common alternative is to use an approach inspired by the work of Link. (See especially Link, 1983. See Krifka, 1989a and Landman, 1989a, 1996, 2000 for foundational works building in part on Link.) In Link's approach there is no type-theoretic difference between plural and singular individuals. So plural individuals are e-type entities just as singular individuals are. However, the domain of entities is structured exactly like the powerset of the set of atomic individuals.

We can set this up as follows. Let D_e be the set of all (i.e. both singular and plural) entities and let $\sqcup$ be a binary operation on elements of D_e, called *summation*. Summation has the following properties:

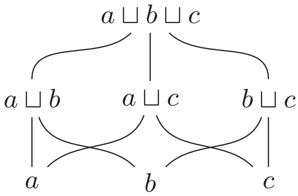

Figure 9.1 *A depiction of the complete atomic join semi-lattice with a, b and c as the atomic elements. The arcs represent the $\leq$ relation.*

(14) a. $(\alpha \sqcup \beta) \sqcup \gamma = \alpha \sqcup (\beta \sqcup \gamma)$ associative
b. $\alpha \sqcup \beta = \beta \sqcup \alpha$ commutative
c. $\alpha \sqcup \alpha = \alpha$ idempotent

Given summation, we now define a partial order $\leq$ on D_e:

(15) $\alpha \leq \beta$ if and only if $\alpha \sqcup \beta = \beta$

The idea is that just as $\{b, c\}$ is the smallest set that contains b and c as elements, so is $b \sqcup c$ – i.e. the *sum* of b and c – the smallest entity that has b and c as its parts. This means that $\sqcup$ is a supremum or *join* operator. The desired structure is a particular kind of lattice, namely a complete atomic join semi-lattice (see Link, 1998, Chapter 6, as well as Landman, 1991, for details). *Complete* since we want the domain of entities to be closed under $\sqcup$; *atomic* since we also want that all atomic parts of sums in the domain are part of the domain themselves. (If we can talk about *Bob and Carl*, then we can also talk about *Bob*.) Finally, it is a *semi*-lattice, since we are only interested in joins, not in meets. An example of a complete atomic join semi-lattice for three atoms a, b and c is given in Figure 9.1.

In (16), I give two handy definitions inspired by Link's work. First of all (16a) says that something is an atomic entity if and only if it only has itself as a part. The operation in (16b) restricts a set of individuals to the ones that are atomic.

(16) a. $Atom(\alpha)$ if and only $\forall \beta \leq \alpha[\alpha = \beta]$
b. $Atoms(A) = \lambda\alpha.\alpha \in A \wedge Atom(\alpha)$

Given these definitions, we can formally express the correspondence between the lattice structure assumed by Link and the powerset structure we were aspiring to:

(17) $\langle D_e, \sqcup \rangle$ is isomorphic to $\langle \wp(Atoms(D_e)) \setminus \varnothing, \cup \rangle$

The operator most borrowed from Link's work is the sum closure operator '$*$' for sets or one-place predicates:

(18) ${}^*X$ is the smallest set such that:
${}^*X \supseteq X$ and
$\forall x, y \in {}^*X : x \sqcup y \in {}^*X$

Link reasoned that while singular nouns referred to sets of atoms (i.e., elements in $\wp(Atoms(D_e))$), plural nouns refer to sets that include plural individuals. (We will ignore for now the hairy issue of whether or not such plural nouns also contain atomic entities in their extension. See below for discussion.)

(19) $[\![boys]\!] = {}^*[\![boy]\!]$

So, if $[\![boy]\!]$ is the set $\{b, c, d\}$, then $[\![boys]\!]$ is the set $\{b, c, d, b \sqcup c, c \sqcup d, b \sqcup d, b \sqcup c \sqcup d\}$. The example (20a) is now predicted to be true, by virtue of the fact that the plural individual $b \sqcup c$ is in the pluralised – i.e.*-ed – extension of the noun *boy*, which we could express in a predicate-logical language as in (20b).

(20) a. Bob and Carl are boys.
b. $^*boy(b \sqcup c)$

The question is now how to account for predicates with different entailment patterns. For this, we need to have a closer look at *distributivity*.

9.3 Distributivity

The sentence in (21) is true in a number of quite different scenarios. In a *collective* understanding of the sentence, Bob, Carl and Dirk jointly carry a piano up the stairs. Conversely, on a *distributive* understanding Bob carried a piano up the stairs by himself, and so did Carl, and so did Dirk.

(21) Bob, Carl and Dirk carried a piano up the stairs.

The distributive understanding can be isolated by adding a floating distributive quantifier like *each*: that is, *Bob, Carl and Dirk each carried a piano up the stairs* only has the distributive reading. With this in mind, predicates with distributive entailments are always understood distributively, since for (22a) the adding of *each* in (22b) seems vacuous.

(22) a. Bob, Carl and Dirk are wounded.
b. Bob, Carl and Dirk are each wounded.

In summary, we get the following overview:

(23)

	entailments			understandings	
	distr	cumul	-	distr	collec
being wounded	yes	yes	-	yes	no
to carry a piano up x	no	yes	-	yes	yes

The stable factor in this table is that all examples allow for cumulative inferences and all examples have distributive understandings. Note that Link's

*-operation amounts to enforcing cumulative entailments. That is, if predicates with plural arguments are pluralised using *, then cumulativity follows, due to the following fact:

(24) $P(\alpha) \wedge P(\beta) \Rightarrow {}^*P(\alpha \sqcup \beta)$

The inverse entailment does not follow, for ${}^*P(\alpha \sqcup \beta)$ could be the case without $P(\alpha)$ being the case. Just take a P such that $P(\alpha \sqcup \beta)$ is true but not $P(\alpha)$.

Landman (1996) proposes accounting for the difference between predicates such as *being wounded* and *to carry a piano up the stairs* by just assuming two things. Firstly, predicates with plural arguments are plural in the sense that they are pluralised using the *-operation. Second, predicates differ with respect to the kind of entities they have in their (singular) extension. For *being wounded* it suffices to assume that its extension only contains atoms. This captures the intuition that it does not make sense for the property of being wounded to be shared among multiple entities. We can now analyse (22a) as (25).

(25) ${}^*wounded(b \sqcup c \sqcup d)$

The cumulativity entailment follows from (25). The inverse distributivity entailment follows from the fact that the only way a plurality can end up in the pluralised extension of the predicate is if its atomic parts were in the singular extension, for $wounded(\alpha)$ is only true for atomic α's. Another way of saying this is that there cannot be any collective understandings. All plural arguments are the result of the *-operation.

Adopting a similar strategy for (21) results in (26).

(26) ${}^*[\![\text{carried a piano up the stairs}]\!](b \sqcup c \sqcup d)$

In Landman's framework, the key to accounting for the properties of (26) is to assume that the extension of predicates such as *to carry a piano up the stairs* might or might not include atoms, and it might or might not include sums; this fully depends on the state of affairs. In a distributive scenario, b, c and d occur in the extension as singular individuals. Given the effect of pluralisation, (26) is then true in that scenario. In the collective scenario the extension just contains $b \sqcup c \sqcup d$ as a plurality, and hence (26) is also true. There is no distributivity entailment, since we cannot know which scenario made (26) true.

Contrary to what my presentation above suggests, it is sometimes assumed that what I have vaguely called *understandings* are in fact different *readings* of an ambiguity.[3] On such accounts, (21) is ambiguous between a reading in which the distributivity entailment holds (the distributive reading) and one in which it does not (the collective one). The latter reading is

[3] As far as I can see, no consensus on this topic has been reached. In fact, this topic is surprisingly absent from the recent literature.

more basic, while the distributive one is derived using the insertion of a distributivity operator. Two main variations on such approaches exist, depending on whether the operator in question is applied to the verb's argument or to the verb itself. Take, for instance, the following two options.

(27) a. $DIST = \lambda\alpha.\lambda P.\forall\beta \leq \alpha[Atom(\beta) \rightarrow P(\beta)]$
b. $DIST = \lambda P.\lambda\alpha.\forall\beta \leq \alpha[Atom(\beta) \rightarrow P(\beta)]$

In a case like (21), insertion of *DIST* will result in a reading that carries a distributivity entailment: $\forall x \leq b \sqcup c \sqcup d[Atom(x) \rightarrow [\![\text{carried a piano up the stairs}]\!](x)]$. Hence, this reading is exactly what one would get by adding a floating *each* to (21). For cases like (21) the choice between (27a) and (27b) is immaterial. It is easy to find examples, however, where these two operators differ in predictions. Following Lasersohn (1995), a sentence like (28a) illustrates this. Here, it is possible for one part of the conjoined verb phrase to get a collective reading while the other part gets a distributive reading. Using (27b), this is easy to capture, as in (28b). However, no easy analysis seems to be available using (27a).

(28) a. Bob and Carl carried a piano up the stairs and then drank a glass of water.
b. $$\left[\begin{array}{c}\lambda x.\ [\![\text{carried a piano up the stairs}]\!](x) \wedge \\ DIST([\![\text{drank a glass of water}]\!])(x)\end{array}\right](b \sqcup c)$$

Assuming we should abandon the option in (27a), we now have two competing accounts of distributivity: one in the form of a freely insertable operator *DIST*, and one as a semantic repercussion of pluralisation using *, as in Landman (1996, 2000). These accounts are closely related. In fact, it is easy to see that the following correspondence holds:

(29) $DIST(A) = {}^*(Atoms(A))$

Some evidence exists for not thinking of distributive understandings as separate interpretations that arise through augmenting a logical form with an additional operator. Schwarzschild (1996) uses one of the classic ambiguity tests from Zwicky and Sadok (1975). Whenever an ambiguous term is elided, it has to be resolved to the same interpretation as its antecedent. As an illustration, take the elaborated version of the famous Groucho Marx joke in (30a). This sentence can mean that the speaker shot an elephant that was wearing pyjamas and that the speaker's sister shot a similar animal or it means that the speaker shot an elephant while wearing pyjamas and that his or her sister shot an elephant in similar attire. Crucially, it cannot mean that the speaker shot an elephant that was wearing pyjamas, while the sister shot an elephant while she was wearing pyjamas. Schwarzschild now observes that for sentences like (30b) such a mixed interpretation is perfectly possible. For instance, (30b) is intuitively true if each of the computers were paid for in two instalments and the entire collection of diskettes were collectively paid for in two instalments. (See Schwarzschild for a more elaborate scenario that makes this understanding likely.)

(30) a. I shot an elephant wearing pyjamas and my sister did too.
b. The computers were paid for in two instalments and the diskettes were too.

While Schwarzschild's observation strongly suggests that we should not really be talking about *readings*, there are some data that seem to indicate that plural sentences at least involve some covert operator (as, incidentally, is the case in Schwarzschild's own account). One reason to believe that this is the case comes from Heim et al. (1991). Consider (31).

(31) Bob and Carl think they will win €1000.

This example has multiple readings depending on how the pronoun *they* is resolved and whether the verb phrases are construed distributively or collectively. Three of those are in (32).

(32) a. Bob and Carl argue that Bob and Carl, as a group, will win €1000.
b. Bob argues that Bob will win €1000 and Carl argues that Carl will win €1000.
c. Bob argues that Bob and Carl, as a group, will win €1000 and Carl argues the same.

In (32a), the plural pronoun *they* is understood as co-referring with the matrix subject *Bob and Carl*. This is a fully expected reading. However, the reading in (32b) is not so trivial to account for. In this case, the pronoun is interpreted as a bound variable. But that means that there has to be some quantificational operator that is responsible for distribution over the atoms in the subject.

While these data are usually thought to indicate the presence of a proper distributivity operator akin to the natural language floating *each* in distributive readings, the observations are not incompatible with a theory in which a single operator accounts for a range of understandings, including Landman's use of *. Also, Schwarzschild (1996) offers an analysis that uses a distributivity operator, without predicting that there are multiple readings. In a nutshell, and simplifying drastically, the idea is that pluralities can be partitioned, that is, divided up into parts and that the distributivity operator quantifies over such parts.[4] A definition of *minimal sum covers* as well as some examples are given in (33), while (34) defines the distributivity operator.

(33) C minimally covers α iff $\alpha \in {}^*C$ and $\neg\exists C' \subset C[\alpha \in {}^*C']$
a. $\{b, c \sqcup d\}$ minimally covers $b \sqcup c \sqcup d$

[4] See Dotlačil (2010) for a more advanced integration of Schwarzschild's idea in a sum-based approach to plurality. The idea of using *covers* to account for different understandings of plural statements originates in Gillon (1987).

b. $\{b, c, d\}$ minimally covers $b \sqcup c \sqcup d$
c. $\{b \sqcup c \sqcup d\}$ minimally covers $b \sqcup c \sqcup d$
d. $\{b \sqcup c, c \sqcup d\}$ minimally covers $b \sqcup c \sqcup d$

(34) $DIST_C(P) = \lambda x.\forall y \in C_x[P(y)]$
where C_x is some pragmatically determined minimal cover of x

This one definition covers a range of readings, depending on what kind of cover is pragmatically given. For instance, (35a) will be interpreted as (35b).

(35) a. These six eggs cost €2.
b. $DIST_C(\lambda x.cost(x, €2))$(the-6-eggs)

On its most salient reading, the relevant cover would be a cover that does not divide the eggs up, but one which just offers a single cell containing the six eggs. This results in a collective understanding. The distributive reading (where these are particularly expensive eggs) results from taking a cover that divides the six eggs up into the individual eggs such that (35b) ends up expressing that each egg costs €2. There are other theoretical possibilities, which are, however, not so salient for the example in (35a). For an example like (36), however, the relevant cover would be one in which the shoes are divided up in pairs, since, pragmatically, that is how shoes are normally valuated. (See Gillon, 1990, for the first indepth discussion of this type of reading.)[5]

(36) The shoes cost \$75. (Lasersohn, 2006)

So far, I have discussed distributive and collective understandings of plural predication, as well as intermediate ones as in (36). I now turn to yet another understanding, *cumulativity*.

9.4 Cumulativity

In the discussion of distributivity above, we saw that one approach (basically that of Landman, 1996, 2000) involves reducing distributivity to pluralisation of $\langle e, t\rangle$ predicates, using Link's *-operation. Notice that in the examples so far we have always *-ed the VP denotation. This is not the only theoretical option. Consider (37).

(37) Two boys carried three pianos up the stairs.

We could imagine quantifier raising the object and thereby creating a derived predicate 'λx.two boys carried x up the stairs'.[6] Using the *-operation, we would then expect there to be a distributive reading for the object: there are three pianos such that each of these pianos was carried up the stairs by

[5] See also Verkuyl and van der Does (1991).
[6] As would be standard in, say, the textbook account of Heim and Kratzer (1998).

a potentially different pair of boys. This reading is available to some, but certainly not all speakers of English. While there may be linguistic reasons to limit such object distributivity, it shows that distributivity is tightly linked to scope.

One way to make the relevant scopal relations more visible is by counting the number of entities that are involved in a verifying scenario. To do this reliably, let me change the example to (38). (A crucial difference from (37) is that while you can carry the same piano multiple times, a book cannot be written more than once.)

(38) Two Dutch authors wrote three Gothic novels.

A collective understanding of (38) is verified by a group of two Dutch authors who collectively wrote three gothic novels. On a distributive reading the verifying situations involve six gothic novels, three for each Dutch author. It is the dependency of the number of books on the number of authors that shows that the subject has scope over the object. Using the number of entities involved as a diagnostic of scope, we can show that another kind of understanding exists, on top of the distributive and the collective one. This is the so-called *cumulative reading* (Scha, 1981). For instance, (39) (a variation on an example from Landman, 2000) is true in a situation in which there were (in total) six ladybird-swallowing frogs and there were (in total) twelve ladybirds being swallowed by frogs.[7]

(39) Six frogs swallowed twelve ladybirds.

The reported reading cannot be a collective reading, since *swallow* is a predicate with distributive entailments. (It makes no sense to swallow a single entity in a joint effort.) It also clearly is not a distributive reading, since the number of ladybirds is twelve, and not seventy-two.[8]

Similarly, (38) has a cumulative reading in which there were two Dutch authors writing Gothic novels and there were three Gothic novels written by Dutch authors. Again, this is not the collective reading. Take, for instance, a verifying situation like one in which one Dutch author writes a gothic novel by himself and then co-writes two more Gothic novels with another Dutch author.

To introduce the popular account of cumulativity, let us go through an elaborate illustration of (38). Assume the following semantics for the subject and the object respectively.

(40) a. $\lambda P.\exists x[\#x = 2 \wedge {}^{*}dutch.author(x) \wedge P(x)]$
b. $\lambda P.\exists y[\#y = 3 \wedge {}^{*}gothic.novel(y) \wedge P(y)]$

[7] Landman (2000) uses a similar example to argue against the reduction of cumulative readings to collective reading, e.g. Roberts (1987).

[8] See Winter (2000) for an attempt at reducing cumulativity to distributivity and dependency and Beck and Sauerland for a criticism of that account.

Here I use # for the 'cardinality' of a sum, as given by the following definition.

(41) $\#\alpha := |Atoms(\lambda\beta.\beta \leq \alpha)|$

The (subject) distributive reading is now given by pluralising the verb phrase:

(42) $\exists x[\#x = 2 \wedge {}^{*}\text{dutch.author}(x) \wedge {}^{*}\lambda x'.\exists y[\#y = 3 \wedge {}^{*}\text{gothic.novel}(y) \wedge wrote(x', y)](x)]$

This is not entirely accurate, since this assumes that the object is interpreted collectively. (It is not entirely clear how books can be collectively written.) So, a probably more accurate semantics is a doubly distributive reading, as in (43):

(43) $\exists x[\#x = 2 \wedge {}^{*}\text{dutch.author}(x) \wedge {}^{*}\lambda x'.\exists y[\#y = 3 \wedge {}^{*}\text{gothic.novel}(y) \wedge {}^{*}\lambda y'.wrote(x', y')(y)](x)]$

The cumulative reading results not from pluralising a derived predicate, but from directly pluralising the binary relation *write* (Krifka, 1989a, 1996; Landman, 1996, 2000). That is, we need to generalise the *-operator to many-placed predicates. Let X be a set of pairs:[9]

(44) $\langle\alpha, \beta\rangle \sqcup \langle\gamma, \delta\rangle := \langle\alpha \sqcup \gamma, \beta \sqcup \delta\rangle$

Now the *-operator can be generalised to binary relations.

(45) ${}^{*}X$ is the smallest set such that ${}^{*}X \subseteq X$ and $\forall x, x' \in {}^{*}X : x \sqcup x' \in {}^{*}X$

The cumulative reading of (38) is now simply (46).

(46) $\exists x[\#x = 2 \wedge {}^{*}dutch.author(x) \wedge \exists y[\#y = 3 \wedge {}^{*}gothic.novel(y) \wedge {}^{*}wrote(x, y)]]$

For instance, if the extension of *wrote* is $\{\langle b, gn1\rangle, \langle b \sqcup c, gn2\rangle, \langle b \sqcup c, gn3\rangle\}$, then ${}^{*}wrote$ will contain $\langle b \sqcup c, gn1 \sqcup gn2 \sqcup gn3\rangle$, verifying (38).

There are two well-studied problems with this account. First of all, because the cumulative reading is scopeless, the above account only works for examples with commutative pairs of quantifiers, such as the two existentials in (46). For instance, (47) also has a cumulative reading, but on a standard generalised quantifier approach to modified numerals, as in (48), the quantifiers are not commutative, since they count atoms and thereby distribute over their scope.

(47) In 2011, more than 100 Dutch authors wrote more than 200 Gothic novels.

(48) $[\![\text{more than } n]\!]\,(P)(Q) =$ true iff the number of atoms that have both property P and Q exceeds n

[9] More general, for n-ary tuples f, g: $f \sqcup g :=$ that n-ary tuple h, such that $\forall 1 \leq m \leq n : h(m) = f(m) \sqcup g(m)$.

Krifka (1999) proposes as a solution to take numerals to be existential quantifiers (as in (40)) and to take their modifiers to be propositional operators on alternative numerical values. So, the interpretation of (47) yields the set of cumulative propositions in (49). The role of the numeral modifiers is now to assert that there is a factual proposition in this set for $n > 100$ and $m > 200$.[10]

(49) $$\left\{ \begin{array}{l} \exists x[\#x = n \wedge {}^{*}dutch.author(x) \wedge \\ \exists y[\#y = m \wedge {}^{*}gothic.novel(y) \wedge \\ {}^{*}\mathrm{wrote}(x, y)]] \end{array} \middle| \; n, m \in \mathbb{N} \right\}$$

A second problem with the pluralisation account of cumulativity comes from examples where a cumulative reading is combined with a distributive one. Such examples were divised by Schein (1993). The standard example is (50). Crucially, there is cumulativity with respect to the three cash machines and the two new members, but the passwords are distributed over these two.

(50) Three cash machines gave two new members each exactly two passwords.

Since each new member was given two passwords, *two new members* has to have scope over *two passwords*. But that scoping should be independent of the scopeless relation between the cash machines and the members. Schein uses examples like (50) as part of an elaborate argument that a plural semantics should be part of a neo-Davidsonian event semantics, where events have a similar part-whole structure as entities.

Partly due to Schein's argument, events play a major role in the dominating approaches to plurality.[11] See, for instance, Kratzer (2007) for recent discussion and Champollion (2010a) for a criticism of some of the arguments for the neo-Davidsonian approach. In the interest of brevity, I refrain from discussing events in this chapter.

9.5 Distributivity and dependency

Since, unlike cumulative readings, distributive readings are scopal, transitive distributive sentences may introduce a dependency between the arguments of the verb. For instance, on the distributive reading, (51) expresses a relation between three boys and (at least) three essays.

(51) Three boys wrote an essay.

This dependency becomes grammatically relevant in at least two different ways. First of all, in a number of languages, indefinites that are dependent

[10] An alternative account is to treat numeral modification as a degree phenomenon. See, for instance, Hackl (2000) and Nouwen (2010). See Geurts and Nouwen (2007) for discussion of a number of complications regarding Krifka's analysis of modified numerals.

[11] See also Parsons (1990) and Lasersohn (1995).

in the way *an essay* is in the distributive reading of (51) have to be marked as such. (For instance, see Farkas, 1997a for Hungarian; Farkas, 2002a for Romanian; Yanovich, 2005 for Russian, and Henderson, 2011 for the Mayan language Kaqchikel). Dubbed *dependent indefinites* by Farkas, such indefinites come with a constraint that they have to co-vary with some other variable. (See Brasoveanu and Farkas, Chapter 8.)

(52) A gyerekek hoztak egy-egy könyvet
the children brought a-a book.ACC
'The children brought a book each.'

Another form of dependency involves anaphora.

(53) a. Three students wrote an article.
They sent it to L&P. (Krifka, 1996)
b. John bought a gift for every girl in his class and asked their desk mates to wrap them. (after Brasoveanu, 2008)

The example in (53a) has many readings. The most salient one is the one in which both sentences are distributive. On that reading, the first sentence introduces a dependency between students and articles, which is then accessed by the pronouns in the second sentence. That is, the second sentence can mean only that each student sent *his or her* paper to L&P. Similarly, there is a salient reading for (53b) in which for each girl, John asked the desk mate of that girl to wrap the gift he bought for *her*.

Such data are hard to account for, especially given some other complicating features of anaphora. For instance, dependent indefinites are antecedents of plural, not singular, pronouns, which have maximal reference. In an example like (54), the singular pronoun is infelicitous and the plural pronoun is interpreted as referring to the set of all essays written by a student.

(54) Several students wrote an essay. I will need to grade them / *it before tomorrow.

In contrast to (54), singular anaphoric reference to a dependent indefinite is possible once the pronoun is in the same kind of dependency environment, as shown by the examples in (53).

A powerful account of these facts is offered by the dynamic mechanisms proposed in van den Berg (1996) and subsequent related work (Nouwen, 2003, 2007; Brasoveanu, 2006, 2008).[12] To get the idea behind these proposals, first consider the simple example in (55).

(55) Two boys were wounded. They are in hospital.

[12] See Krifka (1996) and Kamp and Reyle (1993) for alternative approaches, involving parametrised sums and a representational rule for recovering antecedents respectively. Nouwen (2003) contains a comparison of Krifka's proposal and distributed assignment. See Nouwen (2007) for a (technical) discussion and critique of Kamp and Reyle's approach.

Under a dynamic semantic approach to anaphora, anaphoric relations are captured by assigning antecedent and pronoun the same variable name. (The relevant classic literature is Kamp, 1981b; Groenendijk and Stokhof, 1991; Kamp and Reyle, 1993; see also Asher, Chapter 4, for an overview of discourse semantics that includes a discussion of dynamics.) For instance, the first sentence in (55) could correspond to $\exists x[\#x = 2 \wedge {}^{*}boy(x) \wedge {}^{*}wounded(x)]$. This sentence is verified in a model in which, say, b and c were wounded, by assigning $b \sqcup c$ to x. Let us write $f[x := \alpha]$ to indicate that the assignment function f assigns α to x, and so the relevant variable assignment for the first sentence in (55) are functions of the form $f[x := b \sqcup c]$. The second sentence may now be represented by ${}^{*}inhospital(x)$. By interpreting this open proposition with respect to an assignment function that verifies the antecedent sentence, the pronoun is automatically understood to refer to whichever two boys were referred to in the first sentence.

The innovation brought in van den Berg's work is to assume that the assignment of pluralities to variables happens in a much more structured way. So, rather than using the assignment in (56a), a plurality assigned to a variable, van den Berg uses (56b), a plurality (set) of assignments to the same variable.[13]

(56) a. $f[x := b \sqcup c]$
b. $\{f_1[x := b], f_2[x := c]\}$

The main reason for doing this is that it opens up a way to represent dependencies created by distributivity. For instance, say that Bob is dating Estelle and Carl is dating Ann. This makes (57) true. In a van den Bergian approach to plural dynamic semantics, the sentence will now introduce the variable assignment in (57b), rather than the simplistic (57a).

(57) Bob and Carl are dating a girl.
a. $f[x := b \sqcup c; y = e \sqcup a]$
b. $C = \{f_1[x := b; y := e], f_2[x := c; y := a]\}$

The plurality of variable assignments in (57b) has stored the dependency between boys and girls. In a subsequent sentence, like (58a), a distributive reading can have access to that dependency. Van den Berg therefore proposes that distributivity is universal quantification not over atoms in plural individuals but rather over atomic assignment functions in a contextual set of functions, such as C above.[14]

(58) a. They each brought her a flower.
b. $\forall f \in C[f(x)$ brought $f(y)$ a flower$]$

[13] I see no particular reason why an approach like this would need to involve sets. The same idea could in principle be worked out in a lattice-theoretic framework with *sum functions.* However, I follow here the standard move to use sets of functions.

[14] For the sake of brevity, I am simplifying severely. See Nouwen (2003) for discussion of some complicating factors and for various ways of implementing this idea.

The same framework also has an elegant way of capturing the constraint on Farkas' dependent indefinites, such as the Hungarian reduplication indefinite in (52). Brasoveanu and Farkas (2011) propose that such indefinites are necessarily *evaluation plural*. If C is a set of assignments, let $C(v)$ be the sum given by ${}^{*}\lambda\alpha.\exists f \in C[f(v) = \alpha]$, that is the projection of all values for v in C into a single sum entity. If a dependent indefinite like a Hungarian *egy-egy* noun phrase is associated to a variable x, it presupposes that $C(x)$ is not atomic. For instance, an example like (52), repeated here in (59), is felicitous in the context in (59a), but not in (59b).

(59) A gyerekek hoztak [egy-egy könyvet]$_y$
the children brought a-a book.ACC
a. $C = \{f_1[x := child1; y := book1], f_2[x := child2; y := book2], f_3[x := child3; y := book3]\}$
b. $C = \{f_1[x := child1; y := book1], f_2[x := child2; y := book1], f_3[x := child3; y := book1]\}$

9.6 Conclusions

Space limitations have enforced a somewhat narrow focus on plurality in this chapter. There are a number of key issues I have not been able to pay attention to. In the conclusion of this chapter, let me mention two of these.

So far, I have mentioned two sources of distributivity. First of all, lexically, some predicates are only compatible with atomic entities in their (singular) extension (*being wounded* was the running example). Second, (in at least some approaches) there is additionally a distributivity operator that quantifies over atoms in a sum. A third source is the presence of an inherently distributive quantifier. That is, some quantifiers are *distributive* in the sense that they quantify over atoms only.

(60) A quantifier Q of type $\langle\langle e, t\rangle, t\rangle$ is distributive if and only if for any P of type $\langle e, t\rangle$: $Q(P) \Leftrightarrow Q(\lambda x.P(x) \wedge Atom(x))$

An indefinite quantifier like *three girls* or the definite *the three girls* is not distributive. An example like (61) allows for collective as well as distributive construals.

(61) Three girls carried a piano up the stairs.

Things are different for quantifiers like *every girl*, which are distributive.[15] In (62), any carrying of pianos that involves joint action is irrelevant. Only if each girl carried a piano by herself is (62) true.

[15] One complication is that *every* does have non-distributive readings, as in the following:

(i) It took every/each boy to lift the piano. (Beghelli and Stowell, 1996)

(62) Every girl carried a piano up the stairs.

Similarly distributive is *most girls*:

(63) Most girls carried a piano up the stairs.

If (63) is true, then it is true of most individual girls that they carried a piano by themselves. If the majority of girls jointly carried a piano up the stairs, while a minority stood by and did nothing, (63) is intuitively false.

Quantifiers that are especially interesting from the perspective of plurality are floating quantifiers like *each* and *all*. While *each* enforces a distributive reading in a sentence, as in (64a), the presence of *all* allows for both distributive and collective understandings. Yet, *all* is incompatible with certain collective predicates, as illustrated in (65).

(64) a. The boys each carried a piano up the stairs.
b. The boys all carried a piano up the stairs.

(65) *The boys are all a good team.

See Brisson (2003) for an analysis of *all* using Schwarzschild's (1996) cover analysis of distributivity and collectivity.

While the semantics of *each* is obviously closely related to (atom-level) distributivity, the main puzzle posed by *each* is of a compositional nature. This is especially the case for so-called *binominal each* (Safir and Stowell, 1988). For instance, in (66) *each* distributes over the atoms in the subject plurality, while it appears to be compositionally related to the object. See Zimmermann (2002) for extensive discussion.

(66) These three Dutch authors wrote five Gothic novels each.

Another major issue I have not discussed in this chapter is the interpretation of plural morphology. As I observed at the start, plurals do not generally express *more than one*, for (67) suggests that not even a single alien walked the earth.

(67) No aliens have ever walked the earth.

Krifka (1989a) suggests that while plurals are semantically inclusive, that is they consist of both non-atomic and atomic sums, singulars can be taken to necessarily refer to atoms. The idea is now that, under normal circumstances, use of a plural implicates that the more specific contribution a singular would have made was inappropriate, and hence that a non-atomic reference was intended. Cases like (67) are simply cases in which the implicature is somehow suppressed, for instance, because of a downward monotone environment. See Sauerland (2003), Sauerland et al. (2005) and Spector (2007a) for detailed analyses along these lines. Such approaches often break with the intuition that the plural form is marked, while the singular form is unmarked, and so we would expect that the plural but not the singular contributes some essential meaning ingredient (Horn, 1989).[16] Farkas and de Swart (2010) formulate an account of the semantics of number marking that is in the spirit of Krifka's suggestion but is at the same time faithful to formal markedness in the singular/plural distinction.

Zweig (2008) offers an extensive discussion of the related issue of dependent bare plurals.[17] The most salient reading of (68) is one in which bankers wear one suit at a time, despite the plural marking on the object.

(68) All bankers wear suits.

A typical analysis of (68) is to assume that such sentences are cumulative (Bosveld-de Smet, 1998; cf. de Swart, 2006) and that the plural marking on *suits* triggers an interpretation of the object as a multiplicity of suits. Contrary to this, one could assume that this is a distributive reading and that the plural marking on the object is a result of the dependency the object is part of. Here, the issue of the interpretation of plural morphology meets the issues concerning distributive and cumulative entailments that were central to this chapter. Zweig (2008), for instance, argues that although the cumulative analysis of (68) might be on the right track, this will not do for all examples involving dependent bare plurals. This is because of examples like (69).

(69) Most students wrote essays.

A dependent reading for *essays* in (69) exists, but a cumulative reading for the whole sentence does not, since *most* is a distributive quantifier. Such examples illustrate the complexity of the semantics of the plural and stress that plurality is a compositional rather than a referential phenomenon.

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[16] Most natural languages mark the plural and leave the singular unmarked (e.g. Greenberg, 1966; cf. de Swart and Zwarts, 2010, for discussion of exceptions).

[17] Moreover, he discusses a complication that an event-based semantics for plurality brings.

10

Genericity

Ariel Cohen

10.1 Introduction

We often express our knowledge about the world in sentences such as the following:

(1) a. Ravens are black.
 b. Tigers have stripes.
 c. Mary jogs in the park.

We refer to such sentences as *generics*. They appear to express some sort of generalization: about ravens, about tigers, and about Mary, respectively. Yet it is far from clear exactly what they mean. What does it mean to say that some generalization holds?

It turns out that there are a great many theories trying to answer this question. This, in itself, is a fact that is in need of explanation. Why are generics so puzzling? What is it about them that forces researchers to come up with one theory after another, with no clear agreement on what the correct theory is? And, if they are so strange, why are generics so prevalent?

In this article we will consider some of the puzzles concerning generics, why they are so hard, and the various solutions proposed. Let me say at the outset that readers who expect to find definitive answers to these puzzles will, regrettably, be disappointed. But if not the answers, I hope this article will at least convey the depth and significance of the problems.

10.2 Two types of generic

Before we begin our investigation, we need to note that generics do not constitute a uniform phenomenon. A distinction that is often drawn is between *direct kind predication* and *characterizing generics*.

To see this distinction, consider the following typical example:

(2) Dinosaurs are extinct.

There is no individual dinosaur that is extinct; individual dinosaurs are just not the sort of thing that can be extinct – only the kind *dinosaur* can have this property. A natural account of (2) is that it predicates the property of being extinct directly of the kind *dinosaur*. Krifka et al. (1995) refer to such sentences, which predicate a property directly of a kind, as cases of direct kind predication. They distinguish between them and sentences such as (1a), which predicate a property of instances of a kind, and not of the kind as a whole; these are named characterizing generics.

One test for cases of direct kind predication is to verify that it is impossible to modify the sentence by an overt adverb of quantification. For example, (3) is bad, confirming that (2) is a case of direct kind predication:

(3) $$\text{*Dinosaurs are} \left\{ \begin{array}{c} \text{always} \\ \text{usually} \\ \text{sometimes} \\ \text{never} \end{array} \right\} \text{extinct.}$$

In contrast, (4) is fine, indicating that (1a) is, indeed, a characterizing generic.

(4) $$\text{Ravens are} \left\{ \begin{array}{c} \text{always} \\ \text{usually} \\ \text{sometimes} \\ \text{never} \end{array} \right\} \text{black.}$$

Another test involves scope: characterizing generics, but not direct kind predication, display scope ambiguities. For example, the characterizing generic (5a) may mean either that each stork has a (possibly different) favorite nesting area, or that there is one nesting area favored by storks.

In contrast, (5b) can only mean that there is one predator endangering the species.

(5) a. Storks have a favorite nesting area (Schubert and Pelletier, 1987).
    b. Storks are in danger of being exterminated by a predator.

10.3 Are generics quantificational?

A substantial portion of the research into generics involves the question of whether they involve quantification. Regarding direct kind predication, the answer appears to be simple: Example (2) simply predicates the property of being extinct of the kind *dinosaur*, and no quantification is involved. But what about characterizing generics?

Possibly the first interpretation that comes to mind is that characterizing generics express quantification of some sort. Perhaps a sentence such as (1a) is really just a different way to say something like the following:

(6) Every raven is black.

Things are not that simple, unfortunately. First, note that generics do not express universal quantification: while (1a) is true, (6) is false, because there are some albino ravens. Still, even if the quantifier is not the universal one, perhaps generics use some other quantifier. If this is the case, our role is to figure out what this quantifier is.

This, however, is a far from easy task. Consider the following examples of characterizing generics:

(7) a. Dogs are mammals.
    b. Birds fly.
    c. Mammals bear live young.
    d. The Frenchman eats horsemeat.
    e. Bulgarians are good weightlifters.
    f. Primary school teachers are female.
    g. People are over three years old.
    h. Members of this club help each other in emergencies.
    i. Supreme Court judges have a prime Social Security number.
    j. A: Nobody in India eats beef.
       B: That's not true! Indians do eat beef.
    k. Nephi's dog chases cars.

Sentences (7a)–(7e) are all arguably true, but what is it that makes them true?

Sentence (7a) seems to hold for all dogs, (7b) for most birds, (7c) for most female mammals (presumably fewer than half the total number of mammals), (7d) for rather few Frenchmen, and (7e) for very few Bulgarians.

Sometimes a majority of instances of the kind satisfy the predicated property, and yet the generic is not true: the majority of primary schoolteachers are female, and the majority of people are over three years old, and yet (7f) and (7g) are not true. Even if no emergencies ever occurred, (7h) may be true, and even if all Supreme Court judges happened to have a prime Social Security number, (7i) may be false. The truth of B's answer in (7j) requires only that *some* Indians eat beef, and it is far from clear how often Nephi's dog has to chase cars for (7k) to be true – perhaps only on occasion.

The diversity of interpretations of generics, as exemplified by the sentences in (7), poses severe problems for any theory that attempts to relate the truth or falsity of a generic to properties of individual instances; for example, any theory that relates the truth of (1a) to properties of individual ravens. Given this difficulty, there are two approaches one may take.

One, which Carlson (1995) calls the *rules and regulations* approach, is to deny that any semantic relation exists between generics and properties of individuals; generics, according to this view, are evaluated with respect to rules and regulations, which are basic, irreducible entities in the world. Each generic sentence denotes a rule; if the rule is *in effect*, in some sense (different theories construe differently what it means for a rule to be in effect), the sentence is true, otherwise it is false. The rule denoted by a generic may be physical, biological, social, moral, and so on.

The paradigmatic cases for which this view seems readily applicable are sentences that refer to conventions, that is, man-made, explicit rules and regulations, such as the following example (Carlson, 1995):

(8) Bishops move diagonally.

According to the rules and regulations view, (8) is not about the properties of individual bishop moves, but refers directly to a rule of chess; it is true just in case one of the rules of chess is that bishops move diagonally. It is important to note that, according to the rules and regulations view, *all* generics are so analyzed: for example, (1a) is true not because of the properties of individual ravens, but because there is a rule in the world (presumably a rule of genetics) that states that ravens are black. The rules and regulations view is a cover term for a number of specific theories, which we do not have space to go into here. Generics have been variously analyzed as simple predications of a property of a kind (Carlson, 1977a), default rules (Krifka, 1987), conventions of conversation (McCarthy, 1986; Reiter, 1987), stereotypes (Geurts, 1985; Declerck, 1986), constraints on situations (ter Meulen, 1986; Cavedon and Glasbey, 1997), and primitive generalizations of the human conceptual system (Leslie, 2007).

An alternative approach, which Carlson (1995) calls the *inductivist* view, is to accept the existence of a semantic relation between generics and properties of individuals. Theories that take this view attempt to define this relation in such a way that its nature (possibly in conjunction with facts about context, intonation, and world knowledge) may account for the diversity of readings of generics, exemplified in (7). Again, the inductivist view is just a cover term for a great many specific theories. According to some, the generic quantifier is a restricted universal (Declerck, 1991), "most" (Parsons, 1970a; Nunberg and Pan, 1975) or "significantly many" (Farkas and Sugioka, 1983) individuals, or ambiguous (Schubert and Pelletier, 1987). For reasons to be discussed below, many researchers have proposed modal theories, according to which generics express quantification over normal or stereotypical individuals (Delgrande, 1987; Schubert and Pelletier, 1989; Morreau, 1992; Asher and Morreau, 1995; Krifka, 1995a; Pelletier and Asher, 1997; Greenberg, 2003; Nickel, 2009), or probability judgments (Cohen, 1996, 1999).

Given the wealth of theories concerning generics, how can we even begin to decide which one, if any, is correct?

10.4 Combining the two types of theory

It appears that there are some generics, e.g. (8), that are better explained by rules and regulations theories, and others, e.g. (1a), that are better explained by inductivist theories. One may wish to consider, then, whether the two types of theory can somehow be combined.

This possibility is rejected by Carlson (1995). He describes the two approaches as a dichotomy: we have to choose one or the other, but not both. How can we decide which? One way is to consider a case where the behavior of observed instances conflicts with an explicit rule.

For example, Carlson describes a supermarket where bananas sell for \$0.49/lb, so that (9a) is true. One day, the manager decides to raise the price to \$1.00/lb. Carlson claims that immediately after the price has changed, sentence (9a) becomes false and sentence (9b) becomes true, although all sold bananas were sold for \$0.49/lb.

(9) a. Bananas sell for \$0.49/lb.
 b. Bananas sell for \$1.00/lb.

Consequently, Carlson reaches the conclusion that the rules and regulations approach is the superior one.

This conclusion has been challenged by Cohen (2001). Suppose the price has, indeed, changed, but the supermarket employs incompetent cashiers who consistently use the old price by mistake so that customers are still charged \$0.49/lb. In this case, there seems to be a reading of (9a) that is true, and a reading of (9b) that is false. These readings are more salient if the sentence is modified by expressions such as *actually* or *in fact*:

(10) a. Bananas actually sell for \$0.49/lb.
 b. In fact, bananas sell for \$1.00/lb.

Consequently, Cohen (2001) claims that generics are ambiguous: on one reading they express a descriptive generalization, stating the way things are. Under the other reading, they carry a normative force, and require that things be a certain way. When they are used in the former sense, they should be analyzed by some sort of an inductivist account; when they are used in the latter sense, they ought to be analyzed as referring to a rule or a regulation.[1] The respective logical forms of the two readings are different; whereas the former reading involves, in some form or another, quantification, the latter has a simple predicate-argument structure: the argument is the rule or regulation, and the predicate holds of it just in case the rule is "in effect."

A language that makes an explicit distinction between these two types of reading is French. In this language, generically interpreted plural nouns are preceded by the definite determiner *les*, whereas the indefinite determiner *des* usually induces existential readings. However, *des* may also be used to make a normative statement, that is, to express some rule or regulation.

(11) a. Des agents de police ne se comportent pas ainsi dans une situation d'alarme.
INDEF-PL police officers do not behave like that in an emergency situation.
b. Les agents de police ne se comportent pas ainsi dans une situation d'alarme.
DEF-PL police officers do not behave like that in an emergency situation.

An observation that de Swart (1996) ascribes to Carlier (1989) is that whereas (11a) "would be uttered to reproach a subordinate with his behavior," (11b) "does not have the same normative value, but gives us a descriptive generalization which could possibly be refuted by providing a counterexample." Hence, it seems that the distinction between the inductivist reading and the rules and regulations reading is encoded in French as the *les*/*des* distinction.

10.5 Lawlikeness and modality

Perhaps one of the reasons why it is so hard to determine whether generics are quantificational, and, if so, what the quantifier is, is that generics are *lawlike*.

The distinction between lawlike and non-lawlike statements is well known in philosophy and is easily demonstrated using universally quantified sentences. For example, (12a) intuitively expresses a law of nature; (12b), in contrast, expresses an accidental fact.

(12) a. All copper wires conduct electricity.
b. All coins in my pocket are made of copper.

[1] Greenberg (2003) makes a similar point regarding the ambiguity of generics, but she claims that both readings can receive an inductivist account.

One way to characterize the difference between lawlike and non-lawlike statements is that only the former, not the latter, support counterfactuals. Thus, (12a) entails (13a), but (12b) does not entail (13b).

(13) a. If this were a copper wire, it would conduct electricity.
b. If this coin were in my pocket, it would be made of copper.

Note that we can turn (12a), but not (12b), into a felicitous generic; (14a) is fine (and true), but (14b), under its generic interpretation, is odd (cf. (7i) above).

(14) a. Copper wires conduct electricity.
b. Coins in my pocket are made of copper.

Generics, in general, support counterfactuals; the truth of (15a) entails (15b).

(15) a. Birds fly.
b. If Dumbo were a bird, he would probably fly.

It is tempting to think that rules and regulations theories are particularly well suited to handle this aspect of generics: it seems that all we need to require is that the rule or regulation a generic denotes be nonaccidental. Things are not that simple, however: rules and regulations approaches have difficulties accounting for the fact that generics support counterfactuals. If there is no relation between the truth of (15a) and the flying abilities of actual birds, why should there be such a relation between its truth and the flying abilities of hypothetical birds?

Inductivist theories face difficulties too. If generics involve a quantifier, it has rather special properties: this quantifier must be sensitive not only to the number of individuals satisfying a certain property, but also to whether the statement is lawlike or not. Extensional theories of genericity, therefore, face a substantial problem here. For this reason, many researchers, as we have seen, propose modal treatments of generics; the hope is that the notion of lawlikeness is similar enough to the notion of necessity to be formalizable within a possible-worlds framework.

Modal statements are usually considered to be characterized by three elements (see Kratzer, 1981, and Matthewson, Chapter 18):

1. The modal force: the nature of the quantifier over possible worlds (universal, existential, or perhaps something in between).
2. The modal base: a set of relevant possible worlds.
3. The ordering source: a relation of preference among possible worlds. The modal statement is evaluated with respect to the preferred worlds.

In this section I will concentrate on the issue of the ordering source of generics.

A rather common view is that the ordering source is *stereotypical*. A stereotypical ordering source prefers “worlds in which the normal course of events is realized" (Kratzer, 1981, 47), or "worlds similar to [the actual world] with regard to the 'inherent' or 'essential' nature of things" (Schubert and Pelletier, 1989, 260). Then (1a) would mean something like (16).

(16) In worlds in which ravens exhibit their normal/essential properties, they are black.

Or, more succinctly, if slightly less accurately:

(17) All normal ravens are black.

There is, however, an alternative. Clearly, a generic expresses an inductive inference from a collection of repeated instances. Hume (1748) has famously demonstrated that in order for induction to work, we have to assume that the world is uniform, in the sense that future events resemble past and present ones. Although this assumption is probably not warranted in general, it makes sense to treat an inductive statement as carrying the assumption that the world is uniform. Hence, one may propose that generics are evaluated with respect to a *uniform* ordering source: one that prefers worlds that are uniform. In this case, (1a) would be paraphrased as follows:

(18) In worlds that share the history of the actual world, and whose future resembles the past, ravens are black (see Cohen, 1999, 2012a).

In other words, there has been a high proportion of black ravens, and this high proportion is expected to continue.

How can we decide between the two approaches? The main difference between the two theories of the ordering source of generics concerns which worlds are considered when a generic is evaluated. According to stereotypical theories, generics are sensitive to what happens in worlds in which *normal* or *essential* properties of the actual world are preserved. In contrast, according to uniform theories, generics are sensitive to what happens in worlds in which *stable* properties of the actual world are preserved.

Let us restate these predictions as follows. Consider a generic sentence which, for simplicity, we will represent as $\mathbf{gen}(\psi, \phi)$. Under which conditions can ψ be replaced with ψ', so that $\mathbf{gen}(\psi', \phi)$ will have the same truth value? If generics were extensional, then all we should require is that ψ and ψ' have the same extension in the actual world. According to the stereotypical theories, ψ and ψ' should have the same extension in worlds that preserve the normal/essential properties of the actual world; according to uniform theories, ψ and ψ' should have the same extension in worlds that preserve the stable properties of the actual world. These differing predictions can actually be tested empirically.

Consider (19), from Carlson (1989), originally due to Barbara Partee.

(19) A computer computes the daily weather forecast.

The relevant reading for our purposes is where (19) is a generic sentence about the daily weather forecast.[2] One indication that the definite singular is interpreted generically is that it can be replaced with a bare plural, with no appreciable change in meaning:

(20) A computer computes daily weather forecasts.[3]

Now, Carlson observes that

> "the daily weather forecast" requires an intensional interpretation, where its meaning cannot be taken as rigidly referring to the present weather forecast, e.g. the one appearing in today's copy of the *Times* predicting light rain and highs in the upper thirties. (p. 179)

For example, if today's weather forecast predicts a blizzard, this may well be the main news item. Yet, (19) does not entail the following:

(21) A computer computes the main news item.

While a computer may have computed today something that turned out to be the main news item, this does not hold in general; on most days, the main news item will not be computed by a computer, and hence (21) is false.

We can therefore conclude that generics are, as expected, not extensional. More pertinent to our discussion here is the fact that generics are sensitive to *stable* properties of the actual world: the property of being the main news item is not a stable property of the weather report, and therefore (19) and (21) may have different truth values. The daily weather forecast and the main news item have different extensions in worlds that preserve the stable properties of the actual world, and the substitution of one for the other fails to preserve truth value, as predicted by the uniform theories.

Are generics also sensitive to *essential* properties? The answer appears to be no. Suppose that the weather report is Mary's favorite newspaper column. This is a stable property of Mary, but not an essential one: she would still be the same person, and there would be nothing abnormal about her, if she had other interests.[4] However, (22) has the same truth value as (19), indicating that generics are not sensitive to this distinction.

(22) A computer computes Mary's favorite newspaper column.

The daily weather forecast and Mary's favorite newspaper column have the same extension in worlds that preserve stable properties of the actual world, but not in worlds that preserve essential properties of the actual world. The truth value does not appear to change when one term is substituted for the other, which is in contradiction with the prediction of the stereotypical theories.

[2] The sentence might also be read as an indefinite generic about the nature of computers, but, as Carlson (1989) points out, it would be false on this reading.

[3] See Section 10.7 below for the different realizations of generic noun phrases.

[4] Though there are some philosophers, most famously Leibniz, who would dispute this.

Additional examples are not difficult to come by. It is true in the actual world that the whale is the largest animal on earth, and the quetzal is Guatemala's national bird, but it is not an essential property of either: perhaps being large is an essential property of whales, but it is an accident that no currently living animal is larger; and while Guatemala may have decided to designate the quetzal its national bird because of some essential properties that it has, the decision itself is surely an accidental property. Yet (23a) and (24a) have the same respective truth values as (23b) and (24b).

(23) a. The whale suckles its young.
b. The largest animal on earth suckles its young.

(24) a. The quetzal has a magnificent, golden-green tail.
b. Guatemala's national bird has a magnificent, golden-green tail.

It might be argued that this phenomenon is due not to the sensitivity of generics to stable properties, but merely to a *de re* interpretation of the definite. An anonymous reviewer points out that if the whale appears on the cover of today's newspaper, and the quetzal is featured on the evening news tonight, (25a) and (25b) would follow from (23a) and (24a), respectively, even though being featured on today's newspaper or evening news is clearly not a stable property.

(25) a. The animal on the cover of the newspaper suckles its young.
b. The animal featured on the evening news has a magnificent tail.

While I agree that (23b) and (24b) also have a *de re* interpretation, the point made here is that they follow from (23a) and (24a) under their *de dicto* interpretation. This can be seen if we modify the definite to make it clear that we are referring to its denotation over a prolonged period of time:

(26) a. The largest animal on earth in the last 40 million years suckles its young.
b. Guatemala's national bird since 1868 has a magnificent, golden-green tail.

Note that while (26a) and (26b) still follow from (23a) and (24a) respectively, a similar modification to the examples in (25) would change their truth value:

(27) a. The animal on the cover of the newspaper in recent weeks suckles its young.
b. The animal featured on the evening news since last weekend has a magnificent tail.

Now, (27a) does not follow from (23a), and (27b) does not follow from (24a).

It is easier to construct such examples with definite singular generics, as above, but the same phenomenon can be observed with bare plural generics too. Suppose John fears all bats but no other animal. This is a stable property of John, but not an essential one. Hence, worlds where he likes bats are perfectly normal. And yet (28a) and (28b) have the same truth value:

(28) a. Bats fly.
b. Animals that John fears fly.

Generics, then, are sensitive to stable properties, rather than essential ones, and we can therefore conclude that they are evaluated with respect to a uniform, rather than a stereotypical, ordering source. In other words, generics do not quantify over normal individuals, but over individuals that do not change their relevant properties abruptly.

10.6 Frequency adverbs

It is often pointed out that generics are similar to sentences involving an overt adverb of quantification. Consider the sentences in (1), when modified by an overt adverb.

(29) a. Ravens are usually black.
b. Tigers always have stripes.
c. Mary sometimes jogs in the park.

Just like the generics in (1), these sentences express some generalization about ravens, tigers, and Mary, respectively. The difference is that, unlike generics, which have no quantifier (according to the rules and regulations view), or an implicit quantifier with some special properties (according to the inductivist view), here we have an explicit quantifier. Thus, the sentences in (29) are also similar to overtly quantified sentences such as the following:

(30) a. Most ravens are black.
b. All tigers have stripes.
c. Some occasions of Mary's jogging are in the park.

Some researchers (de Swart, 1991; Chierchia, 1992) have proposed that frequency statements are, in fact, equivalent to sentences such as (30); they express simple quantification. However, a problem with this approach is that frequency statements, like generics but unlike the sentences in (30), are lawlike. For example, the truth of (31), just like the generic (7i), requires more than simply that the current Supreme Court judges have a prime Social Security number.

(31) Supreme Court judges always have a prime Social Security number.

Moreover, frequency statements, just like generics, support counterfactuals. The truth of (29b), for example, entails the counterfactual in (32).

(32) If Simba were a tiger, he would have stripes.

An alternative is to treat frequency statements as just another kind of generic. As Carlson (1995) points out, this is problematic for the rules and regulations approach. While we may expect that there is a (genetic) rule making ravens black, it is hard to accept a rule that states that *most* of them are; while there may be a rule of Mary's behavior that makes her jog in the park, it is hard to imagine a rule that says, in effect: "Mary, jog in the park sometimes!"

Not all versions of the inductivist view fare better. Some of them, being extensional, fail to account for the lawlike nature of generics, and hence cannot account for the lawlikeness of frequency adverbs either.

The normality approach, if applied to frequency adverbs, would mean that they quantify over normal individuals, but it would face a different problem. If frequency adverbs, just like generics, quantify over normal individuals only, (33) would be (wrongly) predicted false, since, by hypothesis, all normal ravens are black.

(33) Ravens are sometimes white.

The alternative modal approach, which proposes a uniform ordering source, fares better: (33) now does not constitute a problem, since being white, while not a stereotypical property of ravens, is nonetheless a stable one.

It seems that such an inductivist approach, which takes generics to express some quantification over possible individuals with respect to a uniform ordering source, appears to offer better prospects for a uniform account of generics and frequency adverbs. The generic quantifier can be taken to be just another frequency adverb, with the semantics of *generally*, *usually*, or something of the sort.

The situation is more complicated, however. There is a difference between generics and frequency adverbs that needs to be commented upon. Sentences (7f) and (7g), although bad as generics, become perfectly fine (and true) if a frequency adverb such as *generally* or *usually* is inserted:

(34) a. Primary school teachers are generally female.
b. People are generally over three years old.

Therefore, the interpretation of generics, though similar to that of some adverbs of quantification, cannot be identical to it.

Cohen (1999, 2004) proposes that generics presuppose their domain to be homogeneous, in the following sense. The generic "ψs are ϕs" requires that the property ϕ hold not only for ψs, but also over every psychologically salient subset of ψ. For example, assuming that it is salient to partition the domain of teachers according to sex, (7f) requires that both male and female teachers be female – a requirement that is clearly violated. Similarly, assuming that a partition of people according to age is salient, (7g) requires that people of all ages be over three years old, hence it is not true. In contrast, frequency adverbs do not require homogeneity. Sentence (34a) only requires that the property of being female hold, in general, of the domain of teachers as a whole, which it does, since the vast majority of primary school teachers *are* female. Similarly, (34b) requires merely that the property of being over three years old hold, in general, of people as a whole, which it does.

10.7 Realizations of generics

No known language contains a specific construction that is exclusively devoted to the expression of genericity (Dahl, 1995). Yet there is no language that does not express genericity in some form or another. Even a language like Pirahã, which has been claimed to lack any phonologically overt quantifiers, uses generics (Everett, 2005).

It follows that expressions used for generics have a double nature: they have generic as well as nongeneric uses. Of particular interest are the forms of noun phrases that may be given a generic interpretation. In English, generic noun phrases may be bare plurals, definite singulars, or indefinite singulars.[5] It turns out that there are differences in the generic interpretations of these constructions; let us look at each one of them in turn.

10.7.1 Bare plurals

The most common way to express a generic sentence in English is with a bare plural, i.e., a plural noun preceded by no determiner. It is well known that bare plurals may receive not only a generic reading, but an existential one as well. Thus, while (35a) makes a generalization about plumbers in general, (35b) states that there are some plumbers who are available.

(35) a. Plumbers are intelligent.
b. Plumbers are available.

There has been much research on the conditions that determine when a bare plural is interpreted generically, and when existentially (Carlson, 1977a; Diesing, 1992b; Chierchia, 1995b; Kratzer, 1995; Dobrovie-Sorin and Laca, 1996; Bosveld-de Smet, 1998; É. Kiss, 1998b; McNally, 1998c; Jäger, 1999; Cohen and Erteschik-Shir, 2002, among others). In this section we will concentrate on the generic interpretation only. What is the denotation of a generically interpreted bare plural?

Some researchers (e.g., Wilkinson, 1991; Diesing, 1992b; Kratzer, 1995) claim that bare plurals are ambiguous: they may denote kinds, in which case we get direct kind predication, or they may be interpreted as indefinites, that is, as variables ready to be bound by the generic quantifier, resulting in characterizing generics.

[5] Definite plurals can be used generically, but only in a few marked, and arguably idiomatic, cases, so they will not be considered here.

There are, however, reasons to believe that generic bare plurals uniformly refer to kinds, in characterizing generics as well as in cases of direct kind predication.[6] Consider the case of a bare plural that serves simultaneously as the subject of two clauses: one is a characterizing generic, and the other expresses direct kind predication.

(36) a. Dodos lived in Mauritius and (they) became extinct in the 18th century. (after Heyer, 1990)
b. Elephants are killed for their tusks and are therefore an endangered species.
c. Dinosaurs, which are now extinct, were very big.

The most straightforward explanation for the phenomena exemplified by the sentences in (36) is that a generic bare plural unambiguously refers to kinds.

Moreover, Carlson (1977a, 1982) points out that generic bare plurals behave in a way that is similar to referring expressions, rather than indefinites or quantifiers. His arguments apply equally well to characterizing generics and direct kind predication. For example, he notes that if the antecedent of a pronoun is a name, it can replace the pronoun without a change in meaning; not so, in general, when the antecedent is an indefinite. Generics seem to behave like names, rather than indefinites, in this regard:

(37) a. Fred walked into the room. *He* smiled (= *Fred* smiled).
b. A man walked into the room. *He* smiled ($\neq$ *A man* smiled).
c. Dogs are intelligent mammals. *They* are also man's best friend (= *Dogs* are man's best friend).

An additional observation, ascribed by Carlson to Postal (1969) is that names and generics, and only names and generics, can participate in *so-called* constructions:

(38) a. Giorgione is so-called because of his size.
b. Machine guns are so-called because they fire automatically.
c. *A machine gun is so-called because it fires automatically.

If bare plurals in characterizing generics denote kinds, a natural question arises: how is a characterizing generic obtained from a kind-denoting bare plural? In order to answer this question, Carlson (1977a) proposes a *realization* relation between an instance and a kind. Thus, for example, $R(x, \textbf{dog})$ indicates that x is an instance of the kind *dog*, i.e., x is a dog. Ter Meulen (1995) and Chierchia (1998b) propose a semantic type-shifting operator, which transforms a kind into the property of being an instance of the kind. Alternatively, Cohen (2012b) argues for a pragmatic operator

[6] Krifka et al. (1995) agree that bare plurals refer to kinds in characterizing generics too, but restrict this only to "well-established kinds." We will discuss this issue further in the next section.

that transforms a predicate over individuals into a predicate over kinds. The application of this type-shifting operator is optional. When it is applied, the result is a characterizing generic; when it is not – direct kind predication. Thus every generic sentence is ambiguous between characterizing and kind interpretations; but one of these readings is ruled out as semantically anomalous. For example, (1a) has a reading where the property of being black is predicated directly of the kind *ravens*. But this reading is ruled out, because a kind is not the sort of thing that can have a color. Similarly, (2) has a reading where individual dinosaurs are extinct. This time, the characterizing interpretation will be ruled out, since individual dinosaurs cannot be extinct.

When interpreted generically, bare plurals may receive collective readings, that is, they may be the arguments of predicates such as the intransitive *meet*, and *gather*.[7] Consider the following example (attributed by Krifka et al., 1995, to Gerstner, 1979):

(39) Lions gather near acacia trees when they are tired.

To account for this fact, Krifka et al. (1995) propose that groups of individuals are also individuals in their own right (cf., e.g., Link, 1983; Ojeda, 1993), and that, therefore, they can be instances of a kind just like single individuals can. Thus, (39) predicates the property of gathering on groups of lions, rather than individual lions. If sufficiently many such groups gather, (39) is true.

There is reason to believe, however, that groups of individuals are not always considered individuals. Consider generics with a distributive property, e.g.:

(40) Lions have a bushy tail.

According to Krifka et al. (1995), (40) is true just in case sufficiently many groups of lions have a bushy tail. The problem is that when a distributive property such as *have a bushy tail* is applied to a group, it needs to hold of all members of the group. For example, (41) means that each one of the lions in the cage has a bushy tail.

(41) The lions in the cage have a bushy tail.

Now suppose that only two of all lions lack a bushy tail. Given that the number of lions is fairly large, sentence (40) ought to be true. However, it can be easily seen that only a quarter of all possible groups of lions contain neither of the “deficient” lions. If we grant that a quarter of all groups of lions is not sufficiently many, (40) would be predicted false.

Sentence (40) would cease to be a problem if we assume that groups are simply not allowed as instances in this case, but only atomic individuals are. And, in general, when the predicated property is distributive, group

[7] See Nouwen, Chapter 9, on collective readings of plurals.

instances are not considered in evaluating the truth of the generic sentence (Cohen, 1996).

10.7.2 Definite singulars

Just like bare plurals, definite singular generics may occur in cases of direct kind predication as well as characterizing generics, as exemplified by the following sentences:

(42) a. The giant panda eats bamboo shoots.
b. The giant panda is an endangered species.

Sentence (42a) is about individual pandas, whereas (42b) is about the kind *giant panda* as a whole. We therefore expect definite singulars to have collective readings, as the following examples indicate:

(43) a. The lion gathers near acacia trees when it is tired. (Gerstner, 1979; Krifka et al., 1995)
b. The antelope gathers near water holes. (Heyer, 1990)

Are the sentences in (43) indeed acceptable, as the cited sources maintain? Some informants agree, but others judge them to be marginal. This marginality, however, may be due to other reasons, perhaps the number feature of the verb; intransitive *gather* is not normally used in the singular. When the collective verb is predicated of a conjunction of definite singular generics, so that the number of the verb is plural, the acceptability of the sentence improves markedly:

(44) Two species of big cats, the lion and the leopard, gather near acacia trees when they are tired.

A noncontrived, naturally occurring example is the following sentence, taken from the entry for *shark* in the *American Academic Encyclopedia*:

(45) Some sharks, such as the tiger shark and the great white, are loners and seemingly swim at random, although they sometimes gather to feed.

We mentioned above that Krifka et al. (1995) claim that bare plurals may only refer to well-established kinds. They reach this conclusion by comparing the distribution of generic definite singulars with that of bare plurals: they find that the distribution of the former is much more restricted. Compare the acceptability of (46a) with the oddness of (46b) (an example that Carlson, 1977a, ascribes to Barbara Partee).

(46) a. The Coke bottle has a narrow neck.
b. ?The green bottle has a narrow neck.

Krifka et al.'s account of this fact is as follows. Definite singulars must refer to a kind in order to be interpreted generically. The kind *Coke bottle* is well established in our culture; hence, the reference succeeds and (46a) is interpreted generically. The kind *green bottle*, on the other hand, is not well established, so the reference fails and (46b) cannot be interpreted generically (it is, of course, fine under the nongeneric reading).

In contrast, both (47a) and (47b) are fine.

(47) a. Coke bottles have narrow necks.
b. Green bottles have narrow necks.

The acceptability of the sentences in (47) is explained by the claim that bare plurals do not always refer to kinds. The subject of (47a) denotes the kind *Coke bottle*, but the subject of (47b) does not refer to any kind – it is interpreted as a variable.

While the distribution of definite generics is, indeed, restricted, it is not clear that the facts about this distribution can be explained in terms of well-established kinds. The acceptability of the definite generic seems to depend on a variety of factors (see Vendler, 1971; Carlson, 1977a; Bolinger, 1980; Dayal, 1992, among others). For example, the definite generic is often more acceptable when the descriptive content of the common noun is richer. Contrast the oddness of (48a) (under the generic reading) with the acceptability of (48b).

(48) a. ?The politician never misses a photo opportunity.
b. The successful politician never misses a photo opportunity.

Yet one would be hard pressed to argue that *successful politician* is a well-established kind, whereas *politician* is not.

There are additional, poorly understood factors affecting the productivity of the definite generic, which appear idiosyncratic and language dependent. Contrast (49a), which is fine, with (49b), which is odd (under the generic reading).

(49) a. The tiger lives in the jungle.
b. ?The dog barks.

Yet there is no reason to suppose that the kind *tiger* is better established than the kind *dog*. The distinction seems to be an idiosyncratic property of English; indeed, there are languages where the equivalent of (49b) is perfectly acceptable, e.g., German:

(50) Der Hund bellt. (Heyer, 1990)

10.7.3 Indefinite singulars

Unlike bare plurals and definite singulars, indefinite singulars may not refer to kinds, as the unacceptability of the following examples indicate:

(51) a. *A giant panda is an endangered species.
b. *A dinosaur is extinct.

There is, in fact, a reading under which these sentences are acceptable, the *taxonomic* reading, according to which some subspecies of giant panda is endangered, or some species of dinosaurs is extinct. Under this reading, however, the subject is interpreted existentially, rather than generically, with the existential quantifier ranging over kinds. Therefore, this reading need not concern us here.

If indefinite singulars may not refer to kinds, we can predict that collective readings are impossible. This is, indeed, borne out:

(52) *A lion gathers near acacia trees when it is tired.

The distribution of the indefinite singular is restricted compared with that of the bare plural, but in ways that are different from those of the definite singular. Consider the following pair (Lawler, 1973):

(53) a. A madrigal is polyphonic.
b. *A madrigal is popular.

While (53a) receives a generic interpretation, (53b) cannot. In contrast, both (54a) and (54b) are fine.

(54) a. Madrigals are polyphonic.
b. Madrigals are popular.

Burton-Roberts (1977) provides a number of additional examples, among which are the following:

(55) a. Kings are generous.
b. *A king is generous.

(56) a. Rooms are square.
b. *A room is square.

(57) a. Uncles are garrulous.
b. *An uncle is garrulous.

Lawler (1973) claims that this difference between bare plural and indefinite singular generics is due to the fact that the latter are restricted to properties that are, in some sense, "necessary," "essential," "inherent," or "analytic." Thus, whereas polyphonicity is an essential property of madrigals, popularity is not; hence, the unacceptability of (53b). One problem with this approach is that it falls short of a complete explanation: why is it indefinite singulars, rather than bare plurals or definite singulars, that are restricted in this way? Moreover, Lawler's proposal fails to account for sentences such as the following:

(58) A madrigal is a popular song.

Although (58) seems to be saying exactly the same as (53b), it is perfectly acceptable.

Krifka et al. (1995) propose an account of indefinite singulars based on the fact that they may not refer to kinds. They suggest that all cases where the indefinite singular generic is disallowed are cases of direct kind predication. That is to say, just as (2) expresses a property directly of the kind *dinosaur*, and not of individual dinosaurs, (54b) expresses a property directly of the kind *madrigal*. Specifically, unlike (54a), the logical form of (54b) does not involve the generic quantifier. Since indefinite singulars cannot occur in cases of direct kind predication, (53b) is ruled out. This approach amounts to disposing with the quantificational account of genericity except for a small number of cases such as (54a). It follows that characterizing generics are, in fact, the exception, rather than the rule.

However, it is not clear that the claim that (54b) is a case of direct kind predication can be maintained. If we apply the relevant tests, it appears that these are cases of characterizing generics rather than direct kind predication: the sentences in (59) are grammatical, and (60) exhibits a scope ambiguity.

(59) a. Madrigals are always popular.
b. Kings are usually generous.
c. Rooms are sometimes square.
d. Uncles are never garrulous.

(60) Madrigals are popular with exactly one music fan.

Burton-Roberts (1977) proposes that indefinite singulars carry a normative force. He considers the following minimal pair:

(61) a. Gentlemen open doors for ladies.
b. A gentleman opens doors for ladies.

Burton-Roberts (1977) notes that (61b), but not (61a), expresses what he calls "moral necessity." Burton-Roberts (1977) observes that

> if Emile does not as a rule open doors for ladies, his mother could utter [(61b)] and thereby successfully imply that Emile was not, or was not being, a gentleman. Notice that, if she were to utter . . . [(61a)] she might achieve the same effect (that of getting Emile to open doors for ladies) but would do so by different means . . . For [(61a)] merely makes a generalisation about gentlemen. (p. 188)

Sentence (61b), then, unlike (61a), does not have a reading where it makes a generalization about gentlemen; it is, rather, a statement about some social norm. It is true just in case this norm is in effect, that is, it is a member of a set of socially accepted rules and regulations.

We have seen above (section 10.4) that Cohen (2001) proposes that generic bare plurals are ambiguous: they may express a characterizing generic, amenable to some sort of inductivist treatment, or they may express a rule, amenable to a treatment within the framework of the rules and regulations view. In contrast, indefinite singulars are not ambiguous in this way: they only express rules. Thus, given the scenario with the supermarket described in section 10.4, only (62b) is true:

(62) a. A banana sells for \$0.49/lb.
 b. A banana sells for \$1.00/lb.

The rule may be a linguistic rule, that is, a definition (see Krifka, 2012). Since polyphonicity forms a part of the definition of a madrigal, (53a) is fine. The acceptability of (58) stems from the fact that it has the classical *form* of a definition, even though it is not, in fact, the approved definition of a madrigal.

10.8 The use of generics

If generics are, indeed, so prevalent, a natural question arises: what are they good for? Why do we use them as often as we do? One possible answer is that generics are used to state default rules.

Our beliefs about the world are almost never certain. In most cases, the conclusions we draw are plausible, but not guaranteed to be true. For example,when I turn the ignition key in my car, I expect it to start. I do not know for certain that it will; sometimes there is some malfunction, and the car fails to start. But it is a reasonable assumption that the car will start, an assumption I am ready to retract if I find out that this is not the case. It is not irrational to assume that the car will start although I do not have complete confidence in it; quite the reverse. The alternative would be to subject the car to a comprehensive inspection by a mechanic every time I am about to start it – clearly an impractical solution, and, in fact, an unnecessary one.

Rules of inference that allow us, for instance, to conclude that the car will start without actually establishing it conclusively, are usually referred to as *default rules*. The most important property that distinguishes them from classical logical rules of inference is that they are *nonmonotonic*: the conclusions may be retracted given additional information. For example, if I see that the car's battery has been stolen, I will no longer expect the car to start. Not so for classical logical rules: if we know that all men are mortal and that Socrates is a man, we conclude that Socrates is mortal, and no amount of additional information will invalidate this conclusion.

There is a sizable body of research on nonmonotonic reasoning.[8] Of particular relevance to our concern here is the fact that, when researchers discuss a default rule, they often characterize it, informally, in natural language; and they usually use a generic to do this. It is, therefore, an appealing idea that the use of generics is often to express default rules. We can say that one

[8] See, for instance, Ginsberg (1987) for a classic collection of papers.

utters (1a) in order to express the following default rule: if we know that an individual is a raven, we should conclude, by default, that it is black.

It is sometimes proposed that the meaning of a generic is a default rule (Krifka, 1987). However, one need not be committed to the claim that the *meaning* is a default rule, to propose that the *use* is that of stating a default rule. What one does need to be committed to is that the meaning of generics supports the conclusions that follow from an appropriate system of default rules.

The problem is that there is little consensus on which inferences regarding generics are sound and which ones are not. For example, ordinary (monotonic) entailment is transitive. If we believe that *A* entails *B*, and *B* entails *C*, we can conclude that *A* entails *C*. But what about nonmonotonic inference?

Sometimes such a conclusion appears valid. Suppose we believe the following:

(63) a. Tweety is a robin.
b. Robins are birds.
c. Birds fly.

We seem justified in concluding, on the basis of this, that Tweety flies. But now suppose we believe the following:

(64) a. Tweety is a penguin.
b. Penguins are birds.
c. Birds fly.

Are we justified in concluding that Tweety flies? Intuitively, the answer is no. This is because we also believe another rule:

(65) Penguins don't fly.

Somehow, (65) ought to take precedence over (64c), and thus we should conclude that Tweety does not fly.

In a sense, (65) is more specific than (64c), and it appears that this is the reason why it overrides it. There have been a number of attempts to formalize this notion of specificity, and to give a semantics for generics that can support it (see, among others, Etherington and Reiter, 1983; Brewka, 1991; Morreau, 1992; Cohen, 1997; Pelletier and Asher, 1997). Suppose we believe (66a) and (66b). We are surely justified in concluding (67) (Pearl, 1988).

(66) a. Red birds fly.
b. Non-red birds fly.

(67) Birds fly.

Any theory of generics of the meaning of generics ought to be able to account for this trivial inference.

But what about inference in the opposite direction? Can we conclude either (66a) or (66b) from (67)? And, in general, can we conclude (68b) from (68a)?

(68) a. ψs are ϕ.
b. ψs that are χ are ϕ.

The general answer appears to be no. For example, we certainly do not conclude (69) from (67).

(69) Dead birds fly.

In order to account for this fact, Pearl (1988) proposes that we can conclude (68b) from (68a) only if we have a rule as in (70):

(70) ψs are χ.

For example, we can conclude (71b) from (67), because we also have the rule (71a).

(71) a. Birds lay eggs.
b. Birds that lay eggs fly.

Thus (69) does not follow, because we do not have a rule saying the following:

(72) Birds are dead.

A problem with this requirement is that it appears to be too strong, blocking desirable inferences. For example, the inference from (67) to (66a) is blocked, whereas it appears that this is a conclusion worth having.

Pelletier and Asher (1997) go to the other extreme: they propose that concluding (68b) from (68a) is always licensed, unless we already have a rule (73):

(73) ψs that are χ are not ϕ.

Thus, (69) does not follow, because we presumably have a rule stating the following:

(74) Dead birds don't fly.

In contrast with Pearl's approach, Pelletier and Asher's view appears too liberal, allowing inferences that appear not to be warranted. For example, we should not, intuitively, conclude either (75a) or (75b) from (67) – whether a sick bird flies or not depends on the type and severity of the disease.

(75) a. Sick birds fly.
b. Sick birds don't fly.

Yet, according to Pelletier and Asher (1997), if we cannot conclude (75b), we should be able to conclude (75a).

An alternative approach is to allow the derivation of (68b) from (68a) only if the property ϕ is independent of the property χ. Thus, (66a) follows from (67), because the ability to fly is independent of one's color; but (75a) does not follow, because being able to fly is not independent of one's health. The problem with this approach is that it is not easy to specify an appropriate notion of independence (but see Shastri, 1989; Bacchus, 1990; Bacchus et al., 1993; Cohen, 1997, for proposals).

Another question is how to treat exceptions to rules. In most work on default reasoning, being an exception to one rule does not affect the applicability of other rules. For example, suppose we have the following rules:

(76) a. Mammals bear live young.
     b. Mammals have hair.

Suppose Pat is a platypus, so she violates (76a), by not bearing live young. Are we still justified in applying (76b) to conclude that she has hair? The answer appears to be yes.

There are cases, however, where this strategy leads to wrong conclusions. Suppose we have an additional rule:

(77) Mammals have a uterus.

Now it appears that we are not allowed to apply (77) and to conclude that Pat has a uterus. Theories of generics that interpret them as expressions of quantification over normal individuals would block the conclusion that Pat has a uterus (see, in particular, Pelletier and Asher, 1997). This is so because by failing to satisfy (76a), Pat has shown herself to be an abnormal mammal, and hence other rules should not apply to her either. The problem is that (76b) will not follow either. Pelletier and Asher (1997) propose to add such a conclusion as a special case, but a more general approach is probably desirable.

Theories that make use of the notion of independence, on the other hand, have better prospects of accounting for such cases. Rule (76b) is applicable, because the property of bearing live young is independent of the property of having hair. In contrast, bearing live young is not independent of the property of having a uterus; hence, we are not justified in concluding that Pat has a uterus.

We have seen that the rules governing our default reasoning can be seen to hinge on a linguistic phenomenon – the meaning of generic sentences. While not necessarily subscribing to Barwise and Cooper's (1981) conclusion that "the traditional logical notions of validity and inference are a part of linguistics" (p. 203), we may safely conclude that when formalizing our common-sense intuitions, it is beneficial to look closely at the language we use to express them.

10.9 Conclusions and speculations

Due to space constraints, this chapter has left out a lot of important and interesting issues concerning generics. However, I hope the little that has been presented has conveyed a sense of the mystery of generics. We have seen at least four puzzling, not to say paradoxical, properties of generics:

1. On the one hand, generics are very common, are attested in all languages, are syntactically simple, and appear to be easily understandable by speakers. But on the other hand, it is very hard to capture exactly what they mean, and a staggering number of theories have been proposed, with no clear consensus reached.
2. On the one hand, generics are lawlike, and hence rather strong statements; on the other hand, unlike real laws of nature, they do not express essential properties of the world, but merely stable properties.
3. On the one hand, generic noun phrases (bare plurals and definite singulars) denote kinds; but, on the other hand, the most common generics – characterizing generics – express quantification.
4. On the one hand, generics have truth conditions; on the other hand, their use is usually not to make a statement, but to express a default rule, which has no truth conditions.

In conclusion, we may consider the question *why* generics are so paradoxical. I am afraid I do not have an answer to this question, but I *can* offer some speculative thoughts.

It is well established that there are two distinct cognitive systems underlying human reasoning (for an excellent overview, see Evans, 2003). System 1 is evolutionarily older; it is characterized by very fast and seemingly effortless responses, but is often incorrect. System 2 has developed later. It is slower, but makes use of much more powerful logical tools than system 1.

Leslie (2007) plausibly argues that the ease and immediacy with which generics are understood is explained if we assume that they are interpreted by system 1. She claims that this entails that the complex interpretations of generics, proposed by many of the theories surveyed in this chapter, are wrong. However, this appears to be a non sequitur: the fact that the processing of system 1 is immediate and easy does not entail that its mechanisms or underlying representations are simple. All that would follow is that the complex interpretation of generics, whatever its nature, will not be available to conscious introspection. This is undoubtedly true, but it is also true of almost every statement in linguistic theory. If this is correct, the first paradox is no paradox after all: generics are easy to interpret because they are interpreted by system 1, yet the formal description of exactly *how* they are processed may be quite complex.

The idea that generics are interpreted by system 1 can also explain why, although modal, their modality is of a rather weak, temporal nature: they are only sensitive to properties that are maintained throughout a long period of time. It is believed that system 1 cannot perform hypothetical reasoning – considering worlds that are substantially different from the actual world. However, it *is* sensitive to time-related properties. For example, as noted by Leslie (2007), people's perception of pain is highly sensitive to the amount of pain suffered at the end of the experiment, which affects judgment much more than pain suffered at other times (Kahneman and Frederick, 2002).

It has been argued that system 2 is quantificational, but system 1 is not. Based on this assumption, Leslie (2007) claims that generics, since they are processed by system 1, cannot be quantificational. However, this does not actually follow. Often, as many studies have shown, after people give an initial response using system 1 reasoning, the slower system 2 applies and people change their response accordingly. Therefore, all that follows is that generics are interpreted as non-quantificational, i.e. predicational, *initially*. The generic may later be reinterpreted quantificationally, after semantic type-shifting (ter Meulen, 1995; Chierchia, 1998b) or pragmatic predicate transfer (Cohen, 2012b) have applied. Indeed, Ricco and Overton (2011, p. 136) argue that "propositional (or quantificational) logical competence develops by way of key transformations within an earlier class-based [i.e., predicational] logical competence."

The last puzzle raises the question why generics are used to express rules rather than truth-evaluable propositions. It turns out that system 1 is much better at interpreting rules than judging truth value.

This is demonstrated nicely with the *Wason selection task* (Wason, 1968). The classic task consists of presenting subjects with four cards, marked *E*, *K*, *4*, and *7*. Subjects are then asked which cards they need to turn over in order to check if (78) is true or false.

(78) If a card has a vowel on one side, then it has an even number on the other side

The logically correct answer is *E* and *7*, but, in fact, few subjects (typically, 10%–20%) give this answer.

It is generally thought that subjects use system 1 in dealing with this task; hence their logically incorrect responses (Evans, 1998). Interestingly, when the task is changed slightly, from judgments of truth or falsity to judgments of whether a rule is obeyed or not, performance improves markedly.

Griggs and Cox (1982) asked participants to imagine that they are police officers enforcing the following rule:

(79) If a person is drinking beer, then the person must be 19 years of age.

Four cards were presented, showing *drinks beer*, *drinks coke*, *22 years old*, and *16 years old*. The correct answer is *drinks beer* and *16 years old*, and, this time, the percentage of correct responses was much higher, around 75%.

The only difference between the two tasks is that subjects were asked to judge if the statement in (78) was true or false, whereas they were instructed to judge if the rule in (79) was obeyed or not. If, indeed, subjects use system 1 in solving the task, it follows that system 1 is much better at dealing with rules than with truth judgments. The assumption that generics are initially processed by system 1, then, nicely explains their primary use as expressions of rules.

If these speculations are on the right track, the puzzling properties of generics are actually not mysterious, but rather direct consequences of the cognitive system that interprets them. The significance of generics, therefore, goes beyond their intriguing linguistic properties. An investigation of generics may shed light on the most basic system of human reasoning.

Part III

Temporal and aspectual ontology and other semantic structures

11

Tense

Atle Grønn and Arnim von Stechow

11.1 Introduction

Our focus in this chapter is the semantics of tense, one of the main devices for encoding time in language. The grammatical category of tense is used to locate a situation or event in time, typically in interaction with aspect. When tense relates the speaker's temporal focus, what is normally called the reference time, to the speech time, we have deictic or absolute tense. Aspect, on the other hand, is concerned with the internal temporal structure of the event, for example, whether the event time is included or not in the reference time.

Tense is typically marked by verbal morphology, normally an affix on the matrix verb or on an auxiliary verb, but the semantic tense operator is not interpreted at the verb. The operator can be located quite distant from the verb at the level of logical form. Thus, we must distinguish between tense semantics and tense morphology.

We will assume that our model contains a set of times I, and, furthermore, that verbs have a temporal argument of the semantic type i (time intervals).

The latter assumption will be revised when we include aspect in the analysis. Times are partially ordered by the relations $\prec$ 'before' and $\succ$ 'after'. Time intervals are coherent sets of time points. Hence, they may overlap, stand in the inclusion relation and so on (von Stechow, 2009b).

While everybody agrees that the meaning of past and future tenses is relational – with past placing the reference time *before* now and future *after* now – there is a long-standing issue in the literature as to the exact status of the reference time: is it quantificational or referential? We argue that this question cannot be answered straightforwardly. In our view, tenses, such as the simple past in English, are ambiguous between an indefinite (quantificational) and a definite (referential) interpretation of the reference time.

We will suggest that the data invite a dynamic account, according to which indefinite terms are analysed as introducing a new discourse marker (dm), whereas definite terms are considered to be anaphoric to an old dm and are in fact entirely presupposed.

Furthermore, since tenses are relational, this last point also concerns the other time involved in the tense relation, what is called the perspective time in Kamp and Reyle (1993) and much subsequent work, but which we will refer to as the temporal centre. For simple tenses in main clauses the temporal centre is either contextually given, that is anaphoric, or uniquely given by the speech time, hence referential and not quantificational. In composite tenses, such as the past perfect in Germanic and Romance languages, the temporal centre is typically an anaphoric definite time, while the reference time is shifted backwards.

Thus, following most contemporary work in the domain of tense and aspect, we should carefully separate the reference time (aka the assertion time) from the temporal centre (aka the perspective time, temporal anchor for the sentence). In contrast, the classical notion of reference time going back to Reichenbach (1947) suffers from the defect of not distinguishing properly between these two temporal parameters.

11.2 Desiderata

The goal of this survey chapter is to indicate what kind of theory of tense is needed for a coherent analysis of examples like in (1) and (2) below. Along the way, we must address a wide range of questions concerning tense: its morphological and syntactic expressions as well as its interpretation at both the sentence and the text level.

(1) John left at 11. He didn't turn off the stove.

(2) John left at 11. He had arrived yesterday.

Barbara Partee (1973a) remarked that the past in the second sentence of (1) cannot be an existential quantifier. If it were an existential quantifier, then we would have two options: it would have the meaning shown in either (3), or (4).

(3) There is a time before now at which he didn't turn off the stove.

This assertion is trivial, since (3) is a very weak statement and is likely to be true. The second option follows:

(4) There is no time before now at which he turned off the stove.

This option is too strong to be true, and it is certainly not the meaning of the sentence in the text. We can solve Partee's puzzle if we interpret the past in the second part of (1) as an anaphoric definite description. Then it would have the meaning in (5):

(5) John leaves at [[a time_1 before now] which_1 is at 11]. He doesn't turn off the stove at [$\underline{\text{that time}_1 \text{ before now}}$].

The key to the solution is that the anaphoric definite description, underlined in (5), is scopeless with respect to negation.

In the second sentence of Example (2), the composite past perfect involves both an indefinite and a definite time, as we see from the paraphrase in (6), where the anaphoric definite description is underlined.

(6) John leaves at [[a time_1 before now] which_1 is at 11]. He arrives at [[a time_2 [before $\underline{\text{that time}_1 \text{ before now}}$]] which_2 is on yesterday].

We will present a general theory that allows for different combinations of (in)definite tense, simple and composite tenses, and temporal adverbials, as in the examples above.

Importantly, both examples above involve an instance of cross-sentential temporal anaphora, so a fully satisfactory analysis must arguably be *dynamic*. The idea that tenses necessitate a dynamic semantics was originally put forth by Hans Kamp and colleagues in the early 1980s (Kamp and Rohrer, 1983). The development of Discourse Representation Theory (DRT) (Kamp and Reyle, 1993) was partly motivated by observations concerning temporal/narrative progression (and lack thereof) with French tenses.[1] We consider narrative progression to be a pragmatic phenomenon (be orderly!) and we will not have much to say about this in our study of temporal semantics. Hence, our argumentation for a dynamic semantics is to some extent orthogonal to Kamp's original insight. As pointed out by a reviewer, our dynamic approach, which is based on the idea that a dynamic treatment of definite/indefinite NPs could be replicated with tenses (and aspects – see Section 11.10), is more in the spirit of Partee (1984b).

[1] We thank an anonymous reviewer for reminding us of this point.

However, we will start our discussion by presenting a standard analysis of semantic tense, tense morphemes and temporal auxiliaries in a compositional, static framework. The idea is to clarify where exactly in the structure the various expressions of time fit in, and what actual contribution they make. This will be the topic of Section 11.3. In Section 11.4 we will have a closer look at the notion of referential tense. Next, in Section 11.5 we will discuss the meaning of temporal adverbials and point out some temporal puzzles which temporal quantification gives rise to. In Section 11.6 we briefly analyse the analytic perfect construction, which we consider to be a sort of tense with either an extended now interpretation or a relative past semantics. In both cases the perfect modifies or changes the reference time. In Section 11.7 we motivate an analysis of tense in terms of (in)definiteness, and we present the general tense architecture assumed here. Finally, in Sections 11.8 and 11.9, we formalise (in)definite tense in a dynamic framework. Section 11.10 shows how the formal analysis can be extended to include aspect. Some of the technical details concerning the dynamic framework can be found in an appendix.

11.3 Tense in compositional semantics

Most contemporary approaches to the syntax–semantics interface assume a structure as in (7):

(7) Architecture $[_{\text{TP}}$ TENSE$[_{\text{PerfP}}$ PERFECT$[_{\text{AspP}}$ ASPECT[vP]]]]

The following example motivates this particular three-way distinction between tense, perfect and aspect.

(8) John has been working much lately.
$[_{\text{TP}}$ N$[_{\text{PerfP}}$ XN$[_{\text{AspP}}$ IMPERFECTIVE[John work]]]]

Although our examples will mostly come from English, the general architecture we discuss should in principle apply to other languages as well.

A complete inventory in (7) would comprise matrix deictic tenses, namely, N, PAST* (i.e. PAST(N)), and FUT* (i.e., FUT(N)), at least two perfect relations, XN (extended now – see Section 11.6) and PAST, a relative FUT, and a number of aspects, such as PERFECTIVE, IMPERFECTIVE, but languages may differ in which combinations of these they allow.

The nomenclature of verbal categories in (7), notably aspect, is most easily analysed on the assumption that the verb comes with an event/state argument, see Rothstein, Chapter 12. We will see how events can be integrated into our tense theory in Sections 11.6 and 11.10, but for most of the discussion we will simplify the picture and leave aspect out. Here we assume that the verb comes with a temporal argument, the time interval (event time) at which the descriptive content of the VP obtains.

However, what does it mean to say that a VP or a sentence is true 'at an interval'? A problem immediately arises with accomplishments (*to build a castle*) which lack the sub-interval property and more naturally combine not with *at*-adverbials, but with *in*-adverbials (*to build a castle in two years*). The latter, however, do not specify the exact interval throughout which the event obtains (see Ogihara, 2007, p. 400 and von Stechow, 2009b for discussion). In the absence of durative adverbials ('from 2 AM to 5 AM'), natural languages thus typically remain vague as to the exact duration of the event. A way of analysing such cases is to introduce a covert perfective aspect operator (see Rothstein, Chapter 12, or footnote 5 below), which captures the temporal configuration by letting the temporal trace of a VP-event be *included in* the reference time.

11.3.1 Present tense

The present N denotes the speech time, a distinguished time s^*. In our typed framework, the semantic present has the simplest type i (mnemonic for interval).

(9) Present: N 'now', type i
$[\![N]\!] = s^*$ ('speech time')

We will not be able to discuss more fine-grained approaches to the present.[2] In fact, for many languages the present is rather a non-past. In languages like Japanese and Russian, Aktionsarten and aspect decide whether the non-past is interpreted as denoting the speech time or a future time (e.g. Russian perfectives with present tense morphology are coerced into a future tense interpretation). Even a quick comparison of examples from English and German suggests that there may be differences in the denotation of present tense in 'our languages' too:

(10) a. (*) Mary comes tomorrow.
b. Mary will come tomorrow.
c. √ Maria kommt morgen.

The distribution of English present is more restricted than that of the German present, since it cannot straightforwardly be combined with future adverbials and is therefore less likely to denote a future time.

11.3.2 Quantificational past

English uses an auxiliary – an existential time shifter – in order to shift the reference time to a time after now (*will come* in (10b)). Many languages, such as French and German, can make use of auxiliaries (formally, a 'present perfect') also to shift the reference time to a time before now. For time reference in the past, English normally uses the simple past:

[2] See Altshuler and Schwarzschild (2013) for a recent discussion of alternative analyses.

(11) Mary called.
$(\exists t)[t \text{ is before now } \& \text{ Mary call}(t)]$
There is a time t before now, such that Mary calls at t.

This statement of the truth-conditions in (11) is, not quite accurately, often attributed to the logician Arthur Prior. Prior (1967) uses the temporal auxiliaries *have* and *will* in the paraphrases of the truth-conditions of simple past and future: 'It has been the case that' and 'It will be the case that'. In Richard Montague's PTQ (1973b), we find the syncategorematic symbol H (mnemonic for *has*).

(12) $[\![H\alpha]\!]^{i} = 1 \text{ iff } (\exists i' \prec i)\ [[\alpha]]^{i'} = 1$ (à la Montague)

In order to evaluate Hα at the evaluation time i, it is not enough to consider the intension of α at i; we also have to consider some $i' \prec i$ and evaluate the intension of α there. As pointed out by Ogihara (2007, pp. 393; 396–397), neither Prior nor Montague intended to represent the meaning of the English past tense *-ed* per se.

In our static framework, P* is a deictic past, while P is the more general version, i.e. a relative past. These are both functors in the object language:

(13) Deictic Past: P*, type (it,t)
$[\![P^*]\!] = \lambda Q_{it}.(\exists t')[t' \text{ is before now } \& \ Q(t')]$

(14) Relative Past: P, type i(it,t)
$[\![P]\!] = \lambda t.\lambda Q_{it}.(\exists t')[t' \text{ is before } t \ \& \ Q(t')]$

'is before' will be written as '$\prec$'. In matrix clauses it will not matter whether we choose P or P*, since the temporal centre of P will be the present N. Of importance, however, is our assumption, which is also in agreement with recent ideas of Irene Heim's, that the temporal centre (perspective time) is the *first* argument of P. Other authors may assume a different type for P, namely, (it,it). We will justify our choice below when we explicate our conception of the syntax–semantics interface.

11.3.3 Have, will

The temporal auxiliaries contribute, in the simplest case, the same semantics as the relative 'Priorian' tenses: they are time shifters, also called verbal quantifiers, that shift the reference time backwards (or forwards):

(15) **have** (English), **avoir** (French): type i(it,t)
$\lambda t.\lambda Q_{it}.(\exists t')[t' \prec t \ \& \ Q(t')]$

A consequence of this analysis is that we somewhat incorrectly predict full synonymy between the indefinite deictic past P* and the present perfect.[3]

[3] This naïve parallel between deictic past and present perfect works better for German or French than for English which has an XN-semantics in the present perfect, see Section 11.6.1 below.

The structure differs, though, since [**have** t_1] is a quantifier generated in the head of the AuxP.

(16) John has called.
Jean a téléphoné.
$[_i\ \text{N}]\ [_{it}\ \lambda_1\ [_t\ [_{it,t}\ \textbf{have}\ t_1][_{it}\ \lambda_2\ [\textbf{John}\ [\textbf{call}\ t_2]]]]]$
$(\exists t')[t' \prec s^* \,\&\, \text{John calls at } t']$

The auxiliary *will* is simply the mirror image of *have*:

(17) **will**: type i(it,t)
$\lambda t.\lambda Q_{it}.(\exists t')[t' \succ t \,\&\, Q(t')]$

'$\succ$' stands for 'is after'.

(18) John will call.
$[_i\ \text{N}]\ [_{it}\ \lambda_1\ [_t\ [_{it,t}\ \textbf{will}\ t_1][_{it}\ \lambda_2\ [\textbf{John}\ [\textbf{call}\ t_2]]]]]$
$(\exists t')[t' \succ s^* \,\&\, \text{John calls at } t']$

Note that English, unlike for instance French, does not have a synthetic/morphological future tense as such.

11.3.4 Tense morphology and interpretation

Judging from the morphology, it would seem that tense is located at the verb. However, most semanticists have treated tense as a sentential operator and so, if we follow this practice, then the relation between tense morphology and semantic tense must be more complicated.

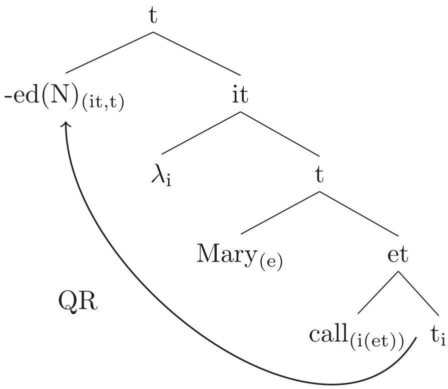
From the examples above, we can see that the morphological past *called*, the participle *called* (*have* subcategorises for a past participle) and the infinitive *call* (the auxiliary *will* subcategorises for an infinitive) all have a tenseless interpretation in our system. Every verb has a temporal argument, which is the first argument by convention:

(19) $[\![\textbf{call}]\!] = [\![\textbf{called}]\!] = [\![\textbf{calls}]\!] = \lambda t\, \lambda x.\ x \text{ calls at } t$

A problem arises from the fact that tense is not interpreted where it is pronounced. Consider the past *-ed* and the meaning given in (13)/(14). Let us assume that at deep structure (DS) *-ed* occupies the place of the temporal argument of the verb. The semantics tells us that *-ed* is an existential quantifier. Like all quantifiers *-ed* has to be QRed for type reasons. The derivation of sentence (11) is therefore the following:

(20) DS: Mary call(-ed)
QR $\Rightarrow$
LF: **-ed** λ_1 **Mary call**(t_1)

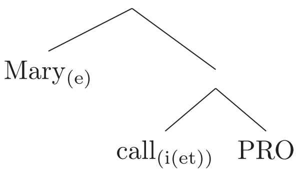
We will adopt the theory of quantifier raising (QR) as described in Heim and Kratzer (1998): quantifiers of type (at,t) are moved to a sentence-initial position. They leave a trace of type a interpreted as a variable x_a. The movement index of the quantifier is interpreted as the binder λ_a. For the example under discussion, this gives us the following structure and meaning:



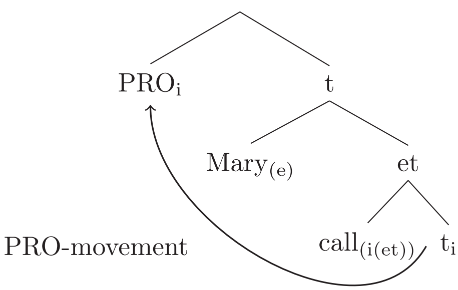
$(\exists t \prec s^*)$ Mary calls at t

In order to mediate between semantics and morphology, we have to assume that the QRed *-ed* is not pronounced at SS (surface structure), but transmits a feature uP (uninterpretable past) to the bound variable t_i, which determines the pronunciation of the verb as a past form.

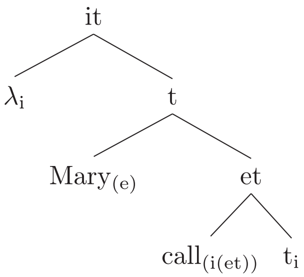
A more abstract but equivalent analysis assumes Heim's theory of PRO (or TPRO; 'temporal' PRO) as a semantically empty pronoun without type and meaning. On this view, the DS of sentence (11) is as follows:



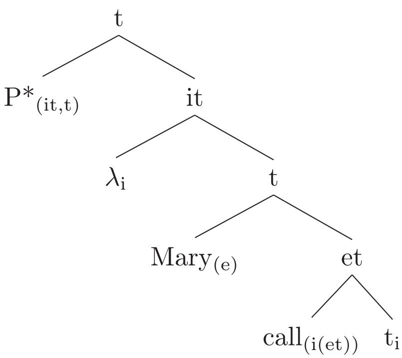
Given that PRO has no meaning, it cannot be interpreted in situ and has to be moved. Since the verb requires a temporal argument, we obtain the structure below.



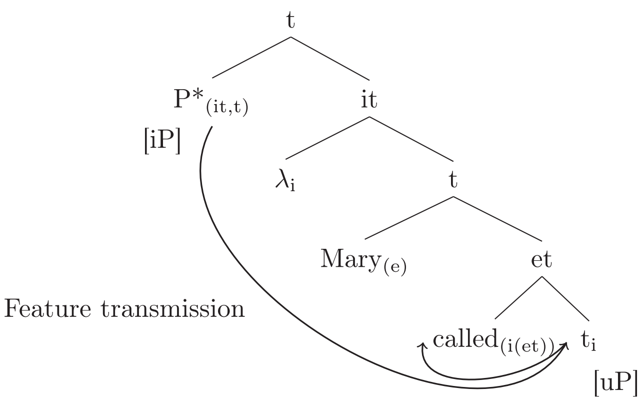
At LF, PRO is deleted by the principle of full interpretation. The movement index i is interpreted as λ_i, and we derive the temporal abstract below.



This structure can be modified by the operator P*, and we get the following:



The important point is that semantic operators like P* are not pronounced but transmit features under binding, here the feature uP, which determines the pronunciation of the verb *call* as a past form.



We write the origin of the feature P as iP ('interpretable past'). The landing site, that is, the morphological function of the feature, is written as uP ('uninterpretable past').

When the main verb is non-finite, as in the perfect and future constructions, the verb itself has no inherent tense feature, but it still inherits a feature via the auxiliary, which in the case of *has called* and *will call* is a present tense feature. The temporal auxiliaries *has* and *will* are so-called verbal quantifiers in the theory of Grønn and von Stechow (2010). They change the reference time of the main verb, but also come with their own morphology, which must be licensed by a higher semantic tense N. When *has* and *will* transmit their present feature to the non-finite verb, we have *feature transmission under semantic binding* (Heim, 1994c, 2005). The inheritance of the feature from the verbal quantifier by the non-finite verb becomes important for further feature transmission into embedded tenses (sequence of tense phenomena), but it does not play any role in ordinary matrix sentences since the feature is not pronounced on the non-finite verb.

11.4 Referential tense

The quantificational, indefinite analysis for the simple past predicts scopal interaction with negation (and also with quantifiers and intensional operators). As we recall from above, Partee's famous example (*I didn't turn off the stove*) challenged the standard Priorian and Montagovian analyses since neither of the two possible scopal relations captures the meaning of the sentence:

(21) a. $(\exists t \prec s^*) \neg$ I turn off the stove at t
b. $\neg(\exists t \prec s^*)$ I turn off the stove at t

The first statement is trivially true and the second is too strong to be true. Partee's claim was that this example showed that the past could not be an existential quantifier 'there is a time before the speech time'. Instead, Partee proposed an analogy between tenses and pronouns: 'I will argue that the tenses have a range of uses which parallels that of the pronouns, including a contrast between deictic (demonstrative) and anaphoric use, and that this range of uses argues in favour of representing the tenses in terms of variables and not exclusively as sentence operators' (Partee, 1973a, p. 601).

Partee presumably had in mind a referential past along the lines of what was later formulated in Heim (1994a), with a presuppositional semantics as follows:

(22) Referential Past
$[\![PAST_i]\!]^g$ is only defined if $g(i) \prec s^*$.
If defined, $[\![PAST_i]\!]^g = g(i)$.

We thus get the following LF for Partee's example with $PAST_5$ being a temporal variable of type i:

(23) $\neg$ I turn off the stove($PAST_5$)

Now, what is the meaning of the verb *turn off* above, a so-called achievement predicate? Turning off the stove is a very short event that takes only a moment, so it is unlikely that PAST_5 denotes a particular moment that the speaker has in mind. Rather, PAST_5 refers to a stretch of time, say the two hours before my leaving. Suppose that this is the interval (10 AM, 12 AM). We must say what *I turn off the stove* means when evaluated with respect to this interval, which we call t_5. Obviously the action cannot take place *at* t_5, because the length of the event is not 2 hours. So the event must take place *in* t_5.

This brings us back to aspect. We have to assume that the lexical entry of the verb contains a covert aspectual operator, namely, the perfective. According to this analysis, the sentence actually means what is expressed in (24).

(24) $\neg(\exists t \subseteq g(5))$ I turn off the stove at t,
where $g(5) \prec s^* \;\&\; g(5) = (10\text{ AM}, 12\text{ AM})$

Nevertheless, even though we have to slightly extend Partee's analysis by adding perfective aspect – the inclusion relation $t \subseteq g(5)$, where t is the event time – the Partee problem convinces us that tenses can be anaphoric/definite.

In Partee's original article, the slogan is that tenses are pronouns. The present tense used deictically is like the indexical first person pronoun *I*, while the past tense is an anaphoric or deictic pronoun – a free variable denoting a particular time in the past. An interesting prediction of this approach, noted by Partee herself, is that the English 'future', which is not a semantic tense but makes use of the time-shifting verbal quantifier *will*, should not be anaphoric in nature.

The referential approach was developed in a static framework by Abusch (1994b), Heim (1994a), von Stechow (1995), Kratzer (1998a) and others. However, just as the indefinite tense analysis traditionally attributed to Prior (1967) cannot be the whole story, there are also arguments against the presuppositional semantics, i.e. the view that tenses are temporal variables with a presupposition.

One problem is the question of how it would be possible, on the latter approach, to explain obligatory backward-shifting of a past in an intensional context under an attitude verb in non-sequence-of-tense (SOT) languages like Russian (Grønn and von Stechow, 2010, 2012).

(25) Ona [. . .] sprosila$^{\mathrm{PAST,PF}}$, spal$^{\mathrm{PAST,IMPF}}$ li on. (Tolstoy, *Anna Karenina*)
She [. . .] asked him if he had slept. (translation from the RuN parallel corpus)

The backward-shifting remains mysterious with the meaning of past given in (22). We can also have backward-shifting in English with an embedded simple past:

(26) John said that Mary left.

Kratzer (1998a) assumes for such examples that the past tense is ambiguous between a referential tense and a quantificational relative past, which she calls *perfect aspect*. In Russian, an embedded synthetic future can shift the event time as well:

(27) Ona byla nemnogo prostuzhena i skazala$^{\text{PAST,PF}}$, chto oni segodnja pobudut$^{\text{FUT,PF}}$ doma. (Kurkov, *Piknik na ldu*)
She had a bit of a cold and said they would be staying in for the day. (translation from the RuN parallel corpus)[4]

Advocates of a referential theory would have to say that the Russian future is ambiguous between a referential tense and an aspect, say *prospective*. The quantificational approach needs no such ambiguities.

There could be a way out of the dilemma if we were to develop a 'mixed' approach, analysing past/future tense as an existential quantifier over *contextually restricted times*. For instance, the Partee example could be analysed as 'at some past time *this morning*' (existential + referential). The anaphoric component can thus be hidden in the domain restriction. We refer the reader to Bäuerle (1978, 1979), Ogihara (2007), von Stechow (2009b), Altshuler and Schwarzschild (2013) for further discussion of this possibility. Instead, we will below advocate an ambiguity approach in the tense domain (indefinite vs. definite tense). This is in our view the simplest analysis, where the distinction between quantificational and referential interpretations is directly reflected at the level of logical form (LF).

11.5 Quantification and adverbials

11.5.1 Tense and quantification

We cannot do justice to all the quantificational puzzles that can arise in the semantics of tense. Here we will only mention one example, the Bäuerle–von Stechow Problem, as an illustration.

(28) a. Yesterday, Mary called exactly once.
b. Yesterday, Mary called exactly 3 times.

Comparison of the two sentences shows that *once* = *at one time*. In the following analysis, both **yesterday**$_{(\text{it})}$ and **exactly one time**$_{(\text{it,it})}$ restrict the past reference time:

(29) $[_{\text{it,t}}$ P N$]$ $[_{\text{it}}[_{\text{it}}$ λ_1 on **yesterday**$(\text{t}_1)]$ $[_{\text{it}}$ at **exactly one time** λ_2 **Mary call**$(\text{t}_2)]]$
$(\exists \text{t})[\text{t} \prec \text{s}^* \ \& \ \text{t} \subseteq \text{yesterday} \ \& \ (\exists!\text{t}')[\text{t}' \subseteq \text{t} \ \& \ \text{Mary calls at t}']]$
$(\exists!\text{t}')[\alpha(\text{t}')]$ means 'There is exactly one time satisfying α.'

The truth-conditions shown are obviously wrong, since they are compatible with a scenario in which Mary also called at a time t″ included in yesterday,

[4] www.hf.uio.no/ilos/english/research/projects/run/corpus/.

but not included in t. This problem has caused a lot of trouble and led many people away from the quantificational analysis of tense. Bäuerle and von Stechow (1980) concluded that past has a predicate meaning $\lambda t.t \prec s^*$. *Mary called* means $\lambda t.t \prec s^*$ & Mary calls at t. The quantification is provided by adverbials such as *exactly once* or, in the default case, existential generalisation. Several people have taken up this proposal, for example Musan (2002), von Stechow (1995) and occasionally Ogihara.

In the following we will ignore this problem. For more puzzles related to tense and quantification, see von Stechow (2002, 2009b).

11.5.2 Temporal adverbials

Temporal adverbials are of various kinds, some of which play a crucial role in determining the reference time of the sentence, and sometimes also the temporal centre (i.e. the perspective time at which the subject locates herself). For *yesterday* and PPs like *on my birthday*, sometimes referred to as positional or definite temporal adverbials, there are several alternative, though ultimately perhaps equivalent, analyses in the literature. Here we will simply assume that these expressions are predicates of times:

(30) Predicate format of positional temporal adverbials, type (it):
$[\![\textbf{on my birthday}]\!] = \lambda t.t$ is on my birthday

Positional adverbials always restrict tense or some other functor which provides the quantification:

(31) Mary called on my birthday.
$[_{it,t}$ P N$]$ $[_{it}$ λ_1 [[**on my birthday** t_1] [**Mary** [**call** t_1]]]]

The relevant version of *Predicate Modification* is as follows:

(32) Let α be a tree of type t with daughters β and γ of type t. Then
$[\![\alpha]\!] = 1$ iff $[\![\beta]\!] = 1 = [\![\gamma]\!]$

The interaction between temporal adverbials and tenses is subject to certain pragmatic constraints. As observed by several authors, speech time modification is usually disallowed:

(33) John leaves at six.
(#) N λ_1 [[t_1 **at six**] [**John leave** t_1]]

The sentence can only have a so-called scheduled reading, that is, a special kind of future reading, and hence the LF in (33) does not capture the meaning of the sentence. Similarly, in (34), the adverbial modifies the past, not the speech time:

(34) John left at six.
N λ_1 P(t_1) [[λ_2 **at six**(t_2)] [λ_3 **John leave**(t_3)]]

Klein invokes a pragmatic principle saying that a definite time (here: the speech time) cannot be further specified (Klein, 1992). We will have more to say about this in connection with the interaction between temporal adverbials and the past perfect. See (40) below.

11.6 The perfect

The analytic perfect construction in Germanic and Romance languages is a rich source of puzzles and idiosyncrasies of various sorts. We will briefly review some of these below.

11.6.1 Present perfect and XN

The so-called Present Perfect Puzzle refers to the fact that positional (definite) past adverbials cannot modify a present perfect in English (or Mainland Scandinavian), but they can in German and French:

(35) a. Mary called yesterday.
b. (*) Mary has called yesterday.
c. $\surd$ Maria hat gestern angerufen. (German)
d. $\surd$ Marie a téléphoné hier. (French)

These facts follow from an extended now (XN) semantics for the English/Scandinavian present perfect – provided that temporal adverbials modify XN – and a relative past semantics for the German/French perfect in combination with an intersective semantics for definite temporal adverbials, see Pancheva and von Stechow (2004) among others.

(36) Extended Now (McCoard, 1978), (Dowty, 1979); quantifier type i(it,t)
$[\![\mathrm{PERF_{XN}}]\!] = \lambda t.\lambda Q.(\exists t')\,[\mathrm{XN}(t',t)\ \&\ Q(t')]$,
where $[\![\mathrm{XN}(t', t)]\!] = 1$ iff t is a final subinterval of t′.

Once more we have to assume an aspect operator[5] in an eventive framework – this time to solve the Present Perfect Puzzle. We will first show how definite adverbials are compatible with the German variant of (35c). We are assuming the same simple denotation for N in both English and German; this will turn out to be correct here:

(37) Maria hat gestern angerufen (German)
N λ_1 PAST(t_1) [λ_2[[t_2 on **yesterday**] [PF(t_2) λ_3 **Mary called**(e_3)]]] (German)
$(\exists t)[t \prec s^* \ \&\ t \subseteq \text{yesterday}\ \&\ (\exists e)[\tau(e) \subseteq t\ \&\ \text{Mary call}(e)]]$

[5] The standard semantics for perfective aspect, following Krifka (1992) and others:

$[[\mathrm{PF}]] = \lambda Q.\lambda t.(\exists e)\ [\tau(e) \subseteq t\ \&\ Q(e)]$, where Q is a predicate of events, and $\tau(e)$ is the running time of e. In our framework, the time argument will be the first: $\lambda t.\lambda Q\ldots$

However, the same adverbial leads to a contradiction in an XN-configuration as in English:

(38) N λ_1 PERF$_{XN}$(t$_1$) [λ_2[[t$_2$ on **yesterday**] [PF(t$_2$) λ_3 **Mary called**(e$_3$)]]]
$(\exists t)[XN(t,s^*)$ & $t \subseteq$ yesterday & $(\exists e)[\tau(e) \subseteq t$ & Mary call(e)]]
$\Rightarrow s^* \subseteq$ yesterday!

We conclude that the combination N + PAST, which we find in German and French, is not available for the English present perfect (probably due to the competition with the simple past). Furthermore, the time adverbial *yesterday* cannot modify the event for type reasons. Note that if the theory referred to event times instead of events, then modification of the event time by *yesterday* would not be blocked.

11.6.2 Past perfect

The past perfect consists of two nested layers of 'past', the backward-shifting lexically expressed by the auxiliary and the past operator licensing the past tense morphology of the auxiliary.[6] In interaction with the past perfect, temporal adverbials may therefore create an ambiguity:

(39) Mary had left at six
a. [$_{it,t}$ P N] [$_{it}$ [$_{it}$ λ_1 **at six**(t$_1$)] [$_{it}$ λ_2 [$_t$ [$_{it,t}$ **have**(t$_2$)] [$_{it}$ λ_3 **Mary left**(t$_3$)]]]]
$(\exists t \prec s^*)$ t at 6 o'clock & $(\exists t' \prec t)$ Mary leaves at t'
b. [$_{it,t}$ P N] [$_{it}$ λ_1 [$_t$ [$_{it,t}$ **have**(t$_1$)] [$_{it}$ [$_{it}$ λ_2 **at six**(t$_2$)] [$_{it}$ λ_3 **Mary left**(t$_3$)]]]]
$(\exists t \prec s^*)(\exists t' \prec t)$ t' at 6 o'clock & Mary leaves at t'

The LF in (39a) is a past-time modification: the leaving is before six. (39b) is a perfect-time or event-time modification, the leaving is at six.

The ambiguity of the past perfect was not attested for the present perfect in English. The present perfect in English is special since it has an XN-semantics, while the past perfect mostly behaves as expected from a compositional point of view, on a par with the present perfect in German. The relative past reading of *had P-ed*, unlike *has P-ed*, is compatible with definite temporal adverbials, as we have just seen. Furthermore, the ban on modification of the higher tense, as we saw in the present perfect, disappears in the English past perfect, where the adverbial can modify either the higher or lower time.

Consider, however, the following contrast:

(40) a. (#) At six John had left at five.
b. At six John had left an hour before.
c. (#) At seven John had left at five.
d. At seven John had left an hour before.

[6] In addition, the past perfect may have an 'XThen' interpretation parallel to XN in the present perfect.

Table 11.1 *The interpretation of complex tenses*

	Present Perfect		Past Perfect	
English	(*)N + PAST	N + XN	PAST(N) + PAST	PAST(N) + XThen
German	N + PAST	N + XN	PAST(N) + PAST	PAST(N) + XThen

The first example in (40a) illustrates Klein's prohibition of double temporal specification (Klein, 1992). However, in the meta-language (40a) and (40b) would be completely equivalent. An explanation for this phenomenon can be found by comparing the truth-conditions of (40a) and (40c) – again the truth-conditions are the same: $[[(40a)]] = [[(40b)]] = [[(40c)]]$. This is not so for (40b) and (40d) with a topic time contrast, a minimal pair which clearly express different propositions. So, when the highest adverbial does not play any role semantically, as in (40a) and (40c), the construction is pragmatically blocked.

The different distribution of combinations involving the perfect auxiliary in English and German is listed in Table 11.1.

Thus, in German, every perfect is ambiguous. While German allows any combination of a tense and a perfect relation, English does not have the combination N + PAST.

Recall from the introduction that the past perfect, interpreted with the admissible combination PAST + PAST, is typically used with an anaphoric higher tense (the temporal centre for the lower tense). Thus, Example (39) above will, when used in a discourse, contain the information $\underline{t \prec s^*}$ & $(\exists t' \prec t)$. The underlined part is a presupposition, a standard case of cross-sentential temporal anaphora. We cannot express this straightforwardly in a static framework. We will turn to this issue in the following sections.

11.7 (In)definite tense

Both the quantificational approach to tense and the alternative referential approach have their weaknesses. There is no simple way of treating temporal anaphora in the quantificational approach.

(41) John came home at 12. Mary was asleep (then).

The referential approach can have the same temporal variable (or the same deictic tense) in both sentences. A drawback of the referential approach, though, is that it cannot account for backward-shifting in embedded contexts, for example in complement clauses. At least non-SOT languages like Russian (see (25) above) and Japanese need quantificational tenses. For more discussion of this question, see von Stechow and Grønn (2013a,b) and Sharvit (2014).

We believe that any theory of tense that is able to overcome the disadvantages of the two approaches mentioned must be a dynamic one. The following system is an intensional version close to other dynamic systems, such as the ones proposed in Muskens (1996) and Beaver (2001). The applications will be focused on tense (and aspect). An alternative dynamic system with a similar focus as ours is Bary (2009).

The main claim is that an indefinite tense introduces a new temporal discourse marker, while a definite tense is anaphoric to an old dm, presupposing its descriptive content, that is, the temporal relation. To implement this idea, we will treat tenses and aspects as purely relational, with a covert indefinite or definite article on top.

Many languages (e.g. Russian) have no overt [±def] marking in the nominal domain. NPs in such languages are then ambiguous with respect to [±def]. Since we find ambiguity in the nominal domain, we should not be surprised to find it in other domains as well. By loosening the correspondence between (in)definiteness and article morphology, we discover that the ambiguity is found not only in the temporal domain, but also in the event domain (e.g. aspect in Russian, see Section 11.10).

11.7.1 The [±def]-ambiguity of tense

One of the motivations for the development of dynamic approaches in the 1980s was the analysis of donkey anaphora in the nominal domain. We note that similar cases can also involve tense, as in the following temporal donkey sentence:

(42) When a farmer had a donkey, the farmer usually beat the donkey.

The past tense in the antecedent should be an indefinite term (like *a farmer/a donkey*), but the past tense in the consequent must be a definite term (like *the farmer/the donkey*). A similar observation was also made in Partee (1984b, pp. 268ff.). The following paraphrase illustrates the intended interpretation of donkey tense:

(43) Usually, when a farmer had a donkey at some past time, the farmer beat the donkey at that past time.

By treating the simple past as ambiguous between an indefinite and a definite tense, contra McCoard (1978) who claims that the simple past is only definite, we can explain a lot of thorny data.

11.7.2 The [±def]-ambiguity and the perfect

The perfect is a shifter – a relative past – and therefore indefinite, though it typically contains a definite temporal centre, cf. (2), repeated below:

(44) John left at 11. He had arrived yesterday.

In the style of Irene Heim's dissertation (1982), we want to say, starting from the first sentence, that a new temporal discourse marker 1_i (i = indefinite) is before now and that John leaves at t_1 (bound variables are always definite), which is at 11. For the second sentence, we intuitively want to pick up the old discourse marker 1_d (d = definite). This time is presupposed to be a past time (before now), and it serves as the temporal centre (perspective time) in a temporal relation with a new discourse marker 2_i, such that $t_2 \prec t_1$ and t_2 is the time of John's arrival yesterday.

11.7.3 A uniform type for ±def

Definites, like pronouns, are commonly analysed as referring terms with contextually dependent anaphoric and deictic uses, while indefinites are existential quantifiers. This view stipulates differences between definites and indefinites along three dimensions: semantic type, uniqueness and presuppositionality (Heim, 2011a). Since the (in)definite article is covert in the tense domain, we want tenses to have a uniform type. In fact, we will propose below a uniform semantic type for definites and indefinites across all domains.

We will adopt the idea from Heim's dissertation, where definites, just like pronouns, carry an old index at LF. However, our implementation will be different, since both indefinites and definites will have the format of dynamic generalised quantifiers (see Muskens, 1996; Beaver, 2001). The restriction of the quantifier in the temporal domain will contain at least the temporal relation contributed by tense proper ($\prec$, $\succ$). In the case of definites, the restriction will be entirely presupposed.

11.7.4 Tense architecture

In the system to be developed in what follows, we have deictic tenses and relational tenses, that is, two-place predicates of times. These are constants which have the same denotation in every model (we will adapt these meanings to the dynamic framework below):

(45) Deictic tenses
$F(N) = s^*$
$F(PAST^*) = \{t \mid t \prec s^*\}$

(46) Relational tenses
$F(PAST) = \{<t, t'> \mid t \prec t'\} = F(have)$
$F(FUT) = \{<t, t'> \mid t \succ t'\} = F(will)$
$F(XN) = \{<t, t'> \mid t' \text{ is a final subinterval of } t\} = F(has)$

We distinguish between the temporal relation and the temporal centre. The T-centres are N (a deictic pronoun), Tpro (a definite dm), TPRO (a semantically void pronoun that will create a temporal abstract). The T-centre is obligatory, while the T-relation is optional. This is the theory we have defended in several recent papers (Grønn and von Stechow, 2010, 2012; von Stechow and Grønn, 2013a,b).

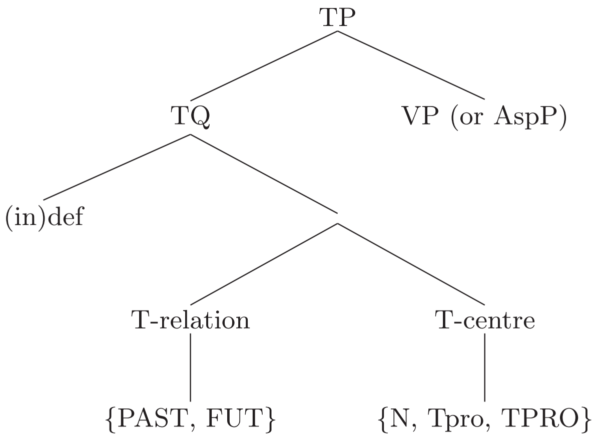


Figure 11.1 *Tense architecture*

To this system we add a covert indefinite or definite article. If the article introduces a new discourse marker, then the tense will be a shifter; if the discourse marker is old, the tense is anaphoric.

We thereby eventually arrive at the tense architecture shown in Figure 11.1.

On this view, most tenses are not simply pronominal as in Partee (1973a), but rather are relations between two times, of which only one is a pro-form.

11.7.5 A note on temporal modification

In our system, tenses are definite or indefinite terms which have the format of (dynamic) generalised quantifiers. In the nominal domain, the restriction and nucleus of a generalised quantifier can easily be modified by intersective adjectives, relative clauses, and so on. We think that there are similar devices in the temporal domain as well.

In von Stechow and Grønn (2013b) we give an intersective analysis of *when* adjuncts as temporal relative clauses. Information structure determines whether the *when*-clause is part of the restrictor or nucleus of the matrix temporal quantifier, as in the following examples with indefinite tense:

(47) a. When I was young, I read *War and Peace*. (the topicalised *when*-clause is a free relative clause in the restrictor of the indefinite article)
b. I read *War and Peace* when I was young. (*when*-clause in the nucleus of the indefinite article)

Which combinations of temporal modifiers and tenses are possible, is, of course, an empirical question, but it is clear that the system needs a lot of flexibility. For instance, the following past perfect (*had left*) should arguably be decomposed into two indefinite past tenses:

(48) a. John's wife had already left, when he came to the party.
b. There is a time at which John's wife leaves (and this time is) before a past time at which John comes to the party.

The temporal centre of the past perfect is not a definite anaphoric tense in this case, but an indefinite past modified by a *when*-clause.

11.8 (In)definite operators in a dynamic framework

Our dynamic framework is presented in the appendix, written in telegram style for those who are interested in the formalisation of the system. An easier way out would be to make the points below informally in the DRT-style of (Partee, 1984b).

11.8.1 Indefinites

Given the framework outlined in the appendix, we can introduce the indefinite operator **ind** which serves not only in the formalisation of the indefinite article in English but also in the covert indefinite article above tense and aspect. The operator **ind** introduces d as a new dm and updates the context with the restriction P(d) and the nucleus Q(d), formally:

(49) The indefinite operator **ind**, type d((d,cc),((d,cc),cc))
F(**ind**) $= \lambda d.\lambda P.\lambda Q.\lambda c\colon d \notin \mathrm{dom}(c).\{<f,w> \mid \exists g \in c\colon g \subseteq f \;\&\; d \in \mathrm{dom}(f) \;\&$
$<f,w> \in (([c \text{ add } d] + P(d)) + Q(d))\}$

This is the typed version of Heim's semantics for indefinites. To understand the definition, we have to introduce Beaver's add-operator. What 'c add d' says is that we make the d-assignments in c a bit bigger: we enlarge their domain by the discourse marker d, where d may have any value. We have to carry out this trivial modification of the context, since c + P(d) might be undefined if d is new.

(50) Beaver's add-operator
$c \text{ add } d = \{<f,w> \mid \exists g \in c\colon g \subseteq_d f \;\&\; <g,w> \in c\}$
[i.e. f is an incrementation of g by adding d to the domain of g]

Let us consider the following example with an indefinite deictic forward shifter in the temporal domain:

(51) It will rain.
ind^5 WILL* RAIN
There is a time f(5) after now and it rains at f(5)

The symbol 5 stands for the dm 5_{di}. This sentence doesn't contain variables. Formally, the context change potential (CCP) of the entire sentence is therefore as in (52):

(52) $\lambda c\colon 5 \notin \mathrm{dom}(c).\{<f,w> \mid \exists\, g \in c\colon g \subseteq f \;\&\; 5 \in \mathrm{dom}(f) \;\&\; f(5) \succ N \;\&\; f(5) \in$
$F(\text{rain})(w)\}$

11.8.2 Definites

The definite article picks up a familiar dm, that is, one that is in the domain of the local context. Furthermore, the entire restriction must by entailed by the context, i.e. it is presupposed. To make this precise, we first say what it means for a CCP to be entailed by a context. The relevant notion is defined by means of Beaver's ↓-operator, which we explain below.

Heim defines entailment in this sense by saying that *c* entails *p* iff *c*+*p*=*c*. The intuition is that an entailed CCP does not add any new information to the context when the sentence is uttered, and hence the context remains the same. However, this does not work for indefinites because indefinites add new dms to the context, so after the update the context is different.

Beaver has found a method that works for indefinites. The crucial ingredient is the ↓ -operator which is defined thus:[7]

(53) $c + \downarrow p = \{<f,w> \in c \mid \exists g : f \subseteq g \;\&\; <g,w> \in c + p\}$

(54) Entailment
$c \models p$ iff $c + \downarrow p = c$.

Therefore the definite operator can be defined as in (55). Presuppositions are written between the colon and full stop.

(55) The **def**-operator type d((d,cc), ((d,cc),cc))
$F(\mathbf{def}) = \lambda d.\lambda P.\lambda Q.\lambda c{:}\ c \models P(d).\{<f,w> \mid \exists g \in c : g \subseteq f \;\&\; <f,w> \in c + Q(d)\}$

So the definite article presupposes its entire restriction, and only the nuclear scope can introduce new information. However, if P merely amounts to the tense relation proper (e.g. $\prec$), then the presupposition can be rather weak, since there may be several indefinite past tenses in the prior context.

As we noted above in Section 11.7.5, *when*-clauses and temporal PPs may be added to the restriction of both **ind** and **def**. In the latter case, to avoid ambiguity, the speaker should make the restriction of the definite as informative as possible, following the pragmatic principle: maximise presuppositions! This will help the hearer to find the correct antecedent.

It should be noted that **ind** and **def**, despite their semantic type, are not genuine quantifiers (like EVERY, which is not treated here), because the result of applying either of them is still an open sentence. In truth-conditional terms, the dm introduced/picked up by the article is a constant

[7] The motivation behind the definition of entailment by means of the ↓ -operator is this:

Suppose we update a context c by uttering the sentence *A*[1] *farmer has a*[2]*donkey*. The semantics of the indefinite article requires that we add a new dm for the indefinite articles, say 1 and 2.

The new context created by this utterance is c_1. This context should entail the CCP *A farmer has a donkey,* because we have just said that. If we add something that has already been said, e.g. *A*[3] *farmer has a*[4] *donkey*, we don't change the information contained in the context c_1. Beaver's definition of entailment takes care of this situation because the ↓ -operator is purely eliminative and doesn't add any new dms to the context.

and ultimately a free variable in some sense. The result of an update is always an open proposition.

11.9 Analysis of tense in a typed dynamic system

We now have to introduce temporal arguments for dynamic predicates. By convention, the temporal argument will always be the first one after the world argument, which is implicit.

(56) $F(SLEEP) = \lambda d_{di}.\lambda d'_{de}.\lambda c{:}\ d_{di}, d'_{de} \in dom(c).\{<f,w> \in c \mid F(sleep)(w)(f(d_{di}))(f(d'_{de})) = 1\}$

We assume that verbs, adjectives, prepositions and tenses have temporal arguments.

(57) Tenses
Present: N is a distinguished dm of type di.
PAST and FUT: type (di,(di, cc))
$F(PAST) = \lambda d_{di}.\lambda d'_{di}.\lambda c{:}\ d, d' \in dom(c).\{<f,w> \in c \mid f(d') \prec f(d)\}$
$F(FUT) = \lambda d_{di}.\lambda d'_{di}.\lambda c{:}\ d, d' \in dom(c).\{<f,w> \in c \mid f(d') \succ f(d)\}$

Thus, tenses are purely relational and must be combined with either the indefinite or the definite article. In the first case, they introduce a new reference time, while in the second case they are anaphoric. Let's see how this works on a concrete example (from German in order to avoid interference with aspect):

(58) Alla schlief. Sie träumte.
ind^1 PAST(N) [λ_2 [def^3 ALLA [λ_5 SLEPT(t_2)(t_5)]]]
def^1 PAST(N) [λ_4 DREAMT(t_4)(SHE_3)]

The first PAST is indefinite. It introduces a new reference time at which Alla was asleep (proper names like 'Alla' are treated as definites). The second PAST is definite. The sentence does not mean that Alla was dreaming at some time or other – it means that Alla was dreaming at the first time. Here is an account of the CCP.

(59) $c_0 + ind^1$ PAST(N) λ_2 def^3 ALLA λ_5 SLEPT(t_2)(t_5) is only defined if $1 \notin dom(c_0)$, $N,3 \in dom(c_0)$. If defined, the result is $\{<f,w> \mid \exists g \in c_0{:}\ g \subseteq_1 f\ \&\ f(1) \prec f(N)\ \&\ f(3) = Alla\ \&\ f(3)$ sleeps at $f(1)$ in $w\} = c_1$
$c_1 + def^1$ PAST(N) λ_4 DREAMT(t_4)(SHE_3) is only defined if
$c_1 \models$ PAST(N)(1). This is given. So we have to calculate
$c_1 +$ DREAMT(1)(SHE_3), which is only defined if $1,3 \in dom(c_1)$, which is the case.
So the result is $\{<f,w> \in c_1 \mid f(3)$ dreams at $f(1)$ in $w\}$.

Next, let us analyse an example involving the past perfect, which is typically used anaphorically.

(60) Mary arrived at 6 AM. John had left.
ind^1 PAST(N) [λ_2 [def^3 MARY [λ_9 [AT 6(t_2) & ARRIVE(t_2)(t_9)]]]]
def^1 PAST(N) [λ_4 [ind^5 HAVE(t_4) [λ_6 [def^7 JOHN [λ_8 LEFT(t_6)(t_8)]]]]]

The text means that Mary left at 6 AM, and John had left before that time. So the past perfect introduces a new past (event) time, whose temporal centre is anaphoric to a given past time. The HAVE in the second sentence is synonymous with a relative PAST. Temporal adverbials ('at 6 AM') are analysed as syntactic adjuncts which semantically combine with the VP through PM.

(61) $[\![\text{AT 6 AM}]\!] = \lambda d_{di}.\lambda c\text{: } d \in \text{dom}(c).\{<f,w> \in c \mid f(d) \text{ is at 6 AM}\}$

The reader may check for herself that the effect of this text on a context c, the domain of which contains 3_{de} and 7_{de}, is as follows:

(62) $\{<f,w> \mid \exists g \in c\text{: } g \subseteq_{1,5} f$ & $f(1) \prec f(N)$ & f(1) is at 6 AM & f(3) = Mary & f(3) arrives at f(1) in w & $f(5) \prec f(1)$ & f(7) = John & f(7) leaves at f(5) in w$\}$

Here is our analysis of the anaphoric PAST in Partee's example:

(63) I left home at 11. I didn't turn off the stove (*at that time in the past*).
ind^1 PAST(N) [λ_3 [AT 11(t_3) & LEFT(t_3)(I)]] (= p)
NOT [def^1 PAST(N) [λ_2 TURN-OFF-STOVE(t_2)(I)]] (= q)

The standard dynamic semantics for $\text{NOT}_{(\pi,\pi)}$ is as follows:

(64) Negation. F(NOT) =
$\lambda p_\pi.\lambda c\text{: } c + p \text{ is defined}.\{<f,w> \in c \mid \neg(\exists g)\ f \subseteq g \;\&\; <g,w> \in c + p\}$

Here is the calculation for the example.

(65) $c_0 + p = \{<f,w> \mid \exists g \in c_0\text{: } g \subseteq_1 f$ & $f(1) \prec f(N)$ & f(1) at 11 & I leave at f(1) in w$\} = c_1$
$c_1 + q = \{<f,w> \in c_1 \mid \neg(\exists g)\ f \subseteq g$ & I turn-off-the-stove at g(1)$\}$
$= \{<f,w> \mid \exists g \in c_0\text{: } g \subseteq_1 f$ & $f(1) \prec f(N)$ & f(1) at 11 & I leave at f(1) in w & $\neg$ I turn-off-the-stove at f(1)$\}$

This is the reading Partee had in mind. Since the entire definite tense is presupposed, we get rid of the scope interaction with the negation without giving up the relational semantics of the deictic PAST, namely that the reference time is before the speech time.

In the next section we will show that the application of the definite/indefinite distinction to the temporal domain is a general phenomenon which concerns not only times, but also events.

11.10 Integrating (in)definite aspect

For simplicity we have chosen to mostly leave aspect and events out of the analysis above. We will now show that we can introduce aspect without having to modify the principles underlying the theory.

Let's illustrate how aspect fits into the picture with a classical example of event anaphora from Russian:

(66) Anaphoric use of the imperfective
V ètoj porternoj ja napisal^{PAST,PF} pervoe ljubovnoe pis'mo Vere.
in this tavern I wrote^{PAST,PF} first love letter to-Vera.
Pisal^{PAST,IPF} [karandashom]$_F$
I-wrote^{PAST,IPF} [with-pencil]$_F$
'In this tavern I wrote my first love letter to Vera. I wrote it with a pencil.' (Chekhov)

Grønn (2004) defends the view that the Russian imperfective is ambiguous. Its core meaning is that the event time includes the reference time, but it can also mean the same as the perfective, namely that the event time is included in the reference time. The same thing happens when an imperfective mentions a previous event, as in (66).

Aspect localises the event time with respect to the reference time; see Klein (1994). This means that we have to change the entries for verbs, so that instead of the time argument, they have an event argument. The combination with tense is mediated by aspect, so the entry for WRITE is as shown in (67), where we are using the notation e for dms of type dv.

(67) $F(WRITE) = \lambda e_{dv}.\lambda d_{de}.\lambda d'_{de}.\lambda c\text{: } e, d, d' \in dom(c)$
$\{<f,w> \in c \mid F(write)(f(e))(f(d))(f(d')) = 1\}$

The semantic aspects are now purely relational, just like tense:

(68) Dynamic aspects: type di(dv,cc)
a. Dynamic perfective:
$F(PF) = \lambda d_{di}.\lambda e_{dv}.\lambda c\text{: } d, e \in dom(c).\{<f,w> \in c \mid \tau(f(e)) \subseteq f(d)\}$
b. Dynamic imperfective:
$F(IPF) = \lambda d_{di}.\lambda e_{dv}.\lambda c\text{: } d, e \in dom(c).\ \{<f,w> \in c \mid f(d) \subseteq \tau(f(e))\}$

Compare these entries for aspect with the traditional ones in footnote 5 above.

As with tense, our new aspects are indefinite or definite. An indefinite aspect introduces a new event, a definite aspect is anaphoric to an old event. The 'fake' Russian imperfective in (66) is a morphological imperfective that can be interpreted as an anaphoric perfective.

Usually, a semantic perfective marks its verb with the [pf] feature. However, when the aspect is definite, the aspect can be neutralised, and instead the unmarked aspectual feature is assigned to the verb. As a result, we get a semantic perfective and an unmarked imperfective verb form.

Here is an account of the Russian example, which for the sake of simplicity is analysed as if it were English. The past tense originates as the first argument of PF. It has to be QRed for type reasons.

(69) ind^1 PAST(N) [λ_6 [ind^2 PF(t_6)[λ_3 [A^4 LETTER [λ_5 WROTE(e_3)(x_5)(I)]]]]].
def^1 PAST(N) [λ_{10} [def^2 [[PF(t_{10})][λ_7 WROTE(e_7)(it_4)(I)]] [λ_8 [A^9 PENCIL [λ_{12} WITH(e_8)(x_{12})]]]]]

It is revealing to see that everything that is indefinite in the first sentence is definite in the second one. An Aspect Neutralisation Rule ensures that the definite PF-operator can license the feature [u-ipf], even though it is a semantic perfective.[8] The second aspect operator could not be a semantic imperfective because one and the same event cannot be both complete and incomplete. It follows logically that the second aspect feature cannot be semantically interpreted.

The meaning of the text is therefore as follows:

(70) $c + (69)$ is only defined if $1, 2, 4, 9 \notin \text{dom}(c)$. If defined:
$c + (69) = \{<f,w> \mid \exists g \in c: g \subseteq f \;\&\; 1,2,4,9 \in \text{dom}(f) \;\&\; f(1) \prec f(N) \;\&\; \tau(f(2)) \subseteq f(1) \;\&\; \text{letter}_w(f(4)) \;\&\; \text{write}_w(f(2))(f(4))(f(I)) \;\&\; f(2)\ \text{with}_w\ (f(9)) \;\&\; \text{pencil}_w(f(9))\}$

This event anaphora example also illustrates the principle 'maximise presuppositions!' by making the restriction of **def** as informative as possible. We want to capture the fact that in the second sentence of (66) only the adjunct 'with a pencil' is focused and provides new information – hence the writing-predicate, not just the aspectual relation, should be backgrounded and part of the presupposition. To achieve this we must make sure that the definite operator takes the aspectual relation *and* the verbal predicate as its first argument (the restriction). The two properties of events are then combined by predicate modification. Only the adjunct 'with a pencil', which is also a dynamic event property, is left in the nucleus of the definite article.

8 In examples such as (66), we assume a checking relation from the semantic PF to the uninterpretable imperfective (!) aspect feature of the event argument of the verb; see Grønn and von Stechow (2012) for technical details.

Our Aspect Neutralisation Rule says that *definite aspects are neutralised with respect to their morphological feature.* Whether a language adheres or not to this rule is an important factor in the division of labour between morphological aspects in Slavic languages. In Russian, perfective morphology is typically used for indefinite complete events (e.g. in narrative progression), while definite aspects – and imperfective morphological aspect – are never used in cases of narrative progression. West Slavic languages, on the other hand, apparently do not have this rule, and the unmarked imperfective is accordingly not used with definite aspect but may occur in contexts of narrative progression.

11.11 Conclusions

Do we need a dynamic framework for temporal anaphora? A static framework would have to represent the arguments of tenses by free variables that are existentially bound on the text level. We would still need the [±def]-distinction to make sure that indefinite variables are new, while definite ones are old. We would have to make sure syntactically that indefinite variables in the scope of negation or other operators are not used later in the text. Furthermore, we would need a fourth kind of free variables in order to represent deictic words, which would not be bound at the text level. It is clear that the restrictions on co-indexing will be very difficult to formulate. Therefore Occam's razor says that the dynamic framework is the better framework for the analysis of temporality.

Appendix: A dynamic framework

The system consists of two parts, one static and one dynamic, with the latter building on the former. The static part is here mainly used for making clear the status of discourse markers that are not interpreted by the outer assignment a, but by the inner assignment f. So our system has dms as constants in the static part. There are also variables for dms that are interpreted by the outer assignment a.

We introduce d (shorthand for de, di or dv) as the type of discourse markers (dm) and π as the type of context change potentials (CCP). Predicates of type dπ are called *dynamic predicates*. With Beaver (2001) we assume that for each dynamic predicate, e.g. [$\mathrm{RAIN}_{di\pi}$], there is a unique first order *static predicate* (here of type it), i.e. we have a corresponding static expression written in small letters: [rain_{it}].

We can also have dynamic λ-abstracts:

(71) $[_{\pi}\ [\mathrm{N}_{di}\ [_{di\pi}\ \lambda\nu\ [\mathrm{RAIN}\ \nu]]]]$ ('it rains')

Apart from type differences, dynamic expressions look virtually the same as their static counterparts, and we can use almost everything we know from Montague Grammar. However, these expressions have a different interpretation, as we will see.

Syntax

For the syntax of the dynamic system we only need expressions of the types d and π and the rule that combines two types a and b to (ab). d and π might therefore be regarded as basic. But for the interpretation it is more perspicuous to decompose π. These are the types we use:

(72) Types

Basic: e (individuals), i (times), v (events), de (dms for ordinary individuals), di (dms for times), dv (dms for events), t (truth-value).[9]

Complex: If a and b are types, (ab) is a type. If a is a type (wa) and (ga) are types.

Intuitively, w is the type of worlds and g is the type of dm-assignments. These types are in some sense intensional. They are not basic but always form functions. We use the following abbreviations: c := (g(wt)) (type of contexts, information states), π := (cc) (type of CCPs).

The lexicon of the language consists of a set of constants and a set of variables for any type a. The dms are constants. Thus the lexicon is $\cup_{a \in Type}$ $\mathrm{Con}_a \cup \cup_{a \in Type} \mathrm{Var}_a$. We assume that there are no constants of type g or w in the lexicon. Thus the language is intensional.

(73) Syntax

Con. If α is a constant of type a, α is an expression of type a.

Var. If x is a variable of type a, x is an expression of type a.

FA. If α is an expression of type ab and β is an expression of type a, then $\alpha(\beta)$ is an expression of type b.

PM. If α and β are expressions of type (at) or (dπ), then [α β] is an expression of the same type, where d stands for de, di or dv.

Abstraction. If x is a variable of type a and α is an expression of type b, then [λx α] is an expression of type (ab).

The rule FA is the combination of a functor and an argument, that is, Functional Application. PM is what Heim and Kratzer (1998) call Predicate Modification.

Semantics

The interpretation function for the language is based on a familiar intensional model

(74) $M = (E, I, V, DM_e, DM_i, DM_v, W, N, \ldots F)$
where E, I, V are sets of individuals, times and events, respectively, and DM_e, DM_i, DM_v are sets of discourse markers for individuals, times and events, respectively. N is a distinguished time (the speech time). F interprets the constants.

Next we define the semantic domains for each type. Let DM be $D_{de} \cup D_{di} \cup D_{dv}$.

[9] Sometimes we ignore the sortal distinction between de, di and dv and simply write d for the basic type of discourse markers.

(75) Semantic domains

$D_e = E$, $D_i = I$, $D_v = V$, $D_{de} = DM_e$, $D_{di} = DM_i$, $D_{dv} = DM_v$, $D_w = W$

$D_g = \{f \mid f$ is a partial function from DM into $E \cup I \cup V$ that respects the types$\}$

$D_{(ab)} = \{f \mid f$ is a partial function from D_a into $D_b\}$

F interprets the predicates by assigning them appropriate intensions.

All the functional domains are partial. It follows from the definition that $D_c = D_{(g(wt))}$ = sets of <f,w> pairs. Similarly, $D_\pi = D_{cc}$ i.e. the partial functions from D_c into $D_{c.}$

The functions in D_g are called *d-assignments*. All the d-assignments in a context c have the same domain. The variables used by these assignments are denoted as dom(c). The worlds used in a context c are called the proposition of c.

(76) Where c is a context:

a. $f \in c := \exists w <f,w> \in c$

b. $\mathrm{dom}(c) = \cup_{f \in c}\, \mathrm{dom}(f)$

c. $\mathrm{Prop}(c) = \{w \mid \exists f <f,w> \in c\}$

(77) Truth

A context c is true in a world w if $w \in \mathrm{Prop}(c)$.

The interpretation function for our language depends on a model M and an outer variable assignment a. We use the usual conventions, that is, a[x/u] is that assignment a′ that is like a except for the variable x, which is mapped to u. Variable assignments must not be confused with dm-assignments, which may be thought of as Kamp's embedding functions (here: inner variable assignments). We use the +-notation of Heim (1982, 1983a), that is, if p is a CCP and c is a context, then c + p stands for p(c). Since p is a partial function, the application might be undefined. The admissibility condition for p is what is called the presupposition of p.

The semantics of the language is defined below:

(78) Definition of $[\![\ldots]\!]^{M,a}$

Con. If α is a constant of type b, $[\![\alpha]\!]^{M,a} = F(\alpha)$ [an intension].

Var. If x is a variable of type b, $[\![x]\!]^{M,a} = a(x)$.

FA. If α is an expression of type ab and β is an expression of type a, $[\![\alpha(\beta)]\!]^{M,a} = [\![\alpha]\!]^{M,a}([\![\beta]\!]^{M,a})$.

PM. If P and Q are expressions of type $(d\pi)$, then $[\![[P\ Q]]\!]^{M,a} = \lambda d \in D_d.\lambda c{:}\ d \in \mathrm{dom}(c).\{<f,w> \mid (\exists g \in c)\ g \subseteq f\ \&\ <f,w> \in ((c + [\![P]\!]^{M,a}(d)) + [\![Q]\!]^{M,a}(d))\}$ [not an intersective 'and'; but a dynamic 'and'].

Abstraction. If x is a variable of type b and α is an expression of type c, then $[\![[\lambda x\ \alpha]]\!]^{M,a} = \lambda u \in D_{b.}[\![\alpha]\!]^{a[x/u]}$.

Dynamic predication

Let us illustrate the system by going through the evaluation of the sentence *he*$_3$ *sleeps*, ignoring tense.

(79) $\text{SLEEP}_{de,\pi}\ (3_{de})$

Since the expression doesn't contain a variable, the evaluation doesn't depend on the outer variable assignment a. Recall that the dm 3_{de} is a constant. Therefore:

(80) $[\![\text{SLEEP}_{de,\pi}\,(3_{de})]\!]^M$
$= [\![\text{SLEEP}_{de,\pi}]\!]^M([\![3_{de}]\!]^M)$ (by FA)
$= \text{F}(\text{SLEEP}_{de,\pi})(\text{F}(3_{de}))$

The result should be a CCP. In order to know which CCP it is, one has to look at the interpretation of SLEEP by F. Recall that we assume with Beaver that SLEEP uniquely determines a corresponding static predicate of type (et) written in small letters, here **sleep**. The correspondence is given by the following meaning postulate (Beaver's MP8):

(81) MP8 (Beaver, 2001, 178)
Let M be a model and let P be a dynamic predicate constant of type (d, cc). Then there is static predicate constant V of type (et) such that for every dm d: $\text{F(P)(d)} = \lambda\text{c: d} \in \text{dom(c)}.\{<\text{f,w}> \in \text{c} \mid \text{f(d)} \in \text{F(V)(w)}\}$

MP8 links dynamic predicates with static ones. Since F($\mathbf{sleep}_{et}$) is an intension, F(**sleep**)(w) is an extension. If d is a dm of type de, then f(d) will be an individual that has to be in the set of the sleepers in w. Beaver's postulate MP8 can be generalised in an obvious way to n-place dynamic predicates. Applied to the meaning of F(SLEEP), the postulate gives us the following:

(82) $\text{F}(\text{SLEEP}_{(de,cc)}) = \lambda\text{d} \in \text{D}_{de}.\lambda\text{c} \in \text{D}_c\text{: d} \in \text{dom(c)}.\{<\text{f,w}> \in \text{c} \mid \text{f(d)} \in \text{F}(\text{sleep}_{et})(\text{w})\}$

Suppose $\text{F}(3_{de}) = 3_{de}$, then we have:

(83) $\text{F}(\text{SLEEP}_{de,\pi})(\text{F}(3_{de})) = \text{F}(\text{SLEEP}_{de,\pi})(3_{de})$
$= \lambda\text{d} \in \text{D}_{de}.\lambda\text{c} \in \text{D}_c\text{: d} \in \text{dom(c)}.\{<\text{f,w}> \in \text{c} \mid \text{f(d)} \in \text{F}(\text{sleep}_{et})(\text{w})\}(3_{de})$
(by F and MP8)
$= \lambda\text{c} \in \text{D}_c\text{: } 3_{de} \in \text{dom(c)}.\{<\text{f,w}> \in \text{c} \mid \text{f}(3_{de}) \in \text{F}(\text{sleep}_{et})(\text{w})\}$
(λ-conversion)

We add the definition of truth in a context.

(84) Let c be a context, w a world and p a CCP. Then p is true with respect to w and c if $\text{w} \in \text{Prop(c + p)}$. (i.e. iff $\text{f}(3_{de})$ sleeps in w.)

12

Aspect

Susan Rothstein

12.1 Introduction

Aspect is a linguistic category pertaining to what Comrie (1976) calls 'different ways of viewing the internal temporal constitution of a situation' (pp. 3–5). Aspect is frequently discussed along with tense and modality (often under rubric of the acronym TAM, standing for 'tense-aspect-modality/mood'), possibly because all three of these are generally expressed either via verbal inflections or via periphrastic forms including auxiliary verbs (Dahl and Velupillai, 2011). Tense and aspect markers are usually interpreted as operators on VP meanings, while mood/modality are markers more usually taken to express operations on propositional meanings. However, it is often difficult to decide which TAM category a particular marker expresses because these categories frequently overlap, as, for example, in the case of the English perfect (e.g. *have eaten*) and the French *imparfait*, which express both tense and aspect.

Assume, following Parsons (1990), Landman (2000) and many others, that verbs and predicates headed by verbs denote sets of events. Tense gives the temporal location of the events denoted by the verbal predicate, usually in relation to a given reference point. In contrast, aspectual properties of a verbal predicate reflect the internal temporal make-up of the situations or events denoted by the predicate, for example, whether the predicate denotes events which hold at an interval or at a point. Modality, although it may be marked morphologically on a verb, indicates in which possible worlds the truth of a proposition is to be evaluated.

Verbs and the phrases projected by a verbal head are of the same semantic type, since all verbal projections denote sets of events. This means that both verbs and VPs have aspectual properties, although not all aspectual properties apply at both levels of projection. Aspectual properties include (i) the lexical aspect or aspectual class or Aktionsart of the head of the verbal predicate, (ii) the telicity or atelicity of the predicate and (iii) the grammatical aspect of the VP, in particular whether it is perfective or imperfective. The lexical aspect of the verb, termed 'situation aspect' in Smith (1991), is determined by the properties of the event type it denotes, for example, whether it is a state, a change of state or a process. The grammatical aspect, or 'viewpoint aspect' (again Smith's terminology), reflects perspective on a situation. The telic/atelic status of the VP reflects whether or not the event is perceived as having an inherently predetermined endpoint. My aim in this chapter is to give an overview of all three kinds of aspectual properties, and to review some of the major advances in our understanding of aspectual phenomena. We will see that although it is tempting to try and reduce at least one of these aspectual properties to another, each is independent, although they interact in interesting and subtle ways. In the first and longer section of the chapter, I discuss lexical aspect and the telic/atelic distinction, and in the second section, grammatical aspect.

12.2 Lexical aspect

12.2.1 Vendler classes

The study of lexical aspect stems from Vendler's (1957) observation that 'the use of a verb may also suggest the particular way in which that verb presupposes and involves the notion of time' (p. 143). We rephrase this in the following way: assume a domain which includes a set of events E, a set of intervals I and a function τ from E into I which maps an event onto its running time, the interval at which it holds (Link, 1987; Krifka, 1992, 1998). We assume, following Parsons (1990) and Landman (2000), that a verb is a predicate of events, denoting a set of events which is a subset of E. Events can then be classified or characterised according to how the event predicate holds of the temporal parts of the events in its denotation. For example, if an event e holding at interval i is in the denotation of the event predicate *run*, then all subintervals of i above a certain minimal duration host subevents of e which are also events of running. This is not true of a predicate like *grow up*: subevents of an event of growing up are not themselves events of growing up (although they may be events of growing). Thus, while (1a) entails (1b), (2a) does not entail (2b):

(1) a. John ran from 1 pm to 4 pm.
    b. John ran from 2 pm to 3 pm.

(2) a. Between the age of 12 and the age of 15, Mary grew up.
    b. Between the age of 13 and the age of 14, Mary grew up.

Vendler identifies four basic classes of verbs which bear different relations to the intervals at which they hold, *activities*, *accomplishments*, *states* and *achievements*. Activities like *run*, *push the cart* and accomplishments such as *grow up* and *build a house* are inherently extended and express progression, but accomplishments have a predetermined endpoint while activities do not. States such as *love* and *live in Amsterdam* and achievements such as *win* and *arrive* do not express progression, but are clearly distinguishable since 'achievements occur at a single moment, while states last for a period of time' (Vendler, 1957, p. 147). Crucially, Vendler shows that these different relations to the time interval have linguistic implications: verbs from different classes interact with temporal modifiers, modals and aspectual operators in predictably different ways because of the different temporal make-up of the events in their denotations. The two central linguistic properties which are associated with the characterisation of verbal classes are (i) natural occurrence in the progressive, which, as Vendler noted, distinguishes between accomplishments and activities on the one hand and states and achievements on the other, as illustrated in (3), and (ii) modification by either *for a time* or *in a time*. The former modifies activities and states, while the latter modifies achievements and accomplishments (restricting our attention only to English, for the moment), as shown in (4):

(3) a. John was running. (activity)
b. John was drawing a circle. (accomplishment)
c. #John was knowing Mary/was knowing the answer. (state)
d. #John was noticing the new curtains. (achievement)

(4) a. John ran for half an hour/#in half an hour.
b. John drew a circle in five minutes/#for five minutes.
c. Mary loved John/knew John for many years/#in many years.
d. Mary won the race/in in ten minutes/# for ten minutes.

Vendler's paper opened a very fruitful field of research in both lexical semantics and aspect, raising the question of how the temporal properties of events are related to the linguistic properties of the predicates which describe them. There has also been much discussion about what general properties of events give rise to the temporal distinctions that Vendler noted. Some of the distinctions that have been suggested are: *homogeneous/non-homogeneous* (states and activities are homogeneous, while achievements and accomplishments are not); *cumulative/quantized* (states and activities are cumulative, achievements and accomplishments are quantized); *dynamic/non-dynamic* (states are non-dynamic, all others are dynamic); *predicates of intervals* vs. *predicates of instants* (activities and accomplishments are necessarily temporally extended and hold of intervals, while states and achievements hold at instants). Another distinction is *atelic* vs. *telic*, which is sometimes taken to be identical to the homogeneous/non-homogeneous distinction. In Section 12.2.3 we will try and clarify these distinctions and the relations between them. Before that, we introduce a fifth class of verbs not discussed by Vendler, namely semelfactives.

12.2.2 Semelfactives

Semelfactives were identified as a fifth lexical class in Comrie (1976), and were brought to prominence by Smith (1991). They include verbs such as *blink*, *wink*, *kick*, *hop* and *jump*, which denote very short events. These events are distinguished from achievements since in a fundamental sense they 'take time'. Achievements like *notice* are truly instantaneous, in that they denote changes from a situation in which $\neg\varphi$ holds (I hadn't noticed) to a situation in which φ holds (I had noticed). As Kamp (1979, 1980) argues, an Aristotelian semantics requires there to be no gap between these situations (i.e. no interval at which neither $\neg\varphi$ nor φ hold), and therefore the change cannot take time. However, semelfactive events do take time. In an event of winking, someone moves an eye from a state of being open to a state of being closed and then back to a state of being open again, so the event cannot be instantaneous, since different things happen at different stages of the event and different states hold at different points during the event. (My eye is open, then it moves to being closed, then it is briefly closed, then it moves to being open, then it is open again.)

In general, semelfactive predicates in English are ambiguous between a semelfactive and an activity reading. Rothstein (2008b) focuses on this ambiguity and analyses semelfactives as denoting sets of naturally atomic minimal activity events. She begins with Dowty's (1979) observation that an activity predicate P denotes a set of iterations of minimal events in P. Dowty shows that, for example, a minimal waltzing requires taking three steps, while longer events in *waltz* are iterations of the three steps that constitute a minimal waltzing event. The same is true for the activity predicate *walk*. A minimal event of walking is an event of x taking a certain number of steps, and a more extended event of walking is a concatenation or iteration of minimal events, that is, an event of taking a greater number of steps. Rothstein (2008b) suggests that semelfactives denote a particular kind of minimal activity. Compare *hop*, which has a semelfactive and an activity reading, with *walk*, which has only an activity reading. *Hop* and *walk* denote sets of iterations of minimal events derived recursively in the same way. The difference between them is that the minimal events in *hop* are intuitively well-defined individuable (and thus countable) atomic events, whereas minimal events in *walk* are not. This means that if someone hops continuously for several minutes, one can plausibly ask 'How many times did she hop before stopping?', whereas if someone walks continuously for several minutes, the question 'How many times did she walk before stopping?' is infelicitous. Under this analysis, semelfactives do not constitute a fifth lexical class, but are a particular kind of activity predicate.

12.2.3 Telicity, lexical classes and the problem of aspectual composition

A telic predicate is usually defined as a predicate denoting a set of events having a fixed terminal point specified by the lexical content of the predicate. Thus, predicates such as *build a house* and *arrive at the station* are telic because the events in their denotation have a predetermined endpoint: the points at which the house under discussion is built and at which the subject arrives at the station respectively. In contrast *run* and *love Mary* are atelic, since there is no lexically specified end to the eventuality. Krifka (1998) stresses that telicity is a property of predicates and not of events, since 'one and the same event of running can be described by *running* (i.e., by an atelic predicate) or by *running a mile* (i.e., a telic, or delimited, predicate)' (Krifka, 1998, p. 207).

A generally accepted diagnostic for the telic/atelic contrast is the use of *in an hour* vs. *for an hour* adverbials. The former naturally occurs with telic VPs and the latter with atelic VPs:

(5) a. John built a house in a week/#for a week.
b. Mary arrived at the station in an hour/#for an hour.
c. John loved Mary for years/#in a year.
d. Mary ran for an hour/#in an hour.[1]

The relation between the atelic/telic distinction and the semantics of lexical classes is central to all research on lexical aspect, and a fundamental issue is whether either can be defined in terms of the other. The close relation between them is indicated by the fact that the *in an hour/for an hour* test is taken as a diagnostic for telicity, and is also used to support the distinction between lexical classes, as seen in (4) above. It thus is very natural to assume that accomplishments and achievements are telic since they occur with *in α time*. The accomplishment predicate *build a house* is telic because the events in its denotation have a predetermined endpoint, the point at which the building of the relevant house is finished, while the achievement *arrive* is telic since it denotes a set of instantaneous events of changing from a situation of not being at place X to being at place X, and when the change is over, the event is over. Similarly, activities and states are naturally atelic, since they go with *for α time*. As discussed in Section 12.2.2, Dowty (1979) shows that activities are concatenations of a sequence of actions which can be iterated, and thus an activity predicate has no natural stopping point and is atelic. States are also atelic, since they are non-dynamic. The non-dynamic property means that if a state holds, this situation will continue unchanged until it is terminated by an external event, and atelicity follows.

However, the relation between lexical classes and a telicity value is not straightforward, as has been discussed in detail in the literature (Verkuyl,

[1] The infelicitous versions of (5c) and (5d) can be coerced into felicitous telic interpretations, as discussed below in Section 12.2.5. *John loved Mary in half an hour* can have an inchoative interpretation, meaning 'John fell in love with Mary in half an hour'. *Mary ran in an hour* is acceptable if *run* is interpreted as 'run a given distance.' For some discussion of aspectual coercion see, among others, de Swart (1998a).

1972; Dowty, 1979; Tenny, 1987, 1994; Krifka, 1989a, 1992, 1998, among others). If verbs belong to a particular lexical class and lexical classes are telic or atelic, then we would not expect the same V to be able to head both VP predicates which are telic and those which are atelic. However, there are at least three sets of cases in which this occurs. This is often referred to as the problem of aspectual composition (the term stems from Verkuyl, 1972), since the telic value of the VP apparently depends on which elements the head V is composed with.

First, verbs like *build*, which are usually associated with the accomplishment class and head telic predicates, nonetheless head atelic predicates when the direct object of the verb is a bare plural or a mass noun, as illustrated in (6). In contrast, verbs such as *push* head atelic predicates, independent of the content of the direct object (7).

(6) a. #John built a house/two houses/the house/many houses for three weeks.
  b. John built houses/housing for three weeks.
  c. John built a house/two houses/the house/many houses in three weeks.
  d. #John built houses in three weeks.

(7) a. John pushed a cart/the cart/two carts/many carts for three hours.
  b. John pushed carts for three hours.
  c. #John pushed a cart/the cart/two carts/many carts in three hours.
  d. #John pushed carts in three hours.

The imperfective paradox (Dowty, 1979) is sensitive to the same phenomenon of aspectual composition. Predicates which can be modified by *for an hour* type adverbials give rise to the entailment in (8a)–(8c), but predicates which can be modified by *in an hour* adverbials don't, as in (8d):

(8) a. John is running *entails* John has run.
  b. John is pushing a cart *entails* John has pushed a cart.
  c. John is eating bread *entails* John has eaten bread.
  d. John is eating the sandwich *does* ***not*** *entail* John has eaten the sandwich.

Dowty notes that the entailments in (8a)–(8c) follow only if a certain minimal initial period has passed, enough to host a minimal instance of the event predicate, but he stresses that the minimal initial period in these cases is very short. Crucially, after the first minimal period, the progressive and the perfect sentences hold at the same instant: if John starts running, then after a short time it is true both that he is running and that he has run. In contrast, in (8d) the perfect sentence entails completion of the *eat the sandwich* event and thus is only true when the eating event is over and John has finished eating the sandwich. So the progressive and the perfect cannot hold simultaneously.

Second, although the status of the direct object does not affect the telicity of VPs headed by activities like *push*, the VP is telic if it contains an adverbial or measure predicate determining the endpoint of the event (see the quote from Krifka, 1998, above). This is shown in the contrast between (9a) and (9b), and between (9c) and (9d):

(9) a. #John ran (in the park) in an hour.
b. John ran to the store/around the park/five miles in an hour/#for an hour.
c. #John pushed the cart in half an hour.
d. John pushed the cart back to the supermarket in half an hour/#for half an hour.

Third, as pointed out in Verkuyl (1972), achievements may head atelic predicates when their arguments are bare plurals or mass and do not express a set quantity. Here the relevant argument may even be the subject:

(10) a. Tourists discovered this village all summer.
b. Guests arrived at the hotel for some hours.

A further issue is negation, which seems to turn a telic predicate into an atelic predicate:

(11) a. #John ate an apple for a week.
b. John didn't eat an apple for a week.

Examples (10) and (11) show that it is not just the theme argument or VP-internal adverbials which influence the telicity of the VP.

These data clearly show that the telicity or atelicity of a VP is not purely dependent on the choice of the head verb. This leads to some fundamental questions about the nature and relevance of verb classes. On the one hand, if verbal classes are naturally associated with telicity features, and verbs do not determine the telicity or atelicity of the VP, then it seems that verbs themselves cannot be associated with verbal classes. For example, assume that accomplishments are telic. It then seems that *build* itself is not an accomplishment, since it heads an atelic predicate in (6d) and a telic predicate in (6c). On the other hand, *build* does seem to have some kind of 'accomplishment features', since the contrast between (6b) and (6c) does not show up when the head is an activity type verb such as *push* (see the examples in (7)). The same questions can be posed about the examples in (8)–(10).

Different linguists have approached this apparently paradoxical issue in different ways. There are two basic approaches. Some, including Verkuyl (1972) and Dowty (1979), have argued that verbal classes should classify VPs rather than Vs. More recently, Rappaport Hovav (2008) and others have taken a more extreme position, suggesting that verbal classes, and in particular accomplishments, do not have linguistic relevance at all. The other point of view is developed in Krifka (1989a, 1992, 1998) and Rothstein (2004, 2008a, 2012). This position assumes that verbal classes do classify verbs, but that verbal classes are not directly labelled telic or atelic. Instead, the verbal class of a verb α constrains how the telicity of the VP headed by α is determined. Thus Krifka (1992) argues that accomplishments like *build* differ from activities like *push* because the thematic relation between *build* and its theme is 'gradual' or incremental, while this is not the case for *push*; in other words, it is the relation between the head and the theme which characterises the accomplishment class.

No matter what approach is taken to the definition of verbal classes, the data in (6)–(10) show the necessity of clarifying the relation between the determination of telicity and the choice of verbal head, and the problem of explaining how aspectual composition works is central in the aspect literature. Again, different linguists have proposed different ways of explaining aspectual composition. In the following section we will examine four approaches, based respectively on mereologies, lexical semantic decomposition, the semantics of scales and the semantics of event individuation. Each way focuses on a different facet of the interface between lexical aspect and telicity.

12.2.4 Aspectual composition

Mereologies

The mereological approach was developed most fully in Krifka (1989a, 1992, 1998) and has received recent attention in Champollion (2010b) (see also Champollion and Krifka, Chapter 13). Krifka's main goal is to solve the problem of aspectual composition, and not to give a basis for the distinction between lexical aspectual classes. His solution is based on the idea that the domain of events is a mereology analogous to the domain of individuals. Krifka proposes that predicates, both nominal and verbal, can be divided into cumulative and quantized predicates. Cumulativity is a property of a predicate P which meets the condition in (12) non-trivially, while quantization is a property of a predicate which meets the condition in (13):

(12) Cumulativity:
P is cumulative iff $\forall x, y : P(x) \wedge P(y) \rightarrow P(x \sqcup y)$
'If P is cumulative, then if x and y are in P, the sum of x and y is also in P'.

(13) Quantization:
P is quantized iff $\forall x, y : x \sqsubset y \wedge P(y) \rightarrow \neg P(x)$
'If P is quantized, then if y is in P, no proper part of y is also in P'.

Krifka's insight is that telicity is connected to quantization: a telic VP such as *build a house* does not have any subparts which also count as events of building a house, and only the complete event is an entity satisfying the VP predicate. Atelic VPs on the other hand are cumulative, since an event in the denotation of *push a cart* can be summed with another such event to make an extended event in *push a cart*. With accomplishments, the VP is quantized or cumulative depending on whether the direct object is cumulative or quantized: *a house* is quantized, since houses do not have proper parts which are also houses, and thus *build a house* is quantized and telic. In contrast, bare plurals are clearly cumulative, as was shown by Link (1983), and thus *build houses* is also cumulative. Krifka suggests that this is because accomplishments have an incremental relation to their direct objects (see also the less formal discussion of this in Tenny, 1987, 1994; Dowty, 1991), more precisely, he suggests that with accomplishments, an incremental theme relation supplies a homomorphism from the extent of the direct object to the extent of the event: each and every part of the theme argument is mapped onto a unique part of the event that it participates in, and thus the whole theme-entity must be mapped uniquely onto the event itself. No extensions of this event are possible either, since once the theme argument has been 'used up', the event is over. This guarantees that when the direct object is quantized, the VP itself must be quantized and thus telicity is explained. If the direct object of *build* is the quantized DP *the house* denoting **h**, then no parts of **h** will be in the denotation of *the house*, and only the entire event itself which has the entire entity **h** as its theme will count as an event in *build the house*. If the direct object is cumulative, then this will not hold, and the VP also will be cumulative and thus atelic.

Krifka characterises the lexical class of accomplishments as a class of predicates where the thematic relation with the direct object is always *gradual* or *incremental*, denoting a homomorphic relation of the kind just described, although the telic status of the VP is dependent on the choice of direct object. Krifka (1998) extends the analysis to aspectual composition with activity-headed predicates as in (9) above. He posits *path* thematic roles which are gradual in the same way that incremental theme roles are gradual, and which thus have the same mereological properties.

Despite its appeal, the mereological approach is problematic. Zucchi and White (2001) showed that NPs such as *at least three Ns* are cumulative on Krifka's definition, but nonetheless give rise to telic VPs as in (14):

(14) John built at least three houses in three weeks.

They propose that indefinite DPs in direct object position have scope over the event quantifier, denoting maximal sums of entities relative to the discourse situation. The VP in (14) is telic since no proper part of an event of building the maximal set of three houses salient in the discourse is also an event of building that same maximal set. Rothstein (2004) shows that while Zucchi and White's solution gets the right results for examples like (14), it cannot be generally correct, since indefinite DPs do not always have wide scope. In (15), where the VP is headed by an activity, the indefinite direct object must have scope under the aspectual operators and the event quantifier, since clearly the sentence requires different pairs of children to satisfy the VP predicate at different intervals during the last 20 years.

(15) This bicycle has carried (at least) two children around Amsterdam for the last 20 years.

Rothstein (2004) further argues that the problem with the mereological approach goes deeper than the problem illustrated in (15). Cumulativity is a property of semantically plural predicates, as the definition in (12) makes explicit. It concerns the possibility of summing and thus distinguishes between semantically plural predicates and semantically singular predicates. A predicate like *books* is cumulative because *books* denotes a set of pluralities and sums of pluralities are also pluralities. *Book* is not cumulative because it denotes a set of singular individuals, and sums of singularities are not singularities. It is important to see that the issue here is one of semantic plurality and not morphological plurality. This is made clear in Chierchia (1998a), who shows that the mass nouns are semantically plural, denoting sets of pluralities, even though they are morphologically singular. Now, applying this to the verbal domain, we see that atelicity cannot be defined in terms of cumulativity since semantically singular VPs, that is, predicates denoting sets of singular events, may be atelic.[2] In (16), the VP is semantically singular, denoting a set of singular events (in this case with a group subject).

(16) John and Mary discussed politicians once for many hours. They never did it again.

The VP, while singular, is atelic. This is intuitively because the singular event had no predetermined endpoint, and thus could be indefinitely extended as a single event. It is not because the cumulativity of the plural direct object predicate projects into a plural, cumulative VP.

A second problem with Krifka's theory is that only a subset of accomplishment verbal predicates have a gradual relation with their theme. Many accomplishment-type verbs show the kind of alternation illustrated in (6) although the extent of the theme cannot be mapped incrementally onto the extent of the event, and this indicates that the contribution of the theme argument to telicity does not have a mereological basis. An example from Rothstein (2004) is *repair the computer* where neither the extent of the computer, nor even the extent or complexity of the problem to be solved determines the extent of the event. (In fact the time the event takes is likely to be determined by the length of time it takes to identify what the problem is.)

Despite these problems, Krifka's account embodies an insight which transcends its details. The insight is that the extent of an event must be **indirectly** measured. Because events do not have physical properties which can be measured directly, the size or contours of an event must be measured via its relation with some other entity, or property of some other entity. Krifka's suggestion is that what is relevant is the volume or extent of the

[2] For discussion of semantic singularity and semantic plurality in the verbal domain, see Landman (1996).

direct object in the case of the accomplishment, and the path argument in the case of a predicate of directed motion. Filip (1993), Rothstein (2004) and Kennedy and Levin (2008) all make use of some variation on this idea. Filip (1993) and Kennedy and Levin (2008) both posit homomorphisms from some scale associated with the incremental theme to the running time of the event. Rothstein (2004, 2012), posits a complex accomplishment event which is the sum of an activity event and a structured event of change, where a homomorphism from the event of change to the activity event determines the running time of the event as a whole.

Lexical semantic decomposition

A different approach to lexical aspect and telicity focuses on decomposing the meaning of the verbal predicate. Dowty (1979, Chapter 2) decomposes verbal predicates using the lexical semantic primitives DO, CAUSE and RESULT. There is a correlation between the lexical semantic properties of the different lexical classes and their temporal properties, discussed later in his book. States are predicates with no internal structure and are thus non-dynamic since they do not involve change. They do not decompose, and they hold at intervals, but because they have no internal structure, they hold homogeneously down to the most minimal of intervals, namely instants. Thus, if a state P holds at an interval i, it will hold at every instant in i. Achievements have the lexical structure BECOME(P), and denote simple changes from $\neg\varphi$ to φ (where φ is $P(x)$). Achievements hold at minimal intervals consisting of the last point at which $\neg\varphi$ holds and the first point at which φ holds, with the assumption that these two instants are adjacent. Activities are decomposed into DO(P) and hold at an extended interval i. They are homogeneous predicates, since they hold at all subintervals of i which are big enough to host at least a minimal instance of the activity (see discussion in Section 12.2.2 above). Accomplishments decompose into DO(CAUSE(BECOME(P))).[3] They hold at extended intervals like activities, since they have a common DO component, but if an accomplishment holds at i, it does not hold at subintervals of i since the BECOME element of the complex event cannot be completed until the end of the interval i. Thus *build the house* decomposes into (DO(CAUSE(BECOME(BUILT)))THE HOUSE$_1$) and holds at interval i, and the end of the relevant interval will be defined by the coming into existence of the house. No subinterval of i can host an instantiation of the same predicate, since it will not be an event of the house with the relevant index coming into existence.

Dowty's work opened the way for an exploration of whether lexical classes could be characterised on the basis of the decomposition of verb meanings, and whether the notion 'accomplishment' could be defined in terms

[3] Importantly, Dowty notes that 'BECOME' does not have identical properties in the decomposition of an achievement and an accomplishment. 'BECOME' is an instantaneous event in the case of achievements but is an extended component in the make-up of accomplishments.

of causality and/or the bringing about of result states. Initial support for the result state approach was provided by the examples discussed in (9), which show that atelic predicates like *run* and *push the cart* may head a telic VP when the V is modified by a PP expressing a result state. Further support comes from (17), where the activity *hammer* becomes part of a complex accomplishment predicate with the addition of a result predicate and displays the sensitivity to choice of direct object characteristic of accomplishments:

(17) a. John hammered the metal for an hour/#in an hour.
b. John hammered the metal flat in an hour/#for an hour.

Further research, however, showed that it is implausible to reduce the semantics of accomplishments to lexical semantic properties such as 'cause' or 'result states' (see Rappaport Hovav and Levin, 1998; Levin and Rappaport Hovav, 1999, and others). Aspectual classes are associated with different subclasses of verbs, each having a wide range of lexical semantic properties. For example, a CAUSE component cannot distinguish between accomplishments and activities since, as Van Valin Jr. and La Polla (1997) show, activities can be causal as in (18a) and (18b).

(18) a. John bounced the ball (= caused the ball to bounce) for ten minutes.
b. Mary galloped the horse (= caused the horse to gallop) for half an hour.

Further, not all accomplishments have a natural causative analysis, as argued by Levin (2000). For example (19) is not naturally paraphrasable as *John caused an apple to be eaten*, nor can an event of John eating an apple be naturally decomposed into an event of John doing something which caused the apple to be eaten.

(19) John ate an apple.

Result states do not allow for a definition of accomplishments either. Rappaport Hovav (2008) argues that an accomplishment like *read the book (in an hour)* does not bring about an identifiable result state any more than an activity like run does. A further problem is that an analysis in terms of lexical decomposition does not allow a natural way to explain the variable telicity effects illustrated in (6)–(10).

Scales

Hay et al. (1999) proposed a different account of telicity and aspectual composition. They observed that with degree achievements such as *widen*, *lengthen* and so on, the telicity of the VP is dependent on the specificity of what they call the 'difference value'. Degree achievement sentences denote sets of events in which a change occurs in the value assigned to a participant in the event on a particular dimensional scale. The difference value is the scalar interval by which that value changes. The VPs in (20) differ in telicity though they have the same definite DP direct object.

(20) a. Kim lengthened the rope for some minutes/#in five minutes.
b. Kim lengthened the rope five inches in five minutes/#for five minutes.

Example (20a) is atelic because no difference value is specified, while example (20b) is telic because *five inches* specifies an exact difference between the state of the rope at the beginning and at the end of the lengthening event: 'the difference value identifies a bound on the measure of change in the affected argument over the course of the event' (Hay et al., 1999, p. 130; see also Kennedy and Levin, 2008). Achievement verbs are inherently scalar, but Rappaport Hovav (2008) and Kennedy (2012) extend this account to cover accomplishment verbs too. As already mentioned in the section on lexical semantic decomposition, Rappaport Hovav (2008) defends the thesis that aspectual composition and the difficulties in decomposing lexical aspectual classes show that Vendler classes are irrelevant. Instead, she claims that the lexical properties relevant for determining telicity are dynamicity and scalarity. She assumes a distinction between dynamic and non-dynamic or stative verbal predicates. Dynamic predicates divide into the inherently scalar and the non-scalar. Inherently scalar predicates are degree achievements such as *cool* and *lengthen*, which denote changes on a scale, and ordinary achievements such as *win* or *notice*, which, as Beavers (2008), suggested are associated with a 'two-point scale'. Activities are dynamic and non-scalar, but may become scalar when associated explicitly with a scale. *Run a mile* and *run to the store* are scalar predicates derived from the dynamic non-scalar predicate *run*, with *a mile* and *to the store* indirectly introducing the relevant scale, and stating the difference value on it. *Eat* is dynamic and non-scalar, but *eat an apple* is scalar since the theme *an apple* indirectly introduces a scale, and the VP is telic since *an apple* gives a precise difference value. An atelic predicate is either non-scalar, or scalar with an unspecified or unbounded difference value. Since all so-called accomplishments are derived from dynamic verbal predicates in this way, Rappaport Hovav assumes that there are no lexical accomplishment predicates. Kennedy (2012) proposes a formal account of telicity in accomplishments which is compatible with this view. DPs are inherently associated with measure functions which can be converted into measure of change functions on an event. Example (21a) has the interpretation in (21b) where $\mathbf{m}_{\Delta}$ is 'a mereological measure function that measures the extent to which the quantity of dumplings changes over the course of an event (of eating, in this case)' (Kennedy, 2012, 4.32, p. 115).

(21) a. Kim ate 10 dumplings in thirty seconds /#for thirty seconds.
b. $\exists e \exists x[\text{EAT}(e) \wedge \text{DUMPLINGS}(x) \wedge \mathbf{m}_{\Delta}(x)(e) = 10]$

Example (21) asserts that there was an eating event, and the measure of change effected on the dumplings is a diminution whose extent is 10 units.

But it is not so easy to get rid of the accomplishment class: if there are no lexical accomplishments, and the scale is introduced only by the direct object, why do we not find similar effects with activity verbs such as *push*? Rappaport Hovav suggests that verbs like *push* are lexically specified as being non-scalar and thus a theme argument cannot introduce a scale. But this is implausible, since *push* and similar verbs do allow adverbials and PPs to introduce a scale, as (9d) above showed. It seems that verbs like *eat* are specified for allowing their themes to introduce a scale, while verbs like *push* are not. This is, of course, essentially the characterisation of lexical accomplishments that Krifka (1992) gave, when he distinguished between verbs with gradual theme arguments and those with non-gradual theme arguments.

From a wider perspective, the scalar change account does not provide a general solution to the problem of aspectual composition, since degree achievement predicates with a bounded difference value may still be atelic if the incremental theme is a bare plural or mass noun.

(22) a. The council widened the road by two metres in three months.
b. The council widened roads by two metres for some years (in order to make room for the new bicycle lanes).

Event individuation

A fourth approach to telicity and lexical classes, developed in Landman and Rothstein (2012a) and Rothstein (2004, 2008a), is based on the concept of event individuation. The impetus for this approach is Bach (1986a), who observed that the atelic/telic distinction in the domain of events parallels the mass/count distinction in the nominal domain.[4] Count predicates denote sets of atomic events (if they are singular predicates) or sets of pluralities generated from a set of atoms (if they are plural predicates). Bach argues that if telic predicates are analogous to count predicates and atelic predicates are analogous to mass predicates, then telic predicates denote sets of atomic events and atelic events denote sets of non-atomic events.[5] He supports this with contrasts such as (23):

(23) a. She read a book three times in the last year.
b. #He ran/slept three times.
c. He ran to the store/around the block/a mile three times.

Since *read a book* is telic and by hypothesis denotes a set of atomic events, it is natural to count occurrences. Bach suggests that the infelicity of (23b) follows because *run* and *sleep* do not denote sets of atomic events, and thus

[4] The parallel is not exact, as discussed in Rothstein (1999).

[5] We leave aside the tricky question of whether telic predicates are singular and denote sets of atoms, or whether they may also be plural and denote pluralities of atoms. There is some evidence that the first is correct.

events of sleeping or running are not countable. (23c) shows that telic predicates headed by *run* do denote sets of countable events.

Event individuation and event identity, and thus also the question of what constitutes an atomic event, are far more complex issues than identity and individuation in the domain of individuals. As Parsons (1990) shows, events can only be individuated under a particular description. Furthermore, despite Bach's observation, Rothstein (2004) shows that atelic predicates can be modified by adverbs like *three times* in an appropriate context, thus the telic/atelic distinction does not straightforwardly reduce to a contrast between atomic and countable predicates on the one hand and non-atomic and non-countable predicates on the other. Rothstein (2008a, 2010) suggests that Bach's analogy between the count/mass contrast and the telic/atelic contrast should be redefined in terms of event individuability, with telic predicates denoting sets of individuable events, while atelic predicates do not. In the nominal domain, criteria for individuability are presupposed if a noun is grammatically count. Thus, *three ideas*, *three fences*, *three conversations* are all felicitous count expressions, despite the fact that what counts as a single idea, fence or conversation is lexically underdetermined and must be contextually specified. In the verbal domain, the criteria for individuability cannot be presupposed, but must be lexically explicit. Telic predicates are those which provide such explicit criteria, while atelic predicates do not do so. Counting normally requires these criteria for individuability, and this explains the contrast between (23b) and (23a)/(23c): (23a)/(23c) express explicit criteria for individuating atomic events, while the unmodified activity predicates in (23b) do not do so. However, contextual factors may make counting of normally atelic predicates possible, as in Example (24):

(24) Normally, John runs every day, but this week, he ran only three times.

Rothstein (2012) extends this discussion and argues that distinctions between aspectual classes verbs are directly related to the issue of event atomicity. Since the various lexical classes have different temporal properties, the aspectual class of a head V constrains the way in which atomic events in the denotation of the VP can be individuated.

The identification of telicity with atomicity is supported by the fact that semelfactive predicates, discussed in Section 12.2.2, are telic, even though they neither contain an explicit expression of measure or result nor have an incremental argument. In particular, they give rise to the imperfective paradox:

(25) a. John was (just) winking at his friend when he saw the teacher looking at him, so he didn't wink after all. He grimaced instead.
b. Fred was knocking on the door, when I arrived, which embarrassed him so much that he didn't knock after all. He turned his knock into a light tap instead. (after Landman and Rothstein, 2012a, Example (13b))

We suggested above that semelfactives denote sets of minimal naturally atomic events, and activities are iterations of such minimal events. If telic predicates are atomic, then we correctly explain why semelfactives are telic – the minimal event has an inherent structure which allows us to identify what counts as one wink or knock. The iterations of these minimal events, which are denoted by activity predicates, do not have context-independent criteria for what counts as one event, and thus unmodified activity predicates are (usually) atelic. While this approach to the atelic/telic distinction explains the role of adverbial phrases in aspectual composition, as illustrated in (23b) and (23c), it does not immediately suggest an explanation for the role of the direct object in determining the telic/atelic status of VPs headed by accomplishments like *build* and *eat*, unlike either mereological or scalar-based theories. However, Landman and Rothstein (2010) suggest an explanation.

Rothstein (2004) and Landman and Rothstein (2010) point out that mereological and scalar-based theories of telicity incorrectly predict that indefinite DPs and mass DPs such as *at least three sandwiches*, *some sandwiches*, *some bread* should all force an accomplishment-headed VP to be atelic since these DPs are all non-quantized. In fact accomplishment-headed VPs are atelic only when the direct object is a bare plural or a bare mass noun. A VP headed by a verb like *eat* is always telic when the direct object is a DP with any kind of determiner, even when the DP is technically cumulative and independent of whether the lexical head of the DP is a count or mass noun. This is illustrated in (26):

(26) a. #John ate some sandwiches/some bread for an hour.
b. John ate a lot of bread in an hour/#for an hour.
c. John ate sandwiches/bread for an hour.

Landman and Rothstein (2010) suggest that the atelicity of sentences like (26c) as opposed to (26a) and (26b) is because the bare nominal direct object denotes a kind. We return to this in Section 12.2.6.

12.2.5 Variable lexical aspect

Assume then that we can distinguish lexical aspectual classes in terms of the internal temporal contours of the events in their denotations, and that this internal structure correlates with specific grammatical properties. Given that the properties of the event type determine the temporal contours and thus the event class, it is reasonable to assume that verbs naturally belong to one or another lexical class. *Live* (or *live somewhere*) is naturally stative; *arrive* is naturally an achievement, *walk* is naturally an activity and *build* naturally an accomplishment. Nonetheless, it is well known that a large number of predicates seem to belong to more than one verbal class (Moens and Steedman, 1988; de Swart, 1998a; Rothstein, 2004 and many others). At least two types of variable lexical aspect can be distinguished:

Lexical ambiguity: A verb is associated with two lexical entries (possibly related by a lexical redundancy rule). Predicates like *wipe* and *clean* seem to be ambiguous in this way: if the theme argument is interpreted as incremental (as in (27a), it has the semantics of an accomplishment, and if not, it has the semantics of an activity as in (27b)):

(27) a. John cleaned the house/wiped the table in half an hour. (And it was clean!)
b. John cleaned the house/wiped the table for half an hour. (But it didn't have any real effect on the dirt.)

Coercion/type shifting: In other cases of aspectual variability, a basic lexical class can be identified, and some grammatical operator triggers a shift in the interpretation of the predicate. Usually, the basic meaning of the predicate is incorporated into a complex predicate with the temporal properties of a different class. An example is *resultative predication*, illustrated in (17) above: the basic activity meaning of the predicate *hammer* is incorporated into a complex predicate *hammer-flat* which denotes an event with the temporal contours of an accomplishment. We saw in (17) that it displays aspectual composition. Example (28) shows that it also leads to the imperfective paradox.

(28) John is hammering the metal flat *does **not** entail* John hammered the metal flat.

Another example is the reinterpretation of stative predicates as inchoatives as in (29):

(29) John knew the answer in ten minutes.

Here the stative predicate $\lambda s.\mathrm{P}(s)$ is incorporated into an achievement predicate $\lambda e.\exists s[\mathrm{P}(s) \wedge \mathrm{INITIATE}(e, s)]$, denoting the set of events of a state in P being initiated. It is unclear whether the incorporation is a type-shifting operation, triggered in (29) by the temporal adverbial in α time, or whether it is a lexical operation, and in fact this may be a parameter at which languages differ.

12.2.6 Atelicity

While most research on lexical aspect has focused on defining telicity, and assumed that atelic predicates fail to be telic, some researchers have tried to give an independent definition of atelicity. Chief among these is Krifka (1989a, 1992, 1998), who associates atelicity with cumulativity as defined in (12). Cumulativity is 'upward homogeneity', the property that a predicate has if it applies both to distinct entities and to their sums, but as argued above, cumulativity cannot be used to define atelicity. Recent work by Landman (2008) and Landman and Rothstein (2010, 2012a,b) argues that homogeneity is relevant in the aspectual domain, but (i) it is not correct to define homogeneity in terms of cumulativity and (ii) homogeneity must be defined differently for stative and dynamic predicates. Landman (2008) argues that stative predicates are *segmentally homogeneous* in the standard way, that is, if a predicate *P* holds of an interval *i*, it holds at all subintervals of *i* down to instants, but that atelic dynamic VP predicates are *incrementally homogeneous*. This means that the initial segments of an event in the denotation of an atelic VP can be incrementally extended into other (singular) events in the denotation of the same VP. *For* adverbials are sensitive to both types of homogeneity and can modify both stative and activity predicates. Landman and Rothstein (2010, 2012a,b) use this to explain aspectual composition with respect to bare NP arguments. They assume that bare NPs denote kinds following Carlson (1977a) and that it is possible to have an episodic relation to a kind. An individual stands in the EAT relation to the kind 'bread' iff she eats instantiations of the bread-kind. VPs such as *eat bread* and *build houses* are then incrementally homogeneous (and thus show atelic properties) since an event of standing in the EAT relation to the bread-kind can be incrementally extended by continuing activities of eating instantiations of the bread-kind. Verkuyl's puzzle, that achievement verbs with bare plural subjects are apparently atelic, is solved in the same way:

(30) Guests arrived at the hotel for some hours. (=10b)

Guests denotes a kind and (30) asserts that there was an (incrementally homogeneous) arriving event with the guest-kind as subject which lasted for some hours, witnessed by instantiations of the guest-kind arriving at the hotel at appropriately spaced intervals during the running time of the event. Complex predicates headed by accomplishments may also be atelic if they meet the condition of incremental homogeneity. Iterative predicates are a good example of this:

(31) a. John passed a milestone in an hour/#for an hour.
b. John passed a milestone every 5 miles for two hours/#in two hours.

Other predicates which become atelic through the application of an operator are also either incrementally or segmentally homogeneous. Negation in particular gives rise to atelicity since the negation of a dynamic predicate denotes a set of states. Thus, the negative predicate *didn't eat an apple for a week* (11b) denotes the (segmentally homogeneous) state in which the dynamic event of eating an apple did not occur. (See Mittwoch, 2001, for a discussion of negative predicates.)

12.2.7 Some conclusions

We have seen that the atelic/telic distinction and the distinction between lexical aspectual classes, or Aktionsart, are separate phenomena. The Aktionsart of a verbal predicate depends on the relation between the predicate meaning and the interval at which it holds. Telicity and atelicity characterise VPs (at least in English): telic predicates denote bounded or atomic events, and atelic predicates denote non-bounded, non-atomic or homogeneous events. Different verbal predicates denote bounded events in different ways, and so the Aktionsart of a verbal head constrains the grammatical conditions under which it may head a telic VP. With this in place, we can now look (briefly) at grammatical aspect.

12.3 Grammatical aspect

12.3.1 Grammatical aspect, tense and telicity

While lexical aspect is dependent on the individual (and idiosyncratic) properties of events denoted by different lexical predicates, grammatical aspect is expressed by inflectional operators expressed either through affixes or through auxiliaries and other periphrastic constructions, whose basic semantic content can, up to a certain degree of subtlety, be specified relatively simply. Much of the complication and interest in the semantics of grammatical aspect comes from the fact that the inflectional operators which express grammatical aspect are realised cross-linguistically in different hierarchical positions in the sentence and interact with lexical aspect and with telicity in different languages in very different ways. Paradoxically, it is thus not as easy to give a general overview of issues related to grammatical aspect as it is for lexical aspect, since we really need detailed language-by-language studies. Smith (1991) presents an overview of the contrasts between grammatical and lexical aspect and the different ways in which they interact in English, French, Russian and Mandarin, and succeeds in giving a sense of how rich cross-linguistic variation can be. (For a much wider survey of cross-linguistic variation in the expression of aspect, see the section on verbal categories in Dryer and Haspelmath (2011).) In this section and the next, I will set out some basic issues concerning grammatical aspect and its interaction with tense, lexical aspect and modality, making reference to (very few) different languages in order to illustrate some of the ways in which languages differ cross-linguistically.

While lexical aspect is dependent on the semantic properties of the verbal predicate, grammatical aspect is introduced by (possibly null) inflectional operators modifying the verbal predicate and indicates what Smith (1991) calls 'viewpoint aspect', the viewpoint from which the event denoted by the predicate is perceived. The major grammatical aspects are perfective and imperfective, which correspond roughly to the contrast between whether the event is perceived from an external viewpoint which is located outside the running time of the event, or from an internal viewpoint located within the running time of the event. However, despite the rough correlation between grammatical aspectual forms and interpretation, there are a number of semantic interpretations associated in particular with imperfective aspect. In English the most common interpretation of imperfective aspect is the progressive, which asserts that an event was in progress, as in (32a). Habitual interpretations are also possible, as in (32b). We will focus on the progressive interpretation here.

(32) a. When I arrived in England, John was building a house.
b. At 16, John was already smoking.

The difference in perspective between perfective and imperfective is expressed most clearly in the framework of Reichenbach (1947). Reichenbach proposed that the semantics of tense and aspect systems could be expressed in terms of the precedence relations between three different intervals, a speech time, S, a reference time, R, and an event time, E. He did not distinguish between grammatical tense operators, which locate an event on the arrow of time, and grammatical aspect, but using his primitives we can say that imperfective aspect occurs when the interval at which the event holds surrounds the reference time, i.e. $R \subseteq E$, while perfective aspect occurs when R is external to the event time. When R is external to the event time, the event is perceived as complete or total, since the viewpoint includes both ends of the event (Smith, 1991), and when R is surrounded by the event time it is possible to focus on part of the situation or event. Tense operators express (among other things) whether the reference and/or event time precede or follow speech time.

Much of the confusion about the relation between tense and aspect follows from the fact that many languages use a single morpheme to mark both. Thus, the French *imparfait* expresses both past tense and imperfective aspect, while the *passé simple* (as well as the *passé composé*) express past tense and perfective aspect. English is relatively straightforward in this respect. The unmarked aspect for the simple past tense is perfective, as in (33a) and (33b). Example (33a) presents the event denoted by the activity predicate *run* as a completed event situated in the past, while in (33b) the simple past of the stative *live* is also naturally interpreted as denoting a set of states which have ended.[6] An explicit morpheme *-ing* may attach to the verb and mark imperfective aspect, and the resulting participle is embedded under the auxiliary *be*. This auxiliary can be marked either [+ past] or [− past] (33c)/(33d), embedded under a future modal (33e) or can be bare as an imperative (33f):

[6] This may be because the progressive of *live* is also available, as in (33c). The choice of simple past thus indicates a decision not to use the progressive and implies boundedness. With a stative such as *love*, where the progressive is not available, an implication of this boundedness is still present. *John loved Mary* tends to imply that he no longer loves her (or that either she or he is no longer alive and thus the 'active' loving has stopped). Here the implication seems to follow from the choice of the simple past as opposed to the present. Obviously, there is a lot more to be said on this topic. One issue is the question of the aspectual properties of the copula. As a reviewer pointed out, the simple past of the copula does not have the boundedness implications usually associated with the perfective. *John was sick yesterday* does not imply that he is no longer sick. We will not discuss the aspectual properties of the copula in this chapter, but they do seem to be different from the aspectual properties of both lexical state verbs and dynamic verbal predicates.

(33) a. John ran yesterday.
b. When I met him, John lived in Amsterdam.
c. John was running yesterday when I called/John was living in Amsterdam when I met him.
d. John is running now/John is living in Amsterdam at the moment.
e. John will be running tomorrow at four o'clock/John will be living in Amsterdam next year.
f. Be sitting at your desks when I come back into the room!

In (33c)–(33f) the imperfective marked predicate denotes a set of events which run at an interval surrounding a reference time, the properties of which are indicated here by a *when*-clause. A perfective is also compatible with a *when*-clause. However, when the main verb is perfective, the only plausible interpretation is that the event denoted by the VP follows the time indicated by the *when*-clause, and there is an implicature that the relation was causal. The contrast between (34a)/(34b) shows this sharply:

(34) a. John was crossing the road when the pedestrian traffic light turned green.
b. John crossed the road when the pedestrian traffic light turned green.

(34a) describes John doing something illegal – starting to cross before the light was green – whereas (34b) describes him as obeying the rules completely, and crossing immediately after the light turns to green.

It follows from the above discussion that both telic and atelic predicates appear in the perfective. Nonetheless, there are differences between them. First, atelic predicates can naturally be modified by durative temporal adverbials, such as *for an hour* while telic predicates cannot, as discussed in Section 12.2.3, and shown in example (6). Second, the boundedness or completedness implication is of a different status. With telic predicates, the boundedness implication is an entailment, while with atelic predicates it stays at the level of an implicature. Thus (35a) is infelicitous, while (35b)/(35c) are felicitous (although (35c) might be expressed more naturally using the present perfect in the main clause):

(35) a. #John built a house and he is still building it.
b. John worked (for several hours) and he is still working.
c. John loved Mary for over 50 years, and he still loves her.

Thus it seems that, at least in English, perfectivity and telicity must be distinguished: a perfective predicate presents an event as a total event preceding (or, in the future, following) a reference point. A telic predicate is a predicate which denotes events with a unique, identifiable endpoint, while if a predicate is atelic the properties of the endpoint are not specified. Both telic and atelic predicates can be perfective. However, if a telic predicate is presented in the past perfective, the assertion that a complete event in its denotation was reached entails that its unique identifiable endpoint has been reached (otherwise it wouldn't be complete). If the unique endpoint has been reached, then the event cannot be extended, hence the infelicity of (35a). If a declarative sentence uses an atelic predicate in the past perfective, then it too makes an assertion that a complete event in the denotation of the predicate has occurred. However, since the endpoint of an event in the denotation of an atelic predicate is given contextually, a change in context allows us to redefine what counts as one event, and assign the event a different endpoint. In (35b), for example, the first conjunct asserts that there was an event which counts as a single bounded event in the denotation of *John worked*. If a bounded event is situated in the past, the implication is that this event is over, and thus without further information *John worked for several hours/this morning* implies that he is no longer working. However, since an atelic predicate does not determine a uniquely identifiable endpoint, we can redefine what counts as a single event. The second conjunct in (35b) . . . *and he is still working* requires us to redefine the event which validates the statement *John worked this morning* as an earlier stage of an extended (but single) event of working which is still going on.

Smith (1991) suggests that some languages allow neutral aspect, in which case, verbs are specified neither as perfective nor as imperfective. In Modern Hebrew both (36a) and (36b) are acceptable. The adverbial in (36a) indicates a perfective interpretation of the predicate, while the adverbial clause in (36b) indicates the possibility of an imperfective interpretation (although the interpretation parallel to (34b) is also available).

(36) a. dani katav sefer tox šana
Dani write-PAST book in year
'Dani wrote a book in a year'.
b. ke-še-higa'ti le- tel aviv, dani katav sefer
when-that-arrived-past-1.sg to Tel Aviv Dani write-PAST book.
'When I arrived in Tel Aviv, Dani was writing a book'.

Similar facts hold for Dutch (Landman, 2008). However, Doron and Boneh (2008) argue that unmarked aspect in Modern Hebrew is perfective. Thus (37), with a simple past tense and no adverbial modifier, implies that the event was total, and thus completed.

(37) dani katav sefer
Dani write-PAST book
'Dani wrote a book.'

Imperfective aspect must be triggered, as, for example, in (38), where the durative adverbial triggers the imperfective. Presumably, the imperfective operator is lexically null.

(38) dani katav sefer be-mešex šana
Dani write-PAST book during year
'Dani was writing a book for a year.'

Landman (2008) argues that in Dutch too, there is a null progressive operator, directly parallel to the English *-ing*. Thus (39) is not an instantiation of neutral aspect but is ambiguous between two different interpretations.

(39) Ik schreef een boek.
I write-PAST a book
'I wrote a book' or 'I was writing a book.'

It is unclear at this point whether we should posit both a null imperfective and a null perfective operator, or whether we can make do with only an imperfective operator, and assume that perfectivity is in some sense default. In any case, there is no reason to assume that the pattern that we see in English, Dutch and Hebrew holds in other languages, and in fact the contrary is the case: there is every reason to assume that expressions of aspect differ widely in different languages. Smith (1991) discusses some very basic contrasts between English, Slavic, Chinese languages and French. Filip and Rothstein (2006) argue that Germanic and Slavic may differ in terms of the scope of the perfective operator, while Bittner (2014) proposes a dynamic model of cross-linguistic variation in the expression of person, tense, aspect and modality. We return to these issues briefly in Section 12.3.3 below.

12.3.2 Imperfectivity and intensionality

A Reichenbachian approach to aspect proposes that an imperfective predicate (or at least an imperfective predicate on its progressive interpretation) denotes a set of events whose running time surrounds the reference time. This misses one crucial issue, namely the intensional aspect of imperfectivity. We already touched on this briefly when we discussed the imperfective paradox, and we now return to it in a slightly different context. Examine the sentences in (40):

(40) a. John built a house.
b. John was building a house (when I arrived in England).

The conditions under which (40a) is true are clear. It is true if there is an event in the past in which John built a house. In contrast, the conditions supporting the truth of (40b) are much murkier. Example (40b) asserts that there was an event of building a house going on which surrounds some relevant reference point, but it allows for the house-building event to be incomplete. So (40b) can be continued with 'but he never finished it'. Many researchers, in particular Dowty (1979) and Landman (1992), have argued on the basis of this data that the imperfective on its progressive reading is inherently intensional: (40b) does assert that an event of building a house occurred, but it allows for the event to be completed in a world other than the actual one. Dowty argued that the event is completed in an inertia world related to the actual world: if John was building a house in this world and got interrupted, then in all normal, or inertia, worlds in which nothing unexpected occurred to interrupt the event, the house got built. Landman (1992) argues that the notion of (un)expectedness and inertia are inappropriate: it may well be that in all normal worlds, we expect the interruption and the incompleteness, but the progressive is nonetheless appropriate. (41) is sad but true:

(41) The hedgehog was slowly crossing the highway when he got run over: Hedgehogs often don't make it across alive.

Landman argues that the appropriate notion of intensionality involves a 'continuation branch'; the assertion in (41) is true if there is a stage of a road-crossing which took place in this world which continued to completion in some alternative world which is not too dissimilar from ours. (For details see Landman, 1992.)

Note, however, that there is no guarantee that the completed event is in the past relative to the speech time, whatever world it occurs in. If I utter sentence (41) a minute or two after the hedgehog got run over, it is unreasonable to assume that if it hadn't been run over, the hedgehog would already be across the road. Thus, the tense operator expressing PAST must apply to a predicate denoting a set of partial events, since only the part of the event which was realised in the actual world is located in the past. The question is how to capture both the perspective-oriented intuition that the imperfective predicate denotes a set of events which surround a reference point, as well as the intensionality of the progressive.

Landman (2008) proposes a solution to this. He argues that the progressive operator denotes a function from events to their stages, where a stage is an initial stretch of the event, as in (42). (CON is the intensional continuation relation between an event e which is part of, or a stage of, a completed event e'. The running time of the event-stage e is in the actual world, but the running time of the complete event e' may continue into some alternative future, see Landman 1992.)

(42) $\text{PROG(VP)} = \lambda e.e' \in \text{VP} : \text{STAGE}(e, e') \wedge \text{CON}(e, e')$

A second operator applies to PROG(VP) and gives the set of final points of the set of stages of the relevant events. Landman calls them perspective states:

(43) $\lambda s.\exists e \exists e' \in \text{VP} : \text{STAGE}(e, e') \wedge \text{CON}(e, e') \wedge \text{FIN}(e, s)$

An assertion like (40b) or (41) asserts that a final point of a relevant stage of an e in the denotation of VP coincides with the reference point.

(44) The hedgehog was crossing the road:
$\exists s \exists e \exists e' : e' \in$ HEDGEHOG-CROSS-THE-ROAD:
STAGE$(e, e') \wedge$ CON$(e, e') \wedge$ FIN$(e, s) \wedge \tau(s) = R \wedge$ PAST(R).
'The final point of a stage of an event of the hedgehog crossing the road coincided with the reference point R which is in the past.'

Since the point which coincides with R is the final point of a stage of the whole event, by implication a non-final stage, the Reichenbachian intuition that the whole event surrounds the reference point is captured and the intensionality is expressed.

12.3.3 Some more about cross-linguistic issues

Morphological expression of grammatical aspect differs cross-linguistically, and the semantic consequences of this are for the most part waiting to be explored (but see Bittner, 2014, for a recent exploration of these issues in a dynamic semantics framework). The precise aspectual contrasts that a particular language expresses depends on the interaction of tense operators, aspectual operators and lexical aspect. English expresses tense and imperfective aspect via separate morphological markers, and thus imperfective aspect can be expressed in the whole range of complex tenses, as in *He will have been writing that book for a long time*. In contrast, in the French *imparfait*, one morpheme expresses both tense and aspect values, but there is no corresponding future form, and imperfectivity in the future must be expressed periphrastically (Smith, 1991, and references cited there). We saw that English has an explicit imperfectivity operator, while Dutch and Modern Hebrew allow null imperfective operators. Modern Hebrew has almost no explicit morphological markers of aspectual contrast, while at the other end of the spectrum, Mandarin and other Chinese languages have no direct expression of tense but do have morphemes expressing aspectual contrast, including two imperfective markers *-zài* and *-zhe*, a simple perfective marker *-le* and an experiential perfective marker *-guo*. I conclude this overview by giving an illustration of one instance of cross-linguistic variation in the working of the aspect, namely the workings of aspectual composition with V-internal arguments. We start with data from Slavic, an aspectual system which has been extensively studied.

In Slavic, grammatical aspect is prima facie a property of verbal heads.[7] Almost all bare (i.e. non-prefixed) verbs express imperfective aspect, while prefixed verbs express perfective aspect. *Stroit*$^{\text{IMPF}}$ is the imperfective form of 'build', and *postroit*$^{\text{PERF}}$ is the most neutral perfective form of the verb. An imperfective stem may be associated with a number of perfective verbs, with the difference in meaning dependent on the choice of prefix: *nastroit'*,

[7] Papers in Svenonius (2004) have argued that perfectivity is either as a V operator or as a VP operator, depending on whether the prefix expressing it is lexical or supralexical. Since the data I discuss here concern lexical prefixes and thus V operators, this need not concern us.

'to build a lot (of NP)', *perestroit'*, 'to rebuild', *zastroit'*, 'to build up an area'. Together with grammatical aspect, telicity and atelicity also seem to be properties of V in Slavic,[8] rather than of VP, and as a result, aspectual composition works differently from in English. In English, as we saw in (6), the properties of the direct object determine whether the VP is telic or atelic, but in Slavic the converse is the case. (45) gives an example from Czech (from Filip and Rothstein, 2006). The bare plural noun *dûti* 'children' is in principle ambiguous between a maximal definite interpretation 'all the children' and an indefinite or possibly kind interpretation. However, as the direct object of a perfective verb, only the maximal definite reading is allowed. Thus in contrast to English, the aspectual properties of the verb constrain the interpretation of the incremental theme.

(45) Za pût minut /*pût minut oblékl[PERF] dûti do
in five minutes /*five minutes dressed childrenPL.ACC in
zimních kabátů.
winter coats
'He put winter coats on (all) the children in/??for five minutes.'

The data discussed above seem to indicate a parametric difference which affects aspectual composition, as suggested in Filip and Rothstein (2006): when telicity is a property of VP as in English and the head of V is an accomplishment verb, the properties of the direct object determine the telicity of VP. When telicity is determined at the V level, this is not the case, and in fact the telicity of the V forced a definite interpretation on the direct object.

In order to show that the cross-linguistic variation cannot be reduced to simple parametric variation, I conclude this section by drawing attention to another pattern of aspectual composition which is found in Mandarin (Liu, 2003); see also discussion in Lin (2007). Liu shows that aspectual composition works as in English when the direct object is a numerical as in (46). The adverbial *zai wu fengzong nei* 'within five minutes' forces a telic interpretation of the VP and is acceptable when the theme of an accomplishment verb is an explicit numerical and not when it is a bare NP:

(46) Lisi neng zai wu fengzhong nei chi san-wan mian/*mian.
Lisi can in 5 minutes in eat 3-bowl noodles/noodles.
'Lisi can eat three bowls of noodles/*noodles in five minutes.'

However, as (47) shows, unlike in English, a demonstrative theme patterns like the bare NP and not like the numerical:

(47) *Lisi neng zai wu fengzhong nei chi na-wan mian.
Lisi can in 5 minutes in eat that-bowl noodles.
Intended: 'Lisi can eat that bowl of noodles in five minutes.'

[8] Braginsky and Rothstein (2008) show that even when (a)telicity and (im)perfectivity are properties of the V, as in Russian, lexical aspectual classes cannot be reduced to either, and that there are perfective and telic activity predicates and imperfective accomplishment predicates.

These contrasts show some properties of cross-linguistic variation in aspectual composition, and the importance of language-specific studies in aspect.

12.4 Conclusions

An article of this type can of necessity only survey some of the issues involved in the study of aspect, and can discuss those only at a relatively superficial level. There is a huge amount of literature which we have not even mentioned (see, e.g., the references in the online bibliography (Binnick, 2004), as well as the bibliography in Binnick, 2012). Among the issues we have not touched on are the aspectual contrasts between the simple past and the perfect tenses (see, e.g., the papers in Alexiadou et al., 2003), the relation between lexical aspect and complex tense-aspect forms (Mittwoch, 2008), the relation between event structure and argument structure (Pustejovsky, 1991b, 1995) and the relation between aspect and modality. We have also not discussed more computationally oriented approaches to aspect and event structure such as Moens and Steedman (1988). Crucially, there has not been space to discuss in any depth the crosslinguistic variation in the expression of grammatical aspect and the interaction of lexical aspect with grammatical aspect, tense and modality. It seems appropriate to end this chapter by emphasising the range of cross-linguistic variation and the dependence of aspectual expression on the particular morphosyntactic properties of individual languages.

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13

Mereology

Lucas Champollion and Manfred Krifka

13.1 Notions of parthood

Mereology (from the Greek $\mu\acute{\epsilon}\rho o\varsigma$, 'part') is the study of **parthood**, an important notion in ontology, natural-language semantics, and cognitive sciences. Examples include rice as part of paella, a thumb as part of a hand, John Lennon as part of the Beatles, the Adriatic Sea as part of the Mediterranean, the battle of Issos as part of Alexander's war against Persia, November 1989 as part of the year 1989, or *hood* as part of the word *parthood*. These examples illustrate that the relation may hold between masses, objects, objects and groups, locations, events, times, and abstract entities (see Simons, 1987 and Winston et al., 1987 for classification of parthood relations).

One important distinction is between what we may call **structured** and **unstructured** parthood. Structured parts are cognitively salient parts of the whole. The thumb is a structured part of a hand: it is one of *the parts* of the hand, besides the fingers and the palm. The hand is itself a cognitively salient, integrated whole and not just a random collection of parts. Similarly, *hood* is a structured part of the word *parthood*: it is a suffix with a meaning of its own, attached to the stem *part*, and contributing to the overall meaning of the word. The notion of unstructured parthood, in contrast, can be illustrated with the water in the left half of a cup as part of the water in the entire cup, or the letter sequence *artho* as part of the sequence *parthood*. Unstructured parts need not be cognitively salient parts of the whole but may slice up the whole in arbitrary ways. (For discussion of related philosophical issues, see Simons, 1987; Moltmann, 1997; Varzi, 2010. For linguistic applications of a structured notion of parthood to the semantics of mass nouns, plurals, and events, see Moltmann, 1997, 1998, 2005. A summary and critical discussion of Moltmann, 1997 is provided in Pianesi, 2002.)

The two part relations have different structural properties. Structured parthood is not transitive, as has often been noted (e.g., Cruse, 1979; Moltmann, 1997). The thumb is a structured part of the hand, and the hand is a structured part of the arm, but the thumb is not a structured part of the arm. Linguistic evidence for this comes from the fact that we can say *the thumb of this hand*, or *a hand without thumb*, in contrast to **the thumb of this arm*, or **an arm without thumb*. In contrast, unstructured parthood is transitive: for example, the sequence *rth* is part of *artho*, and *artho* is part of *parthood*, hence *rth* is part of *parthood*. For unstructured parts, we can use *part* as a mass noun (x is *part* of y); for structured parts, as a count noun (x is *a part* of y). For unstructured parts of rigid entities that hang together, we may also use the word *piece* (see Cruse, 1986). As a consequence of transitivity, unstructured parts may overlap, in contrast to structured parts. For example, *art* and *tho* are both unstructured parts of *parthood*. (For discussion on the transitivity of parthood, see Varzi, 2006 and references therein.)

In this chapter, we will focus on unstructured part relations. This is not to deny that structured part relations are of great importance in natural-language semantics. There are two such structured part relations: **meronymy** (the relation between meronyms like *hand* and holonyms like *arm*) and **hyponymy** (the relation between hyponyms like *poodle* and hyperonyms like *dog*, in English expressed by words like *kind* or *type*). These relations structure large parts of the lexicons of natural languages, and they have certain general properties (see, e.g., Kay, 1975 for taxonomies, based on the hyponymy relation, and Cruse, 1986 for a textbook treatment). In this, we make no claim about the semantics of the English word *part* and related expressions like *a part*. (See Moltmann, 1997, 1998 for discussion of the semantics of the expressions *part* and *a part*.)

We will take the parthood relation to be reflexive, which is at variance with how English *part* is used. We will write $\leq$ for parthood and distinguish it from irreflexive $<$, which will be called **proper** parthood.

If we consider parthood for entities extended in space or time, we may restrict the notion of part to **contiguous** parts, for example, strings like *art* or *ood*, or we may allow for non-contiguous parts, such as discontinuous strings like *pa—od* or *p–r–h–o*, as parts of *parthood*. Contiguity is a topological notion, and from topology we also can derive notions like **borders** or **interior parts** of objects. The formal notion of parthood typically is understood in such a way as to allow for non-contiguous parts. Even structured parts can be non-contiguous; for example, the fingers are considered part of the hand, and circumfixes and infixes lead to non-contiguous morphological parts of words. (For combinations of mereology and topology, see Smith, 1996; Casati and Varzi, 1999; Forrest, 2010.)

Parthood relations have played an important role in philosophy, especially ontology (see Simons, 1987 and Varzi, 2010 for overviews). Yet the formal study of parthood relations took off in the foundations of mathematics, as an alternative to set theory. Set theory is based on two parthood relations, element $\in$ and subset $\subseteq$, and a corresponding type-theoretic distinction (if $\alpha \subseteq \beta$, then α and β must be sets; if $\alpha \in \beta$, then just β is required to be a set). Consequently, set theory distinguishes between singleton sets and their elements ($a \neq \{a\}$), and assumes an empty set. Mereology was proposed by Leśniewski (1916), see Simons (2011) and Leonard and Goodman (1940) as a simpler alternative without such assumptions. It does not distinguish between elementhood and subsethood, and it does not assume abstract entities like sets. Consequently, it does not distinguish between singleton sets and their elements, and does not entertain the notion of the empty set.

This article will be concerned specifically with some of the applications that mereology has found in natural-language semantics. After a section on essential formal properties of the (unstructured) parthood relations and their axiomatization, we will deal with linguistic applications in the nominal domain, in the expression of measurement functions, and in the verbal domain.

13.2 Axiomatizations of mereology

The notion of parthood has been captured with various axioms. The most congenial approach to mereology is to take the notion of **part** as central; this gives us an order-theoretic perspective. There is another approach that starts with the notion of **sum**; this is the lattice-theoretic perspective.

13.2.1 The order-theoretic perspective

We present an axiomatization of the parthood relation known as classical extensional mereology (CEM). This system is the one most commonly used in natural-language semantics, and comes closest to a standard in mereology.[1] However, there are alternatives: see, for example, Rescher (1955) for an alternative axiomatization of the parthood relation. We take reflexive, unstructured parthood ($\leq$) as the primitive relation and formulate axioms that impose constraints on it. The following axioms constrain parthood to be a partial order:

Axiom (Reflexivity)

$$\forall x(x \leq x) \tag{13.1}$$

Axiom (Transitivity)

$$\forall x \forall y \forall z((x \leq y \wedge y \leq z) \rightarrow x \leq z) \tag{13.2}$$

[1] The discussion in this section is based on Champollion (2010b) and on the excellent surveys of mereology in Simons (1987), Casati and Varzi (1999), and Varzi (2010).

Axiom (Antisymmetry)

$$\forall x \forall y((x \leq y \wedge y \leq x) \rightarrow x = y) \tag{13.3}$$

We often want to talk of objects that share parts. For this purpose, we introduce the auxiliary concept of **overlap**, which we write as $\circ$, following Simons (1987) and Link (1998).

Definition (Overlap)

$$x \circ y =_{\text{def}} \exists z(z \leq x \wedge z \leq y) \tag{13.4}$$

With the part relation, we can define the notion of **sum**, also called **fusion**. Sums formally capture the pretheoretical concept of collection – that which you get when you put several parts together. In natural-language semantics, two common applications of sums are conjoined terms and definite descriptions. For example, Link (1983) proposes to represent the denotation of the conjoined term *John and Mary* as the sum of the individual John with the individual Mary.[2] Sharvy (1980) suggests representing the denotation of a definite description like *the water* as the sum of all water. We come back to definite descriptions in Section 13.3.2.

As discussed in Hovda (2009), there are several ways to define sum, and while they are equivalent given the CEM axiom system, they are not logically equivalent. This means that when putting together the axioms, it is important to choose the definition carefully to make sure that the axioms that use it lead to CEM as intended. The definitions below are metalanguage statements about shorthand expansions, that is, they indicate what formula "sum(x, P)" is a shorthand for. Intuitively, this shorthand stands for "x is a sum of (the things in) P".[3]

The first definition of sum is due to Tarski (1929):

Definition (Sum (1))

$$\text{sum}(x, P) =_{\text{def}} \forall y(P(y) \rightarrow y \leq x) \wedge \forall z(z \leq x \rightarrow \exists z'(P(z') \wedge z \circ z')) \tag{13.5}$$

A sum of a set P is a thing that consists of everything in P and whose parts each overlap with something in P.

The second definition appears in Simons (1987, p. 37) and Casati and Varzi (1999, p. 46):

[2] See Winter (2001) for a dissenting view. For Winter, *and* is always translated as generalized conjunction, in this case as conjunction of two generalized quantifiers, and the equivalent of sum formation enters the system through a collectivization operator on the resulting quantifier.

[3] If we formulate our theory in first-order logic, whichever one of these two definitions we pick must be interpreted as an axiom schema, or a list of axioms in each of which $P(y)$ is instantiated by an arbitrary first-order predicate that may contain y as a free variable. If we formulate our theory in second-order logic, we can instead understand the definition we pick as quantifying over a predicate variable P, which may be interpreted as ranging over sets, as suggested by our paraphrases. The set interpretation makes the theory more powerful (Pontow and Schubert, 2006; Varzi, 2010). The main issue here is that there are only countably many formulas, but uncountably many sets. In the following, we will talk about sets rather than axiom schemas.

Definition (Sum (2))

$$\text{sum}(x, P) =_{\text{def}} \forall y(y \circ x \leftrightarrow \exists z(y \circ z \wedge P(z))) \tag{13.6}$$

A sum of a set P is a thing such that everything which overlaps with it also overlaps with something in P, and vice versa.

The following fact follows from either definition of sum:

Fact

$$\forall x(\text{sum}(x, \{x\})) \tag{13.7}$$

The proof is immediate if sum is defined as in (13.6). If sum is defined as in (13.5), we can rewrite (13.7) as $x \leq x \wedge \forall z(z \leq x \rightarrow z \circ x)$. The first conjunct follows from reflexivity (13.1); the second follows from the fact that parthood is a special case of overlap, which in turn follows from reflexivity.

Different mereology systems disagree on what kinds of collections have a sum, and whether it is possible for one and the same collection to have more than one sum. In CEM, sums are unique, and therefore two things composed of the same parts are identical. This is expressed by the following axiom:

Axiom (Uniqueness of sums)

$$\forall P(P \neq \varnothing \rightarrow \exists! z\ \text{sum}(z, P)) \tag{13.8}$$

The operators in (13.9) and (13.10) give us a way to refer explicitly to the sum of two things, and to the sum of an arbitrary set. In the following, $\iota x P(x)$ is only defined if P holds of exactly one individual, and when defined, it denotes that individual.

Definition (Binary sum)

$$x \oplus y =_{\text{def}} \iota z\ \text{sum}(z, \{x, y\}). \tag{13.9}$$

For example, the meaning of the term *John and Mary* can be written as $j \oplus m$.

Definition (Generalized sum)

For any nonempty set P, its sum $\oplus P$ is defined as ιz sum(z, P). (13.10)

For example, the meaning of the term *the water* can be written as $\oplus$water.[4]

If Tarski's definition of sum (13.5) is used, CEM is defined by the axioms of reflexivity (13.1), transitivity (13.2), and antisymmetry (13.3) taken together with uniqueness of sums (13.8). In fact, this setup makes axioms (13.1) and (13.3) redundant, because any transitive relation that satisfies axiom (13.8) is provably reflexive and antisymmetric. If the definition of sum in (13.6) is used, transitivity and uniqueness of sums are not sufficient to define CEM, as there is a model of these axioms in which we have one element that is

[4] The semantic literature following Sharvy (1980) often uses the equivalent notation $\sigma x P(x)$ rather than $\oplus P$. We use $\oplus$ to make the connection between binary and generalized sum clearer.

Table 13.1 *Correspondences between CEM and set theory*

	Property	CEM	Set theory
1.	Reflexivity	$x \leq x$	$x \subseteq x$
2.	Transitivity	$x \leq y \wedge y \leq z \rightarrow x \leq z$	$x \subseteq y \wedge y \subseteq z \rightarrow z \subseteq z$
3.	Antisymmetry	$x \leq y \wedge y \leq x \rightarrow x = y$	$x \subseteq y \wedge y \subseteq x \rightarrow x = y$
4.	Interdefinability	$x \leq y \Leftrightarrow x \oplus y = y$	$x \subseteq y \Leftrightarrow x \cup y = y$
5.	Unique sum/union	$P \neq \varnothing \rightarrow \exists! z\ \mathrm{sum}(z, P)$	$\exists! z(z = \cup P)$
6.	Associativity	$x \oplus (y \oplus z) = (x \oplus y) \oplus z$	$x \cup (y \cup z) = (x \cup y) \cup z$
7.	Commutativity	$x \oplus y = y \oplus x$	$x \cup y = y \cup x$
8.	Idempotence	$x \oplus x = x$	$x \cup x = x$
9.	Unique separation	$x < y \rightarrow \exists! z(x \oplus z = y \wedge \neg(x \circ z))$	$x \subset y \rightarrow \exists! z(z = y - x)$

not part of itself. Adding reflexivity and transitivity rules out this model but still does not exclude certain more complex models which are not models of CEM. Tarski's definition of sum is therefore to be preferred. (For discussion and proofs of these facts, see Hovda, 2009.)

The properties of parthood described by CEM are very similar to those of subsethood in standard set theory. More specifically, one can prove that the powerset of any given set, with the empty set removed, and with the partial order given by the subset relation, satisfies the axioms of CEM. The empty set must be removed because it is a subset of every other set (a "bottom element"), but CEM precludes anything from being part of everything. For practical purposes one can therefore often regard sums as sets, parthood as subsethood, and sum formation as union. Some correspondences between CEM and set theory are listed in Table 13.1. Readers who are unfamiliar with mereology might find this table useful to strengthen their intuitions about the properties of the parthood relation and of the other operations in CEM.

13.2.2 The algebraic (lattice-theoretical) perspective

Above, we have developed the notion of mereology starting out from the notion of parthood, deriving from it the notion of sum, or fusion. In the most succinct formulation, Properties 2 (transitivity) and 5 (unique sum) in Table 13.1 are considered axioms, and the other properties follow from them as theorems. Alternatively, we may start out with the sum operation, and derive from that the part relation.

That is, we may start out with the notion of a **lattice**, or to be specific, a **join semi-lattice**. This is defined as a structure $\langle L, \oplus \rangle$, where L is a set, and $\oplus$ is a two-place operation on this set called **join** (full lattices also have an operation of **meet**, $\otimes$). For each two elements $x, y \in L$, the join $x \oplus y$ is defined, and $x \oplus y \in L$. By definition, the join operation of a lattice meets properties 6 (associativity), 7 (commutativity), and 8 (idempotence). (For full lattices with a meet operation, the law of **absorption** holds: $x \oplus (x \otimes y) = x$,

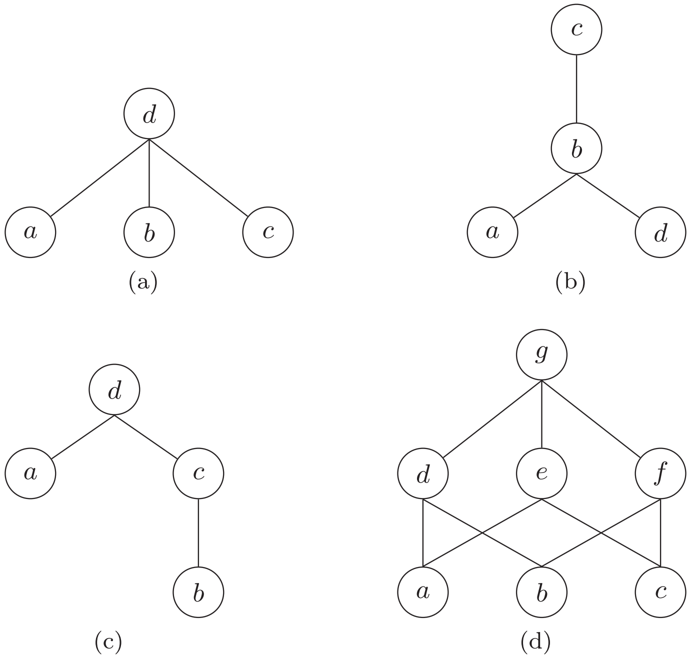

Figure 13.1 *Lattices*

$x \otimes (x \oplus y) = x$.) If we furthermore impose property 9 (unique separation), the join operation has the same properties as the sum operation in mereology. A lattice in which unique separation holds is called **complemented**. Given unique separation, if we define parthood in terms of join as in property 4, then the properties of reflexivity (13.1), transitivity (13.2), and antisymmetry (13.3) follow as theorems.

In order to qualify as a mereology, the join semi-lattice must not have a bottom element. This entails that there is no general meet operation. However, we can still define a restricted meet of $x \otimes y = z$ as the largest element such that $z \leq x$ and $z \leq y$, provided that there is such an element.

Unique separation plays an important role in excluding non-intended models of parthood such as in Structure 13.1(a) in Figure 13.1 above. (The models in Figure 13.1 show the parthood relation exhaustively. The elements that form the leaves of these models — a, b, c in Structure 13.1(a), for example — are atoms, and they are pairwise disjoint.) Intuitively, we want $a \oplus b$ to consist of a and b and nothing else that is not already part of a and b. To see that unique separation is violated in Structure 13.1(a), notice that a is a proper part of d, and that there is more than one thing x disjoint from a such that $a \oplus x = d$. Specifically, $a \oplus b = a \oplus c = d$. Structures like 13.1(a) have "too many" parts. Structures like 13.1(b) and 13.1(c), on the other hand, have "too few" parts; in both of them, b is a proper part of c, but there is no other immediate proper part of c. Such structures are excluded by unique separation as well, as we have $b < c$, but there is no x disjoint from b such that $b \oplus x = c$. If we have three atomic elements, a, b, and c, then the only structure with three atomic elements a, b, c satisfying commutativity, associativity, idempotence, and unique separation is Structure 13.1(d). Note that Structure 13.1(d) is isomorphic to the powerset of the set $\{a, b, c\}$ minus the empty set, where parthood corresponds to the subset relation. This isomorphism is the reason for the correspondences in Table 13.1 above.

The role that unique separation plays in eliminating Structures 13.1(a), 13.1(b), and 13.1(c) is played by distributivity in full lattices, that is, lattices with a bottom element (where distributivity, here for sets, states that $x \cup (y \cap z) = (x \cup y) \cap (x \cup z)$).

Structure 13.1(d) would also be identified as the lattice that is generated by the atoms a, b, c, where the join operation satisfies commutativity, associativity, and idempotence, does not express equalities that are not required by these laws (such as $a \oplus b = a \oplus c$ in 13.1(a)), and does not entertain any differences not required by these laws (such as $c \neq b$ in 13.1(b) and 13.1(c)). Such structures are called free lattices that are generated by a set of atoms (see Landman, 1991).

The notion of join as introduced above entails that the join of any finite subset of L is uniquely defined. That is, for any non-empty finite subset $L' \subseteq L$, the elements of L' form a unique join, which is the minimal upper bound of L' (the smallest x such that for all $a \in L$, $a \leq x$). This is because by commutativity, associativity, and idempotence, the order of joining two elements, of more than two elements, and of joining the same element repeatedly does not matter. We can write $\oplus L'$ for this minimal upper bound, corresponding to the generalized sum operation in the previous section. As a consequence, every finite lattice is **bounded**, in the sense that there is an $y \in L$ such that for all $x \in L$ it holds that $x \leq y$. However, this does not guarantee that join is defined for infinite sets. The existence of a unique minimal upper bound for infinite sets would have to be stipulated explicitly. The resulting structure is often called a **complete join semi-lattice**, where completeness implies that all subsets of L have a join; but recall that the empty set has no join, as this would require a bottom element. The structure can also be described as a complete lattice with the bottom element removed, or equivalently, as a complete Boolean algebra with the bottom element removed.

The algebraic conception of a lattice generates similar structures as the order-theoretic conception; a fundamental theorem of lattice theory shows that the two coincide (see Grätzer, 1996; Landman, 1991). The algebraic perspective is motivated by the fact that natural language allows for a conjunction of terms, expressed by *and*, which is to be modeled by the join operation. As this conjunction can only generate phrases of finite length, we might not even want to require that it is infinite. However, if the join operation is used to define the part relation, and the part relation in turn is used to render the meaning of definite descriptions, then a finite join operation is not sufficient to cover terms like *the natural numbers*, whose nouns apply to an infinite number of entities.

Other comparable systems are the logic of plurality defined by Link (1983, 1998), the part-of structures of Landman (1989a, 1991, 2000), and the lattice sorts and part structures of Krifka (1990a, 1998). These systems are clearly intended to describe CEM. For example, Link (1983) and Landman (1989a) explicitly argue that modeling reference to plurals requires systems with the power of a complete join semi-lattice. However, careful review shows that many of these axiomatizations contain errors or ambiguities and therefore fail to characterize CEM as intended (Hovda, 2009).

13.2.3 Mereology versus set theory, and the issue of atomicity

In the wake of Massey (1976) and Link (1983), most theories of plurals and mass nouns have been formulated in a mereological framework. Given the correspondences in Table 13.1, working directly with set theory instead of mereology might look like a better choice. After all, set theory is better known and more generally accepted than mereology. Indeed, early approaches to plural semantics adopted set theory (Hausser, 1974; Bennett, 1974).

So what are the reasons for preferring mereology? Some authors, such as Link (1983), have advanced philosophical reasons: following the philosophical doctrine of "composition as identity," they take an ontological commitment to sums to be less substantive than a commitment to sets, because a sum is taken to be nothing over and above its parts, as opposed to a set. Related to this, sets are abstract, but sums are concrete if their parts are concrete. This corresponds to how we conceive of sum individuals: the plural individual consisting of these three apples has a certain weight and is situated in space – properties that sets, as abstract entities, arguably lack.

However, others, like Landman (1989a), have argued that these reasons are independent of linguistic considerations and that sets can be used as a **model** of sum individuals. In order to do so, mereological atoms need to be identified with the singleton sets that contain them (Scha, 1981; Schwarzschild, 1996).

With ordinary set theory, we are forced to assume that everything is ultimately composed of **atoms**, represented by singleton sets:[5]

Definition (Atom)

$$\mathrm{atom}(x) =_{\mathrm{def}} \neg\exists y(y < x) \tag{13.11}$$

An atom is something which has no proper parts.

However, atomistic mereologies may cause problems for the modeling of events, mass entities, and spatiotemporal intervals, where one does not want to be forced to assume the existence of atoms.

[5] Alternatively, one can provide room for non-atomic structures in set theory by modifying the standard axioms so as to allow infinitely descending sequences of sets, as in the ensemble theory of Bunt (1985).

By themselves, the axioms of CEM do not specify whether atoms exist or not: among the models they describe, there are some in which everything is made up of atoms (in particular, this includes all models that contain finitely many elements), some in which there are no atoms at all, and intermediate cases. Either (13.12) or (13.13) can be added to CEM to constrain it to one of the two limiting cases. For example, many authors assume that the count domain is constrained to be atomic. The referents of proper names and the entities in the denotations of singular count nouns are then taken to be mereological atoms.

Axiom (Optional axiom Atomicity)

$$\forall y \exists x(\text{atom}(x) \wedge x \leq y) \tag{13.12}$$

All things are made up of atoms.

Axiom (Optional axiom Atomlessness)

$$\forall x \exists y(y < x) \tag{13.13}$$

Everything is infinitely divisible.

When neither of these axioms is added, the system remains underdetermined with respect to whether or not atoms exist. This underdetermination is one of the advantages of mereology: when we describe the domains of space, time, and mass substances, we do not need to decide whether atomic events and atomic instants of time exist or whether mass substances can be infinitely subdivided.

A different kind of atoms, called impure atoms or groups, is used in Landman (1989a, 2000) and elsewhere to model certain instances of collective predication and group nouns like *committee* or *team*. Groups are atomic entities which are derived from sums via a special group formation relation or operator. Group formation introduces a distinction between the sum $a \oplus b$ whose proper parts are the individuals a and b, and the group that corresponds to this sum. This group has a and b as "members," but it has no proper parts. Groups can be seen as adding a notion of structured parthood into mereology that is otherwise absent, and formally speaking, the group formation operation is not a part of CEM but added on to it. Landman's view on group nouns is influential but not uncontested; other authors assume that group nouns involve reference to set- or sum-like pluralities (Bennett, 1974), or to integrated wholes (e.g., Moltmann, 1997, 2005), that they involve sum formation of discourse referents instead of objects (Krifka, 1991), or that it is not possible to recover the membership of a group from the denotation of a group noun (see Barker, 1992). Pearson (2011) points out that group nouns as a class are heterogeneous: some of them (e.g., *bunch*, *collection*) behave less like *committee* and more like measure nouns (Section 13.3.2).

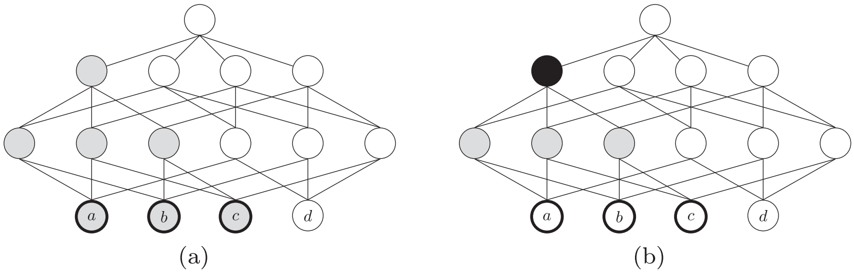

Figure 13.2 *Cumulative and quantized sets*

13.3 Linguistic applications

13.3.1 Nominal domain

One of the principal applications of mereology in semantics is the characterization of oppositions such as **count–mass** and **singular–plural** in terms of higher-order properties. For example, various authors have identified the properties of mass and plural terms like *gold* and *horses* with the notions of **cumulative reference**: if two things are gold, then their sum is also gold (see Quine, 1960b), and if you add some horses to some other horses, then you again get some horses (see Link, 1983).

Definition (Cumulative reference)

$$\text{CUM}(P) =_{\text{def}} \forall x \forall y (P(x) \wedge P(y) \rightarrow P(x \oplus y)) \tag{13.14}$$

A predicate P is cumulative if and only if whenever it holds of two things, it also holds of their sum.

As an example, consider Structure 13.2(a) in Figure 13.2; the gray circles form a cumulative set.

Cumulativity can be generalized for infinite sets as follows:

Definition (Cumulative reference)

$$\text{CUM}(P) =_{\text{def}} \forall P'(P' \neq \varnothing \wedge P' \subseteq P \rightarrow \oplus P' \in P) \tag{13.15}$$

A set is cumulative if and only if it contains the sums of all of its nonempty subsets.

The dual of cumulative reference, **divisive reference**, has also been proposed to describe mass terms (see Cheng, 1973). While cumulative reference "looks upward" from the part to the sum, divisive reference "looks downward" from the sum to the parts. On the view that mass terms like *gold* have divisive reference, this means that any part of anything which is gold is also gold.

Definition (Divisive reference)

$$\text{DIV}(P) =_{\text{def}} \forall x (P(x) \rightarrow \forall y (y < x \rightarrow P(y))) \tag{13.16}$$

A predicate P is divisive if and only if whenever it holds of something, it also holds of each of its proper parts.

The assumption that divisive reference holds of mass denotations runs into the **minimal-parts problem**. If we want it to apply to mass nouns like water, divisivity is at odds with chemistry, as a hydrogen atom as part of an H_2O molecule does not count as water. The problem of divisivity is even more obvious with heterogeneous mass terms like *fruit cake* (e.g., Taylor, 1977): a portion of fruit cake may contain sultanas, but these sultanas do not themselves qualify as fruit cake. Most semanticists accept that mass nouns do not in general have divisive reference (see Gillon, 1992). Many authors have modified the definition of divisive reference to avoid the minimal-parts problem, for example, by adding a "granularity parameter" that prevents it from applying to parts that are lower than a certain threshold (see Champollion, 2010b). Landman (2011) proposed a further distinction beyond atomicity: **mess nouns** like *lemonade* have overlapping atoms, while the atoms of **neat nouns** like *furniture* do not overlap; this cuts across the grammatical mass/count distinction, as, for example, *fence* is a messy count noun.

There is another property that has been proposed to model semantic properties of nominals, **quantized reference** (see Krifka, 1989a):

Definition (Quantized reference)

$$\mathrm{QUA}(P) =_{\mathrm{def}} \forall x(P(x) \rightarrow \forall y(y < x \rightarrow \neg P(y))) \qquad (13.17)$$

A predicate P is quantized if and only if whenever it holds of something, it does not hold of any of its proper parts.

For example, the fat circles in Structure 13.2(b) form a quantized set, and so do the gray circles. Singular count nouns are interpreted as quantized sets. If we consider count nouns as applying to atoms, quantization follows vacuously; if not, quantization seems to be an essential property (as e.g. a proper part of a chair is not a chair). However, there are count nouns like *twig* or *sequence* for which quantization is a problematic assumption (Zucchi and White, 2001): A part of a twig may also be a twig, and a part of a sequence may also be a sequence. One possible line of response is that the meaning of these nouns is partially specified by context, and that when the context is fixed, each of them denotes a quantized set (see Chierchia, 2010; Rothstein, 2010).

Given the denotation of a singular count noun, the denotation of the corresponding plural count noun can be described by **algebraic closure**, often represented by the star operator (see Link, 1983). Algebraic closure extends a predicate P so that whenever it applies to a set of things individually, it also applies to their sum.

Definition (Algebraic closure) If set P is nonempty, then

$$^{*}P =_{\mathrm{def}} \{x \mid \exists P'\ P' \neq \varnothing \wedge P' \subseteq P \wedge x = \oplus P'\}. \qquad (13.18)$$

The algebraic closure of a set P is the set that contains any sum of things taken from P.

As an example, suppose the set $C = \{a, b, c\}$ is the set of all cats. Then C represents the meaning of the singular count noun *cat*. The algebraic closure of C is written $^*C$ and is the set $\{a, b, c, a \oplus b, b \oplus c, a \oplus c, a \oplus b \oplus c\}$. This set contains everything that is a cat or a sum consisting of two or more cats, so it is a superset of C. Also, it is a cumulative set; whenever $x, y \in C$, then $x \oplus y \in C$. In Structure 13.2(a), the set of gray circles is the algebraic closure of the set of fat circles.

Other definitions of algebraic closure are also sometimes found in the literature. For example, Sternefeld (1998) renders Link's definition as follows:

Definition (Alternative definition Algebraic closure) For any set P, $^*P$ is the smallest set such that

$$\begin{aligned} &(i)\ \ P \subseteq {}^*P; \\ &(ii)\ \text{If } a \in {}^*P \text{ and } b \in {}^*P, \text{ then } a \oplus b \in {}^*P. \end{aligned} \tag{13.19}$$

This reformulation is equivalent to the one in Definition 13.18 for finite P, but the equivalence breaks down when P has countably infinite cardinality. Definition 13.18 amounts to powerset formation; by Cantor's diagonal argument, the powerset of a countably infinite set is uncountably infinite. Definition 13.19, by contrast, amounts to forming the union of countably many countably infinite sets. Given the axiom of choice, this union is itself only countably infinite. So given a countably infinite P such as *the set of natural numbers*, the cardinality of $^*P$ will vary depending on the definition.

In most mereological approaches to the semantics of count nouns, a plural count noun denotes roughly the algebraic closure of the set denoted by its singular form. There is disagreement on whether the denotation of a plural noun also contains entities denoted by its singular form (see Farkas and de Swart, 2010). On the **exclusive** view, singular and plural forms of a count noun denote disjoint sets (see Link, 1983; Chierchia, 1998a). For example, if in Structure 13.2(a) the set $\{a, b, c\}$ forms the denotation of *cat*, then the four gray circles without bold lining form the denotation of *cats*. The plural form *cats* essentially means *two or more cats*. On the **inclusive** view, the plural form of a count noun denotes its algebraic closure (see Krifka, 1989b; Sauerland, 2003; Sauerland et al., 2005; Chierchia, 2010). In 13.2(a) this is the set of all gray circles. The plural form essentially means *one or more cats*. The inclusive view assumes that when singular reference is intended, singular and plural forms are in pragmatic competition, and the more specific singular form blocks the plural form. There are good arguments against the exclusive view (see Schwarzschild, 1996, p. 5). For example, suppose that there is only one doctor. On the exclusive view, the plural form *doctors* denotes the empty set. Therefore, the exclusive view cannot derive the meanings of sentences like (1) compositionally without resorting to devices such as intensionality.

(1) No doctors are in the room.

A more tricky problem is presented by dependent plurals, that is, bare plurals which are c-commanded by a plural coargument (see de Mey, 1981).

(2) Boys / Some boys / Several boys / Five boys flew kites.

These sentences have a reading which entails that each of the boys in question flew one or more kites (which is a problem for the exclusive view) and that the total number of kites flown was two or more (which is unaccounted for by the inclusive view). A possible solution may be to take the inclusive view and to treat the inference that at least two kites were flown in total as a grammaticalized scalar implicature (Spector, 2007a; Zweig, 2009; see also Sauerland, 2003 and Sauerland et al., 2005 for a similar proposal).

Mass nouns generally do not show a singular/plural contrast, except if coerced to count nouns, as in *we ordered three beers*. In English, they typically occur in the singular, although some plural nouns have been argued to be mass (e.g., *clothes*, see Ojeda, 2005). If mass nouns are intrinsically cumulative, then plural formation has no function, as it does not change their denotation – if CUM(P), then $P = {}^*P$ (Chierchia, 1998b).

Proof Assume CUM(P); as it always holds that $P \subseteq {}^*P$ we just have to show that ${}^*P \subseteq P$. Assume to the contrary that ${}^*P \not\subseteq P$, that is, there is an a, $a \in {}^*P$ and $a \notin P$. Then there is, following (13.18), a P' with $P' \subseteq P$ and $a = \oplus P'$. But as P is cumulative, we have $\oplus P' \in P$, following (13.15). Hence $a \in P$, contrary to assumption. □

However, there are cases in which mass nouns can be pluralized with special meaning effects, for example, in Greek for expressing large quantities (see Tsoulas, 2008).

We end this section by pointing out that bare plural and mass terms also can be used to refer to kinds, as in *Potatoes were first cultivated in South America*, or *Nylon was invented in 1935*. (For further reading, see Krifka et al., 1995; Chierchia, 1998b; Krifka, 2004; Delfitto, 2005; Cohen, 2007; Lasersohn, 2011; Doetjes, 2012.)

13.3.2 Measure constructions

We now turn to constructions like *three liters of milk* or *two cats*. Such expressions refer to quantized sets; no proper part of an entity that falls under *three liters of milk* also falls under *three liters of milk*, and no proper part of an entity that falls under *two cats* should fall under *two cats*. We can derive the quantized status of *two cats* from the properties of its parts. We introduce the following operator:

Definition (Atomic number)

$$\text{atoms}(x) =_{\text{def}} \text{card}(\{y \mid y \leq x \land \text{atom}(y)\}) \tag{13.20}$$

The atomic number of x is the cardinality of the set of atoms that are part of x.

With this, we can interpret *two cats* as $\{x \mid {}^{*}\text{cat}(x) \land \text{atoms}(x) = 2\}$, which can be shown to be a quantized set, assuming that *cat* only applies to atoms. This set is represented by the gray circles in Structure 13.2(b), if the set of cats is $\{a, b, c\}$. However, this kind of representation is not useful for pseudopartitive expressions based on measure nouns and mass nouns, like *three liters of water*. Here, we assume a **measure function** that stands in a systematic relation to parthood. Measure functions can be thought as mapping substances to positive real numbers (see Krifka, 1989a), in which case *three liters of water* may be represented as $\{x \mid \text{water}(x) \land \text{liters}(x) = 3\}$. Alternatively, measure functions map substances to degrees which are in turn mapped to numbers by what we may call **unit functions**, in which case *three liters of water* may be represented as $\{x \mid \text{water}(x) \land \text{liters}(\text{volume}(x)) = 3\}$ (Lønning, 1987). While we will use the former representation for convenience, the latter one has advantages: for example, *three inches of water* may be represented using either inches(depth(x)) or inches(diameter(x)) depending on context. (For other advantages, see Schwarzschild, 2002a.)

Not every measure function is permissible in a pseudopartitive; while *three liters of water* is admissible, **three degrees Celsius of water* is not. This constraint is related to the distinction between **extensive** and **intensive** measure functions (see Krifka, 1998). In physics and measurement theory, an extensive measure function is one whose magnitude is **additive** (see Krantz et al., 1971a; Cohen et al., 2007). For example, when one considers the water in a tank, *liters* is an extensive measure function because the water as a whole measures more liters than the volume of any of its proper parts. But *degrees* is not extensive because the temperature in degrees of the water as a whole is no different from the temperature of its proper parts.

One way of making this notion precise is the following:

Definition (Measure function) A measure function μ is extensive on a set $S \subseteq \text{dom}(\mu)$ iff:

$$\forall x(x \in S \rightarrow \forall y(y < x \land y \in \text{dom}(\mu) \rightarrow \mu(y) < \mu(x))) \tag{13.21}$$

For every proper part of every element in the set, the function returns a lower value than for that element.

Not all measure functions used in pseudopartitives are extensive in this strict sense. If two feet of snow fell on West Berlin and two feet of snow fell on East Berlin, then two feet, and not four feet, fell on Berlin as a whole. So the notion of extensivity needs to be appropriately relativized.

Intuitively, the underlying measure function *height* is still extensive as long as we restrict ourselves to layers of snow piled on one another rather than adjacent layers (see Schwarzschild, 2006; Champollion, 2010b).

Given that the measure function *liters* is extensive on the set of all water quantities, we can show that the denotation of *three liters of water*, $\{x \mid \text{water}(x) \wedge \text{liters}(x) = 3\}$, denotes a quantized set.

Proof Take an x in the set and a proper part y, $y < x$. Then either $\neg\text{water}(y)$, in which case y cannot be in the set; or $\text{water}(y)$, in which case, since *liters* is extensive, we have $\text{liters}(y) < 3$, so y cannot be in the set. □

We find the definite article in expressions like *the two cats*, or *the three liters of water*. It has been suggested to interpret the definite article as generalized sum (e.g., Link, 1983). This works well for cumulative sets; for example, in the model above, *the cats* would refer to $\oplus\text{cat} = a \oplus b \oplus c$, the sum of all cats, represented by the black circle in Structure 13.2(b). However, this would not work in the case of quantized sets; for example, *the two cats* should not be defined in the model above, but $\oplus\{x \mid x \in {}^{*}\text{cat} \wedge \text{atoms}(x) = 2\}$ is defined, and would also refer to the black circle in Structure 13.2(b). Following Montague (1973a) (see also Sharvy, 1980), we can alternatively interpret the definite article as referring to the supremum of a set (see Krifka, 1989b):

Definition (Supremum of a set P)

$$\text{sup}(P) =_{\text{def}} \iota z(P(z) \wedge \forall x(P(x) \rightarrow x \leq z)) \tag{13.22}$$

The supremum of a set P is the single element z in P that is greater than or equal to any of its elements.

Many sets will not have a supremum. For a cumulative set like ${}^{*}C$, the supremum $\text{sup}({}^{*}C)$ exists and is identical to $\oplus{}^{*}C$. For a non-cumulative set like $\{x \mid x \in {}^{*}C \wedge \text{atoms}(x) = 2\}$, the supremum exists only if it is a singleton set, and then refers to the element in this set – hence, only if there are exactly two cats. This captures the intuitive meaning of *the two cats*, and the proposal can be extended to *the cat* as well, if *cat* applies to atomic cat entities; the expression will be defined only if there is exactly one cat, and will refer to that cat.

The notion of measure function in a mereological setting has been fruitful to explain interesting linguistic phenomena. Krifka (1989b) has suggested that count nouns in English like *cat* do not refer to atoms but contain a built-in measure function, called "natural unit." In this they differ from count nouns in languages like Chinese, which require a classifier. Krifka (1990b) and Doetjes and Honcoop (1997) have analyzed sentences like *4000 ships passed through the lock*, on the reading where any given ship may pass through the lock many times, as involving the construction of a complex additive measure function for events.

13.3.3 Verbal domain

Mereological notions have been applied to predicates to model certain cases of conjunction, as in *the girls sang and danced*, which is true if some of the girls sang and the other girls danced. Link (1983) proposed to lift sum formation to predicates. Take $^*S$ and $^*D$ to be the set of singers and dancers; then *sang and danced* denotes the set $\{x \oplus y \mid x \in {}^*S \wedge y \in {}^*D\}$, the set of individuals consisting of singers x and dancers y. Krifka (1990b) has extended this to other types, for example to prepositions, to handle cases like *the planes flew above and below the clouds*.

The notion of parthood has been used to formally reconstruct the telic–atelic opposition. Mereology makes it possible to formally relate this opposition to the singular–plural and count–mass oppositions (e.g., Bach, 1986a; Krifka, 1989b; Moltmann, 1997; Champollion, 2010b). Stating generalizations across nouns and verbs is easiest if these categories both denote sets, so it is convenient to assume that verbs denote sets of events (the neo-Davidsonian position, Parsons, 1990). A reformulation of mereological applications to the verbal domain into eventless semantics is possible in most cases, though not always conspicuous in practice (see Bayer, 1997).

Divisive reference has been used to formally capture the notion of atelicity. A verbal predicate like *run* is **atelic** or, according to Vendler (1957), an activity; it has the property that "any part of the process is of the same nature as the whole." In a neo-Davidsonian event semantics, *run* will be interpreted as a set of events R. Now Vendler's characterization can be restated by claiming that activities, and other atelic predicates like states (e.g., be *happy*), have divisive reference: Let $e \in R$ be an event of John running from his house to the store. Now e will have parts, e.g., a part $e' \leq e$ in which John runs from his house halfway to the store, and a part $e'' \leq e$ in which he runs from the halfway point all the way to the store. These parts e' and e'' will themselves be running events, and hence be elements of R. As with mass nouns, divisiveness is limited by the minimal-parts problem; there may be certain parts of e that are too small to count as running. A notion that is similar to divisive reference is the subinterval property, which holds of any predicate P just in case whenever P holds at a temporal interval, it also holds at every subinterval of it (Bennett and Partee, 1978; Dowty, 1979). Cumulativity and nonquantization are also occasionally invoked to model atelicity. The differences between these various notions are investigated in Champollion (2010b).

Constructions such as *for two hours* can be seen as the verbal equivalent of pseudopartitives (cf. *two hours of running*). Restricting our attention to events that cannot be executed simultaneously, like runnings by one agent, we find that $\{e \mid e \in R \wedge \text{hours}(e) = 2\}$ is a quantized set, if *hours* is an extensive measure function. The verbal predicate *run for two hours*, then, is **telic**, an accomplishment; other examples of telic predicates are accomplishments like *run a mile* and *build a house* and achievements like *reach the summit*. Telic predicates imply, according to Vendler (1957), "definite and unique time periods" and may be characterized using quantized reference and related notions (Krifka, 1998). Filip (2008) analyzes perfectivity as a grammatical operation that expresses telicity and involves maximalization, similar to the definite article in the nominal domain.

There is a correspondence between the parts of an event and the parts of the participants of an event, which has been expressed in Krifka (1989b, 1992) in terms of a homomorphism-like relation. For example, let e be the event in which John (j) lifts a certain box b, hence j is the agent and b is the theme of e, which we note as $\text{AG}(e) = j$ and $\text{TH}(e) = b$.

Similarly, assume that e' is the event in which Mary (m) lifts a certain table t. We assume that AG and TH have the homomorphic property called "summativity" or "cumulativity" in Krifka (1989a,b); Landman (2000):

Definition (Cumulativity of Θ)

$$\Theta(e \oplus e') = \Theta(e) \oplus \Theta(e') \tag{13.23}$$

The Θ-participant of the sum of two events is the sum of the Θ-participants of the two events.

Let L be the set of lifting events; we then have $e \in L \wedge \text{AG}(e) = j \wedge \text{TH}(e) = b$ (*John lift the box*) and $e' \in L \wedge \text{AG}(e') = m \wedge \text{TH}(e') = t$ (*Mary lift the table*). We then also have $e \oplus e' \in L \wedge \text{AG}(e \oplus e') = j \oplus m \wedge \text{TH}(e \oplus e') = b \oplus t$, i.e., we can derive the truth of *John and Mary lifted the box and the table*. One condition, of course, is that L is cumulative. Such inferences motivate the assumption of **lexical cumulativity** (called "lexical" because it is taken to apply to all verbs, but not to all verb phrases): whenever two events are in the denotation of a verb, so is their sum (see Scha, 1981; Schein, 1986, 1993; Krifka, 1989b, 1992; Lasersohn, 1989; Landman, 1996, 2000; Kratzer, 2007). In this property, verbs are similar to mass nouns or bare plurals.

But there are problems with cumulativity of thematic relations. Suppose that there are three events e_1, e_2, e_3 in which Al dug a hole, Bill inserted a rosebush in it, and Carl covered the rosebush with soil. Then one can say that there is also an event, e_4, in which Al, Bill, and Carl planted a rosebush. Do we consider e_4 equal to the proper sum event $e_1 \oplus e_2 \oplus e_3$? If we do, this scenario is a counterexample to the cumulativity assumption (Kratzer, 2003). The themes of e_1, e_2, e_3 are the hole, the rosebush, and the soil, and the theme of e_4 is just the rosebush. The theme of e_4 is not the sum of the themes of e_1, e_2, and e_3, violating cumulativity. A possible objection is that e_4 is not actually the sum of e_1, e_2, and e_3. Even though the existence of e_4 can be traced back to the occurrence of e_1, e_2, and e_3, nothing forces us to assume that these three events are mereological parts of e_4 (for general discussion and other solutions, see also Williams, 2009; Piñón, 2011).

It has been observed (e.g., Verkuyl, 1972) that mereological properties of the arguments or adjuncts of verbs have an impact on mereological properties of complex verbal constructions. For example, *drink milk* is atelic, whereas *drink two liters of milk* is telic. This can be explained on the basis of general properties of thematic relations. We show that *drink milk* is cumulative, and therefore atelic. Assume that D and M are cumulative; then the set $\{e \mid D(e) \wedge \exists x(M(x) \wedge \mathrm{TH}(e) = x)\}$ is cumulative, too.

Proof Assume that e_1, e_2 are two events in this set; this means that there are x_1, x_2 such that $M(x_1)$, $M(x_2)$, and $\mathrm{TH}(e_1) = x_1$, $\mathrm{TH}(e_2) = x_2$. As M, D, and TH are cumulative, $e_1 \oplus e_2$ is also in this set. Hence *drink milk* denotes a cumulative set. □

To show that *drink two liters of milk* is quantized, and therefore telic, we have to assume that certain thematic roles have the additional property we may call Distinctiveness (see also the notion of incremental theme in Dowty, 1991):

Definition (Distinctiveness of Θ)

If $e \neq e'$, then $\Theta(e) \neq \Theta(e')$. (13.24)

Distinct events have distinct Θ-participants.

This applies, for example, to the theme of *drink*: two distinct drinking events will have two distinct entities that are drunk.

Proof of quantization of "drink two liters of milk" Assume that 2LM is quantized, and assume that e_1 is an event in $\{e \mid D(e) \wedge \exists x(\mathrm{2LM}(x) \wedge TH(e) = x)\}$. Hence there is an x_1 such that $\mathrm{2LM}(x_1)$ and $\mathrm{TH}(e_1) = x_1$. Assume now a proper part e_2 of e_1, that is, $e_2 < e_1$, hence $e_2 \neq e_1$. By distinctiveness, there is an x_2 such that $\mathrm{TH}(e_2) = x_2$ and $x_2 \neq x_1$, and by cumulativity, $x_2 \leq x_1$, hence $x_2 < x_1$. As 2LM is quantized, we have $\neg\mathrm{2LM}(x_2)$, but then also $e_2 \notin e_1$; hence the set $\{e \mid D(e) \wedge \exists x(\mathrm{2LM}(x) \wedge \mathrm{TH}(e) = x)\}$ is quantized, too. □

The notion of homomorphism inherent in lexical cumulativity, Definition 13.23, also applies to **trace functions**, which map events to those entities (e.g., intervals) that represent their temporal and spatial locations (Krifka, 1989b). Trace functions have been used for many purposes; among others, they relate event semantics to interval semantics; they are involved in the denotation of adverbials like *for an hour* and *to the store*; and they play the same role as measure functions in the analysis of pseudopartitives such as *three hours of running*. Commonly, two such functions are assumed: temporal trace or runtime (τ) and spatial trace or location (σ). For example, if e_1 and e_2 are two events, the runtime of their sum, $\tau(e_1 \oplus e_2)$, is the sum of their runtimes, $\tau(e_1) \oplus \tau(e_2)$. (For more on temporal and spatial trace functions, see Hinrichs, 1985; Lasersohn, 1988; Krifka, 1998; Link, 1998, as well as Zwarts, 2005, 2006, where the spatial and temporal trace functions are combined into one.)

The telic–atelic opposition, as well as the singular–plural and count–mass oppositions, can be formally related to the collective–distributive opposition (Champollion, 2010b). Distributive predicates require any event in their denotation to be divisible into events that are atomic with respect to the appropriate thematic role. For example, any plural event in the denotation of the distributive predicate *smile* must be divisible into parts that have atomic agents and that belong to the denotation of the same predicate. This captures the distributive entailment from *John and Mary smiled* to *John smiled*. By contrast, the subjects of collective predicates like *be numerous* or *gather* can be plural entities whose parts do not themselves satisfy the predicate. Formally, the subinterval property can be modified and generalized so that it covers both the property of being atelic and the property of being distributive. Instead of requiring a predicate that holds at a certain interval to hold at every subinterval, we can require a predicate that holds of a certain plural individual to hold of every atomic part of that plural individual.

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14

Vagueness

Hans Kamp and Galit W. Sassoon

14.1 Introduction

Vagueness is an ultimate challenge. An enormous diversity of literature on the topic has accumulated over the years, with no hint of a consensus emerging. In light of this, Section 14.2 presents the main aspects of the challenge vagueness poses, focusing on the category of adjectives, and then gives some brief illustrations of the pervasive manifestations of vagueness in grammar.

Section 14.3 deals with the Sorites paradox, which for many philosophers is the hallmark of vagueness. The efforts to solve the Sorites paradox have uncovered a range of important connections between vagueness and other aspects of language and thought. Linguists traditionally leave it to the philosophers to deal with the Sorites and put their own efforts into dealing with other correlates of vagueness in natural language and their consequences for grammar.

Section 14.4 reviews some of these additional phenomena, centering around three issues: (i) the controversial connections between vagueness and morphological gradability, (ii) the similarity and differences between the phenomena of vagueness and imprecision, and (iii) the ways in which vagueness infiltrates various grammatical constructions we find in language, with consequences for the architecture of grammar. The aim of this section is to highlight the main questions which any theory of vagueness will ultimately have to address.

14.2 Indications of vagueness

Almost all of the literature on vagueness focuses on the vagueness of predicates. Moreover, much of the literature on vague predicates has concentrated on adjectives. For much of this chapter we follow the tradition in both these respects.

14.2.1 Vagueness in adjectives

Relative adjectives, such as *tall, short, big, small, clever*, and *obtuse*, have long since been prominent examples of vagueness, as opposed to **sharp adjectives** like *prime* or *even*, which exemplify what it is for an adjective not to be vague. A third type of **absolute adjectives**, such as *clean, dirty, straight*, and *bent*, suggests that presence or absence of the features indicative of vagueness may not be a black or white matter (see Section 14.4 for more on this point). The present section explains this classification. Positive forms of relative adjectives, as in *Danny is tall* or *The pencil is big*, exhibit a bundle of features indicative of vagueness, as follows.

First, the truth values of predications involving such adjectives are dependent on the **context of utterance**. In particular, they depend on a contextually determined set of entities. Since Klein (1980), this set is called the **comparison class**. A subset of this class is designated as the contextual extension of the adjectival projection. For instance, a basketball player may count as a tall man, yet not as a tall basketball player; a certain model of a car may count as big for a car, but small for a truck; and an idea can be considered clever for a five-year-old, but not for a university professor (Kamp and Partee, 1995).

Moreover, the usage of relative adjectives involves a **subjective component** (Fara, 2000; Kennedy, 2013; Barker, 2013; Crespo and Veltman, 2014). Decisions about the cutoff between, for example, tall and not tall entities in a comparison class are affected by the range and distribution of heights of entities in the class. However, there is no uniquely determined method for determining the cutoff even after a comparison class has been fixed (Klein, 1980; Kennedy, 2007b). Decisions may vary depending on speakers' contextual interests, goals, and desires (Fara, 2000). For example, a certain hat may count as *expensive* when it is meant to be worn on a regular basis, but *inexpensive* when you are shopping for something to wear on a special occasion, like your wedding. And even when this goal-related aspect of the context has been fixed, a certain amount of indeterminacy remains: the truth of judgments like *This hat is expensive* or *This boy is clever* can still depend on personal opinion.

In contrast to relative adjectives, absolute adjectives, it has been noted since Unger (1975) and Kennedy (1999), appear to have clear, lexically-determined extensions. For instance, predicating *clean* of a shirt may seem to be right only if it doesn't have a single speck of dirt on it. Otherwise it is dirty, regardless of how it may compare with other entities. Similarly, no comparison class seems needed to determine whether a container is empty or a wall is *straight* (Rips and Turnbull, 1980), and the truth values of such propositions appear to be immune to interests or desires. Nevertheless, here too we find contextual dependence. The form this dependence takes is indicated by adjective-modifying phrases like *clean for a street in this area* (an example of a **comparison class-determining for-phrase**; see Cruse, 1980) or **judgment-determining** phrases, as in *In my opinion, this room is clean*.

Second, relative adjectives clearly exhibit **borderline cases**, for which it is not clear whether the adjectives truly apply or not. For instance, out of a group of ordinary pencils that vary in size an 18 cm pencil is obviously long. A 5 cm pencil is obviously not long. But it is not clear whether 10 cm or 12 cm pencils are long or not. Absolute adjectives are different in this respect, at least in first approximation: if cleanliness is a matter of total absence vs. presence of dirt, every entity is either clean or not. However, a closer look suggests that here too there is room for uncertainty: when does a shirt truly qualify as clean; when a surface as truly flat?

Let us ignore these more delicate questions for now and assume for the sake of argument that absolute adjectives are sharp, while relative adjectives are not. A simple way to explicate this difference is in terms of the *extensions* of these two types of adjectives. The application domain of an absolute adjective, that is, the set of things to which the adjective can be applied in principle, is divided into two parts, the *(positive) extension* of the adjective, consisting of the entities of which the adjective is definitely true, and the *negative extension*, consisting of those for which the adjective is definitely false. The positive and the negative extensions cover the entire application domain. In contrast, the application domain of a relative adjective is divided into three parts: a positive extension, a negative extension, and a "truth value gap" consisting of its borderline cases.[1]

It has been argued that modeling the vagueness of a predicate as tripartite division of its application domain into positive extension, negative extension and truth value gap is too simple. Intuitively, the boundaries between the three parts of the application domain – e.g., the boundary between the definitely big pencils and the borderline big pencils, and that between the borderline big and definitely not big pencils – cannot be sharp. They too should be fuzzy in their turn, like regions populated by their own, "second order" borderline cases. But how should we model this? Fuzziness of first order boundaries is known as **second order vagueness**. Likewise, fuzziness of the boundaries at the next level is referred to as **third order vagueness**, and so on. Vagueness anywhere from second order up is subsumed under the term **higher order vagueness**. The variation in opinions on the topic of higher order vagueness is extreme (see, e.g., Fine, 1975b; Williamson, 1994, 1999; Barker, 2006; Shapiro, 2006; Sorensen, 2010; Wright, 2010). Since our

[1] See Križ and Chemla (2014) for a discussion of experimental methods for research of truth value gaps.

primary focus is on the semantics of vagueness as it manifests itself in the ways we speak, and since there is no room to discuss all aspects of vagueness, we have decided not to include higher order vagueness among the topics of this contribution.

Third, some of the context dependence of vague predicates is mediated by **tolerance**: small differences have no consequences for membership (Dummett, 1975b; Wright, 1975; Kamp, 1981a). In particular, the role of tolerance is easy to recognize in relative adjectives; entities sufficiently resembling extension members count as members too. For example, if a 20 cm pencil is long, then, intuitively, any pencil insignificantly shorter – say, one shorter by just 1 mm – is also long. Successive application of *long* to a series of pencils, each one insignificantly shorter than the one before it, eventually leads one to assign the predicate to entities of which it plainly is not true. This, in a nutshell, is the case in situations in which the **Sorites paradox** arises. Tolerance is what gives rise to it (see Section 14.3).

On a first pass, absolute adjectives are immune to the paradox. However, we already noted that absolute adjectives behave as sharp predicates only up to a point and that the picture is, therefore, more complex. This also applies to many non-adjectival predicates that may appear sharp at first sight, but where a closer look reveals fuzziness at the fringes. To see this, let us examine two important classes of absolute adjectives and compare them more closely to relative adjectives. Absolute and relative adjectives have been claimed to differ in the type of **modifiers** they license (see discussion in McNally, Chapter 15). Modifiers such as *slightly* and *perfectly* appear to favor predicates for which a conventional criterion exists to determine membership. More specifically, they have been analyzed as relating to membership criteria defined in terms of minimum and maximum membership thresholds. For instance, the modifier *slightly* felicitously combines with adjectives like *dirty* whose membership criterion merely requires the existence of some minimal amount of dirt, and *perfectly* combines with adjectives like *clean* whose criterion requires maximum cleanliness or complete absence of dirt. This distinction between adjectives governed by minimum criteria and adjectives governed by maximum criteria seems to explain the contrasts between (1a), (1b), and (1c) (Kennedy and McNally, 2005a; Kennedy, 2007b).

(1) Degree modifiers indicating presence/absence of vagueness
  a. {slightly, #perfectly}{dirty, wet}
  b. {#slightly, perfectly}{clean, dry}
  c. {#slightly, #perfectly}{tall, short}

The acceptability of this type of modifiers with relative adjectives is reduced, as in (1c), and becomes fully acceptable only when an appropriate membership criterion is contextually accommodated, for instance, when, for example, *slightly tall* is interpreted as conveying "slightly too tall for some (contextually determined) purpose", or, alternatively, when the expression is used to refer to borderline cases, which can be thought of as constituting the fuzzy boundary between positive and negative extensions (Kagan and Alexejenko, 2011; Lassiter, 2011b; Sassoon, 2012; Solt, 2012). Relative adjectives co-occur more frequently and naturally with "strengthening" modifiers like *very* or *extremely* (Syrett, 2007).

Another distinction between absolute and relative adjectives comes from **inference patterns** such as those illustrated in (2a)–(2c) (Rotstein and Winter, 2004; Kennedy and McNally, 2005a). The distinction relates to different membership criteria. The comparative "X is dirtier than Y" entails that X is covered by some amount of dirt and, therefore, counts as dirty. Similarly, the comparative "X is cleaner than Y" entails that Y necessarily fails to be maximally clean and therefore counts as not-clean. By contrast, a relative adjective selects a contextual standard; therefore a comparative form such as "X is taller than Y" does not entail that either entity is in the positive or in the negative extension.

(2) Inference patterns indicating presence/absence of vagueness:
   a. Minimum criterion: X is dirtier than $Y \Rightarrow X$ is dirty.
   b. Maximum criterion: X is cleaner than $Y \Rightarrow Y$ is not (maximally) clean.
   c. Contextual criterion: X is taller than $Y \not\Rightarrow X$ is tall / Y is not tall.

Back to tolerance, Burnett (2014, forthcoming) argues that features of vagueness can be manifested **asymmetrically** in absolute adjectives with a minimum and maximum criterion. Recall that when 1 mm counts as an irrelevant difference, then both *tall* and *not tall* are tolerant, namely speakers assent to both (3a) and (3b), respectively, where $\supset$ stands for material implication.[2] By contrast, both the sharply defined predicate *prime* and its negated form *not prime* are intolerant, which is shown by the fact that speakers assent to neither (3c) nor (3d).

(3) Symmetric vagueness: For all x, y:
   a. x is tall and x and y's heights differ by 1 mm $\supset$ y is tall. (true)
   b. x is not tall and x and y's heights differ by 1 mm $\supset$ y is not tall. (true)
   c. x is prime and x and y differ by one $\supset$ y is prime. (false)
   d. x is not prime and x and y differ by one $\supset$ y is not prime. (false)

For maximum-criterion absolute adjectives, such as *straight*, the matter is different. Here the positive form may be tolerant – that is, in at least some contexts speakers assent to (4a) – but at the same time, the negated form is not tolerant; for example, (4b) is falsified by individuals x with a single

[2] A natural way to express (3a) is: "Every individual which differs only by one millimeter from a tall individual is tall." The form of this statement is captured even more clearly here: "Every individual y one millimeter shorter than a tall individual x is tall as well."

1 mm bend, which may count as not straight, and individuals y that have absolutely no bends and which, therefore, cannot but count as straight. In minimum-criterion absolute adjectives such as *bent*, the negated form may be tolerant – in at least some contexts, speakers assent to (4d) – but the positive form cannot; for example, (4c) is falsified by a rod x with a single 1 mm bend, which can be considered bent, and a rod y that has absolutely no bends and, therefore, does not qualify as bent.

(4) Asymmetric vagueness: For all x, y:
  a. x is straight and x and y differ by a 1 mm bend $\supset$ y is straight. (sometimes true)
  b. x is not straight and x and y differ by a 1 mm bend y is not straight. (always false)
  c. x is bent, and x and y differ by 1 mm bend $\supset$ y is bent. (always false)
  d. x is not bent, and x and y differ by 1 mm bend $\supset$ y is not bent. (sometimes true)

The contexts in which speakers assent to (4a) or (4d) are contexts in which they are willing to consider as *straight* or *not bent* also objects which are not maximally straight. For these expressions, there are some contexts in which they give rise to borderline cases, fuzzy boundaries and Sorites arguments. Burnett, who demonstrates this in detail, calls these expressions "potentially vague". There seems to be a great deal of variation between speakers on this point. Some accept tolerance-governed interpretations of absolute adjectives, others do not. This variation is reflected in a debate among scholars over whether these interpretations are manifestations of vagueness or of mere imprecision (see Section 14.4.2 and 14.4.3).

Fourth, it is important to distinguish between the theoretical problem that tolerance-governed predicates present because of their occurrence in Sorites arguments and the practical constraints that tolerance may be thought to impose on the actual use of such predicates: any given context in which the predicate can be used should restrict the set of entities to which the predicate is applied in such a way that somewhere there is a "jump" within the set: a partition of the set into two non-empty subsets S^+ and S^-, such that no member of S^- falls within the **tolerance range** of any of the elements of S^+. If such a jump separates the clear positive cases and clear negative cases of the tolerance-governed predicate, no Sorites argument can be constructed for it on the basis of the given set; and the Sorites problem can be kept at bay at the conceptual level by assuming that there exists a partition separating positive and negative extensions and that the boundary between the positive and negative extension runs somewhere through the middle of the gap (Gaifman, 2010; Pagin, 2010a,b; van Rooij, 2011a; Cobreros et al., 2012b; Burnett, 2014).

One aspect of the context dependence of tolerance-governed predicates is the tolerance relation itself. How similar must two entities be to count as within each other's tolerance range? This often depends on context as well.

For instance, as noted by Fara (2000), it depends on the context whether "one grain of coffee makes a difference" – it does not when you make a pot of coffee in the way we normally do that, but it may in the context of a scientific experiment (e.g., one which investigates how different amounts of caffeine affect mice). Translated into the language of tolerance-governed predicates: for any number k, k, and $k + 1$ grains may be within each other's tolerance range for the predicate "a suitable number of grains of coffee" in one context of use, but not in some other context.

Fifth, there is the question of how vagueness relates to **ambiguity**. Example (5) shows that the ellipsis test for ambiguity (Zwicky and Sadok, 1975; Barker, 2006) works out differently for vague predicates than it does for classical examples of ambiguity like the noun *bank* or the verb *wave* (which is ambiguous between the waving done by people and the waving done by flags).

(5) a. Ann went to a bank, and Bill did too.
b. #Ann waved, and the flag did too.
c. Bill is tall, and his six-year-old daughter is too.

Example (5a) has only two readings: (i) Ann went to a financial institution and Bill went to a financial institution, and (ii) Ann went to a river bank and Bill went to a river bank. This indicates that the ambiguity of bank in the first conjunct must be resolved before the first conjunct can be used to interpret the second, elliptical conjunct. (5b) is another illustration of the same point. Here the subject of the first clause, a person, disambiguates the occurrence of *wave* in this clause to the sort of waving that is done by people. Once that disambiguation has taken place, the first clause is no longer suited to resolve the ellipsis of the second clause. If the adjective *tall* was ambiguous in this same sense between "tall as applied to human adults" and "tall as applied to human six-year-olds" then (5c) should have been false (or else the description of an anomalous situation in which Bill's daughter is some giant monster). But (5c) can be truly asserted of a perfectly normal situation, in which Bill is tall for an adult and his daughter tall for a six-year-old girl.

A similar difference arises between (6a) and (6b) with regard to the interpretations of *bank* and *tall* as applied to different members of the quantifier restriction (Kennedy, 2007b).

(6) a. Everyone in Bill's family went to the bank.
b. Everyone in Bill's family is tall.

Sixth, an important aspect of relative adjectives is their behavior in compound predications that have the logical form of classical **contradictions** or **tautologies**. It was long held that, for instance, the predicate *tall or not tall* was tautological and could therefore be regarded as true of all entities in tall's application domain, including its truth value gap, and that, likewise, the predicate *tall and not tall* is false of all entities in the application domain

(Kamp, 1975; Kamp and Partee, 1995; Barker, 2006). That compound predicates like *tall or not tall* and *tall and not tall* can be seen as true or false of entities in the truth value gap of *tall* has been seen as evidence for the **supervaluation** approach to vagueness (see Section 14.3.2 and below). However, more recent experimental work casts doubts on this assessment of the data (Alxatib and Pelletier, 2011; Ripley, 2011; Serchuk et al., 2011; Égré et al., 2013). Rather than making vacuous claims, often, predications like '*a* is tall or not tall' and '*a* is tall and not tall' are used to state or highlight that *a* belongs to the truth value gap of *tall* and **not** to its positive or negative extension.

One problem with these results is that there is considerable variation among speakers' reactions to clauses of the form '*a* is tall and not tall'. There have been different responses to these facts in the literature. We mention two of these:

(i) When we interpret the utterance of other speakers, we normally do not assume that they knowingly make empty or contradictory claims. So when it superficially looks like that is what they are doing, then we try to reinterpret what they say. This is how we deal in particular with utterances of apparent contradictions and tautologies like "*a* is tall and not tall" and "*a* is tall or not tall": We try to reinterpret the different occurrences of *tall* they contain in such a way that their content becomes non-vacuous (i.e. non-empty and non-contradictory; Kamp and Partee, 1995).

(ii) The data involving apparent tautologies and contradictions with vague predicates show that one or more of the logical words in these predicates – *and*, *or*, *not* – are used in a sense that differs from the ones attributed to them in the semantics of classical logic. The task for the theorist, therefore, is to identify what the different sense or senses are and to determine how these affect the logic of *not*, *and* and, *or* (Alxatib and Pelletier, 2011; Ripley, 2011; Serchuk et al., 2011; Cobreros et al., 2012b; Burnett, forthcoming).

At the present time, no consensus has been reached as to which of these two strategies has got things right. Perhaps different strategies are right in capturing the linguistic and logical dispositions of different groups of speakers.

14.2.2 Beyond adjectives

While adjectives seem especially prone to truth value gaps and to the contextual variability that is indicative of vagueness, it is clear that vagueness is not limited to this category. Widely discussed examples of vague nouns are *heap* and *mountain*, which have played a key role in the literature on predicates that give rise to borderline cases, fuzzy boundaries, and Sorites problems. Intuitively, a collection of one or two grains does not make a heap, and if no collection of n grains makes a heap, neither does any collection of $n + 1$ grains. The paradoxical conclusion is that for no n does a collection of n grains make a heap. Much the same goes for *mountain*. If an elevation of 2,500 meters counts as a mountain, how could an elevation of 2,499 meters fail to qualify? And where is the dividing line between mountains and hills?

Tolerant scalar properties such as number of grains, or merely size or volume, appear to play a role in classification under these nouns. They help determine what constitutes a heap or a mountain, although other properties, such as substance and shape, matter as well. Similarly, classification of an individual a under nouns like *child*, *adult*, *boy*, or *girl* depends in part on how old a is, and the vagueness of *old* infiltrates the semantics of these names as well. (A noun is vague as soon as at least one of its satisfaction criteria is vague.)

Typically, nouns – for example, *chair* or *tomato*, but the choice is quite arbitrary – are multidimensional (Kamp, 1975) and relatively sharp (Kamp and Partee, 1995). Psychological research, however, suggests that nouns do have a gap similar to that seen in vague adjectives. For example, tomatoes fall somewhere between fruit and vegetables, and three-legged seats with a small back fall between chairs and stools (Labov, 1973; Hampton, 1997). Speakers rarely change their minds about the categorization of clear instances of nouns, but they do so often in borderline cases like curtains for *furniture* or avocado for *vegetables* (McCloskey and Glucksberg, 1978).

Moreover, classification under nouns is governed by similarity. Entities classify under nouns if their scores along multiple dimensions sufficiently match the ideal values for the noun, or if they are closer to the ideal values of the noun than to the ideal values of any salient alternative (Hampton, 1997; Gärdenfors, 2004). Van Deemter (2010) provides ample illustrations of the way similarity and tolerance join to give rise to the Sorites paradox in the sharpest of nouns, including natural kind nouns like *frog* or *tadpole*, or mathematical concepts like *theorem*, *corollary*, or *finitism*.

Importantly, expert taxonomical criteria are vulnerable to vagueness. For example, the traditional foundation for the division of the animal kingdom is interbreeding: two animal groups belong to the same species if they can interbreed. But in actual fact the interbreeding criterion is far less unequivocal than must have been thought when it was first introduced, and when taken strictly, it leads to a gamut of mutually overlapping species (see van Deemter, 2010, chapter 2, for a discussion of the insufficiency of this and other scientific criteria for natural kind terms).

These various manifestations of vagueness strongly suggest that nouns are vaguer than is usually acknowledged in the linguistic literature. Like vague adjectives, nouns provide evidence for borderline cases, contextual variance in categorization judgments, lack of precise boundaries, and the Sorites paradox.

In fact, this aspect of vagueness penetrates into the sharpest looking words. The *meter*, for example, is defined as the distance between two marks on a certain rod in Paris, when found at a certain temperature and atmospheric pressure. However, as Russell (1923) points out, the marks are not points, so the distance between them is not defined with total precision. In addition, temperature is never quite uniform within an object, and so it is with other physical magnitudes: There is always some margin of error involved in their measurement. So vagueness encroaches even upon physical predicates that are given by what look like perfectly sharp definitions (see Williamson, 1994). Moreover, these considerations pertain, *mutatis mutandis*, to verbs as well as to nouns (see, for instance, Altshuler and Schwarzschild, 2013, for a discussion of fuzzy boundaries in stative predicates in relation to the cessation problem).

It has been argued that even proper names are subject to vagueness (Russell, 1923; Lewis, 1988). Typically, the question when a proper name refers to its bearer has no fully precise answer. There may be long stretches of time when a name attaches firmly and unequivocally to its bearer; but there are, nevertheless, times when this is not clear, for example, at the time of birth of a person or of the creation of an artifact or the foundation of a city; and likewise at the end of an entity's life span – the death of the person, or the destruction of the city or artifact. In the case of proper names, however, it is less clear that we must situate the vagueness in the name, rather than seeing it as a kind of vagueness or indeterminacy in the temporal extent of the thing named. This second possibility of vagueness in the temporal or spatial extension of real entities, also known as "vagueness in the world" or "metaphysical", or "ontological" vagueness, has long been a topic of dispute within philosophy. Some philosophers acknowledge vagueness in the world as *sui generis*, while others follow the early lead of Russell in regarding vagueness exclusively as a matter of language (or at most as a matter of general cognition). Since the focus of this article, as part of a handbook on semantics, is on vagueness in language, vagueness in the world is not one of its themes and we will, therefore, leave it at this brief mention of it. (See Unger, 1980; Tye, 1990; van Inwagen, 1990, for discussion.)

Other domains in which vagueness is prominent are those of quantifying expressions, frequency adverbs (Lewis, 1979c), and adjectival modifiers (Lakoff, 1971a). For example, *many* and *few*, as they are found, for instance, in statements of the form "Many/few *A*s are *B*s", are evidently vague, while expressions such as *every*, *some*, and *three* have generally been treated as sharp. Similarly, *very* and *slightly* are vague modifiers, while *perfectly* and *completely* may be regarded as sharp (Lasersohn, 1999). *Usually*, *generally*, and *normally* are vague quantificational adverbs, while *always*, *sometimes*, and *three times* are sharp (Kadmon and Landman, 1993; Veltman, 1996; and Cohen, Chapter 10). The quantifier *most* is vague, while *more than half* and *more than two-thirds* are sharp (see Solt, 2015b, for significant corpus results and discussion). A notorious example of vague grammatical constructions are those expressing genericity, among them generic indefinites (Carlson and Pelletier, 1995).

Notice, however, that sharp quantifiers or modifiers like *every*, *ten*, or *one hundred* are implicated in two other kinds of vagueness. First, like all quantifying expressions, they usually involve *domain restrictions* (von Fintel, 1994). Sometimes, these are fixed explicitly and precisely, as in *Every egg/ten eggs in this basket is/are spoiled*. However, often domain restrictions are determined by context, and often only loosely, thereby making room for vagueness in the semantic contribution of the quantifying expression. Second, an expression like *everyone* is often used in a way that is loose in another sense. *Everyone is coming to the meeting* may be accepted as true even if a member of the council who has been in a coma for some time will (obviously) not be coming. Moreover, *One hundred people turned up at the lecture* will often be accepted as correct, although there were in fact only 99 or 98 (Lasersohn, 1999). Note that this kind of sloppy use of round numbers seems to implicate vagueness of the kind governed by tolerance: If the presence of 98 people at the meeting is enough to justify the claim that a hundred turned up, what about 97? And if 97 is enough, what about 96? Likewise, if the absence of the council member who is in a coma does not falsify *Everyone is coming to the meeting*, what about some other council member who is in good health, but who has never attended any of the meetings in the past and has made a point of declaring openly that he will never go? For more on this, see Section 14.4.2.

14.2.3 Intermediate summary

In this first perusal of our topic, with its primary focus on relative adjectives as prototypical examples of vague predicates, we have come across the following features that are indicative of vagueness and that affect the truth conditions of vague predications:

(7) Indicators of vague expressions
  a. Contextual variability in truth value judgments
  b. Dependence on a comparison class
  c. A subjective component in truth value assessment
  d. Borderline cases
  e. Fuzzy boundaries
  f. Tolerance
  g. Susceptibility to the Sorites paradox
  h. Behavior under ellipsis
  i. Informative uses of contradictions and tautologies
  j. Modifiers that select for certain types of vague predicates

All these features raise doubts about the logic of vague predicates. In particular, a potential threat is posed by (7d). Classical logic is the logic of sharp predicates: It is the contribution made by sharp predicates to the truth conditions of the sentences they are part of that ultimately determines the relation of logical consequence (i.e., the semantic characterization of logical validity) to be that of the classical predicate calculus. It may not be immediately obvious what happens when vague predicates are taken into account as well as sharp ones, but it seems reasonable to suspect that this will affect the consequence relation to the point of changing the logic.

The question of what effects vagueness has on logic has led to a multitude of different reactions and to proposals of a considerable range of different vagueness logics. A proper survey of these proposals would require an article of its own. In a handbook on semantics, the logical aspects of vagueness are a lesser priority. Nevertheless, if we see it as part of the task of semantics to explain how the linguistic form of a sentence determines the information from which an interpreter can proceed to derive further conclusions, through the application of certain logical principles, then what these principles are, and what the logical form is of the information to which they are applied, cannot be ignored. In what follows in the next sections, we have tried to strike a balance between aspects of logic that are of intrinsic importance to someone with a central interest in the logic of vagueness and the relevance that logical questions have for the semantics of vagueness. The logic of vagueness is the central concern of Section 14.3.

14.3 The Sorites paradox

In this section we discuss the Sorites paradox, considering the versions illustrated in (8) and (9).

(8) **Base Premise**: 1,000,000 grains of sand can make a heap of sand. (Premise 1)
Inductive Premise: (For all n) If $n + 1$ grains of sand can make a heap, then so can n grains. (Premise 2)
Conclusion: One grain of sand can make a heap.

(9) **Base Premise**: 1,000,000 grains of sand can make a heap.
Conditional Premises:
1. If 1,000,000 grains of sand can make a heap, then so can 999,999 grains.
2. If 999,999 grains of sand can make a heap, then so can 999,998 grains.
...
...
Conclusion: 1 grain of sand can make a heap.

The responses are discussed in the following sections, divided into the following types (Sorensen, 2013):

(i) Denial of the Base Premise of one version of the paradox (skepticism).
(ii) Denial of the Inductive Premise or one or more of the Conditional Premises (Epistemicism, Supervaluationism, Subvaluationism).

(iii) Constraints on the usage of vague predicates (pragmatic contextualism).
(iv) Denial of the validity of the argument (multiple truth values/notions).

14.3.1 Denial of the first premise: skepticism

The first type of response denies its base premise. This is one way to remove the paradoxality from the argument. But what independent reasons could there be for holding the premise false? You are looking at a heap of 1,000,000 grains of sand. It is clearly and unambiguously a heap, by any standards for the application of *heap*. How is anybody going to argue you out of that, if it is not by arguing that the concept is paradoxical, or incoherent in a way that the Sorites paradox reveals?

Let us, for the sake of argument, go along with the assumption that the argument is valid and its second premise true. Why, then, should we infer that the premise must be false rather than that the conclusion is true? Either inference flies in the face of what appear to be incontrovertible facts. One seems to be as bad as the other. Why choose between them?

We can avoid choosing as follows. What follows from the two assumptions we have retained is that the first premise and the conclusion of (8) have the same truth value.[3] It follows that the positive extension of the predicate is either empty or else it is all of the predicate's application domain. In other words, either no number n is such that n grains of sand can make a heap or else all numbers n have this property.

This is still strong medicine. However, there are some predicates for which the "all-or-nothing" conclusion involved – either nothing satisfies the predicate or else everything does – does have some independent support. We saw in Section 14.2 that it is necessary to distinguish between relative adjectives and absolute adjectives and that the latter come in two varieties, maximum criterion (*clean*, *flat*) and minimum criterion (*dirty*, *uneven*). The strict satisfaction conditions for a maximum-criterion adjective like *flat* are to the effect that a surface x is flat if and only if x has no unevennesses: As soon as there is some bit of unevenness to x, we can imagine a surface y which is just like x except flatter. However, that would disqualify x as flat.

If this is the right definition of *flat*, then there are arguably no flat surfaces in physical reality. Moreover, if that is true, then *flat* has an empty extension in the real world. So, on these assumptions, *flat* satisfies the all-or-nothing condition. The same is true for the complementary predicate to *flat*, the minimum-criterion predicate *uneven*: For a surface x to be uneven, it is necessary and sufficient that x have some unevenness, however slight. But

[3] This is not quite correct as it stands. An additional principle is needed to exclude the possibility that the first premise is false and the conclusion true. For Sorites arguments involving number predicates this principle is a monotonicity principle to the effect that when $n < m$ and n satisfies the predicate, then so does m. For other predicates, such as, e.g., *big pencil*, the monotonicity principle has to be stated somewhat differently, but the general idea should be clear.

surely every physical surface will have *some* unevenness somewhere, so every physical surface will be uneven: the positive extension of *uneven* consists of its entire application domain.

In light of the above discussion, it might have been thought that at least for those absolute adjectives for which the all-or-nothing condition is fulfilled, we get a resolution of the Sorites paradox along the lines sketched above. However, somewhat ironically, absolute adjectives are predicates for which such a resolution of the paradox is neither plausible nor necessary (Kennedy, 2007b). Notice that if absolute adjectives were to satisfy the all-or-nothing condition in the real world, then these adjectives would have no meaningful application in practice. In practice, the maximum and minimum criteria that govern absolute adjectives are applied leniently or sloppily. How lenient will depend on context. Here too what depends on context is some kind of tolerance: Context will determine, to a greater or lesser extent, how much dirt we tolerate – e.g., on the shirt or on the carpet – before we stop calling the thing clean and get ready to start calling it dirty.

When absolute adjectives are used in this lenient way, then of course they will be vulnerable to Sorites effects again. If the difference between clean and dirty is just a matter of how much dirt, then *clean* and *dirty* turn into tolerance-governed predicates in the earlier sense that small differences make no difference to their satisfaction conditions.

14.3.2 Denying Inductive and Conditional Premises: partial knowledge or partial information?

A second strategy for dealing with the Sorites paradox is to acknowledge the Base Premise of (8) and (9) as true and the conclusion as false, but to argue that the other premises (the Inductive Premise in (8) and one or more of the Conditional Premises in (9)) are false. A number of approaches follow this strategy. Salient among them are two: Epistemicism and Supervaluationism.

Epistemicism

According to the *epistemicist* view, the Sorites is not a problem. Vagueness is just a form of ignorance (Williamson, 1994). When an entity *a* appears to us to belong to the truth value gap of the "vague" predicate *P*, that is always because we do not *know* whether or not it is a case of *P*. Some of that knowledge is irremediable, because of the way in which we are situated, as members of a speech community who have to acquire their language as well as they can, and who cannot do better than use predicates like *P* to the best of their knowledge of how the satisfaction conditions of *P* are grounded in the language that is the common property of their community. According to the epistemicist view of vagueness, this epistemic fact about the extension of *P* must be distinguished from the true (though unknowable) satisfaction conditions of *P*. These are the satisfaction conditions of a sharp predicate, and it is they that enter into the definition of logical consequence, which will therefore give us the classical notion, and with it classical logic.

For Epistemicism the second premise of (8) is false, and so is one of the Conditional Premises in (9). It is just that it is fundamentally impossible for us to know which of those conditionals is false. And likewise, we cannot know which instance of the second premise of (8) is responsible for its falsehood. Another example is (10), which expresses that being one day apart in age is within the tolerance relation for the predicate *child*. On the epistemicist view, (10) must be false as well. Moreover, and for the same reason, (11), the negation of (10), is true, although we cannot hope to find any particular n which instantiates this existential statement.

(10) For any n, if an n days old human being is a child, so is an $n + 1$ days old human being.

(11) There is a number n such that an n days old human being is a child but is no longer a child at $n + 1$ days.

Epistemicists (Williamson, 1994, 2002; Fara, 2000; Sorensen, 1988, 2001) accept this last consequence. However, it is in particular the inescapability of this consequence of epistemicism that epitomises what its critics find hard to swallow.

Supervaluationism

As opposed to Epistemicism, Supervaluationism assumes that vague predicates are genuinely partial (Lewis, 1970; Fine, 1975b; Kamp, 1975; Kamp and Partee, 1995; Keefe, 2000). This assumption is implemented using partial models $\mathcal{M}_0$ in which a vague predicate P has a positive extension $[\![P]\!]^+$, a negative extension $[\![P]\!]^-$, and a truth value gap $[\![P]\!]^?$. For simplicity we assume that the application domain of P includes all of the Universe U of the model. In the formal developments that follow, this will from now on be taken for granted. Distinctive of the supervaluation approach is that it considers, in conjunction with each such partial model $\mathcal{M}_0$ a set S of models that extend $\mathcal{M}_0$ (where a model $\mathcal{M}'$ is an extension of a model $\mathcal{M}$ iff for each predicate P, $[\![P]\!]^+_{\mathcal{M}} \subseteq [\![P]\!]^+_{\mathcal{M}'}$ and $[\![P]\!]^-_{\mathcal{M}} \subseteq [\![P]\!]^-_{\mathcal{M}'}$).[4] We follow the tradition in confining ourselves to the special case of a language $\mathcal{L}$ of first order predicate logic with one or a few partial predicates. Unless mentioned otherwise, we assume that $\mathcal{L}$ has just one partial predicate P.

The set S of extensions can be thought of in various ways. Stalnaker (1975) shows how a construction of this kind can be used to model many aspects of information states in a background context c. In this interpretation the members of S are the states of affairs, or "possible worlds", that

[4] See, for example, in van Fraassen (1969), Kamp (1975), Fine (1975b), Stalnaker (1975, 1978), van Benthem (1982), Groenendijk and Stokhof (1984), Veltman (1984, 1996), Landman (1991), Barker (2002), and others.

are compatible with the given information state. When we think about information states as states of information about the partial predicate P, then the models in S should be thought of as giving the different ways in which the truth value gap of P in the "ground model" $\mathcal{M}_0$ could be resolved in a manner that is consistent with that information state. A different way to think of S is as the set of possible modifications of the semantics of the predicate P. This could be either as an enduring change of the language $\mathcal{L}$ to which P belongs – that is, $\mathcal{L}$ is changed into a new language $\mathcal{L}'$ – or as a more "local" effect: as the modification of a given context c of use for P to a more specific context c', in which certain questions about P's extension that remained undecided in c have now been settled. Such special contexts will typically last only for the duration of the given utterance or conversation and revert to the neutral context reflected by the ground model when the circumstances of the utterance no longer prevail.

This latter way of thinking about S suggests that we should distinguish between contexts of use and the information that contexts carry about the extensions of partial predicates: In general this latter information is only one part of the total information carried by the context. We capture this distinction by assuming that each context c determines a partial model Mod(c), which incorporates the information in c about the extensions of the predicates of $\mathcal{L}$. We write $c \leq c'$ to convey that c' carries at least as much information as c; $c \leq c'$ entails that $\mathrm{Mod}(c) \leq \mathrm{Mod}(c')$, where for two partial models $\mathcal{M}$ and $\mathcal{M}'$ for $\mathcal{L}$, $\mathcal{M} \leq \mathcal{M}'$ iff for every predicate P of $\mathcal{L}$ $[\![P]\!]^+_{\mathcal{M}} \subseteq [\![P]\!]^+_{\mathcal{M}'}$ and $[\![P]\!]^-_{\mathcal{M}} \subseteq [\![P]\!]^-_{\mathcal{M}'}$. From now on we assume that the contexts form a set C and that S_C is the set of corresponding models: $S_C = \{\mathrm{Mod}(c) \mid c \in C\}$. When $\mathcal{M} \leq \mathcal{M}'$, we say that $\mathcal{M}'$ is an *extension* of $\mathcal{M}$.

These stipulations lead us to structures of the form $\langle C, \leq, \mathrm{Mod}\rangle$, with $\leq$ a partial order of C and Mod a function from C to partial models of $\mathcal{L}$. We assume, in addition, that C always has a $\leq$-minimal context c_0, which stands in the relation $\leq$ to all members of C. We refer to $\mathrm{Mod}(c_0)$ as the *ground model* of $\langle C, \leq, \mathrm{Mod}\rangle$.[5]

The models in S_C can be either partial models or complete (that is, classical) models. We refer to the set of complete models in S_C as T_C. The members $\mathcal{M}$ of T_C are called *precisifications* (*of* those models Mod(c) in S_C such that $\mathrm{Mod}(c) \leq \mathcal{M}$). With these additional notions we can represent our structures as 5-tuples $\langle C, \leq, c_0, \mathrm{Mod}, T\rangle$.

In the application of these models to the analysis of vagueness, the relation $\leq$ between models should **only** reflect the resolution of the truth value gaps of partial predicates. That is, when $\mathcal{M} \leq \mathcal{M}'$, then the universes of $\mathcal{M}$ and $\mathcal{M}'$ should be identical. In fact, it is useful to restrict attention to Supervaluationist models $\langle C, \leq, c_0, \mathrm{Mod}, T\rangle$ in which all models have the same universe. In other words, each model Mod(c) in S_C has the same universe as

[5] Sometimes the assumption is made that $\mathrm{Mod}(c_0)$ is minimal in an absolute sense: for every partial predicate P, $[\![P]\!]^+_{\mathrm{Mod}(c_0)} = [\![P]\!]^-_{\mathrm{Mod}(c_0)} = \varnothing$; however, we do not adopt this as a general assumption.

Mod(c_0). Models that satisfy this additional constraint of model constancy will be called *Supervaluationist models*, or *SV models*.

The semantics of vague predicates can depend on context in a variety of ways, and not only on the extensions that the contexts assign to them via their associated models. That is why it is important to be able to distinguish in general between contexts and models. But in many applications of the supervaluation methods to vagueness it is only the extensions that matter. In those applications, it is possible and convenient to identify contexts with their associated models. This identification leads to *SV* models of the form $\mathcal{M}^* = \langle C, \leq, c_0, T\rangle$, where C is now a set of partial models and $\leq$ the model extension relation. A further specialization is to *SV* models in which all models in C other than c_0 are complete. Such *SV* models are often represented as $\langle \mathcal{M}_0, S\rangle$, where S is a set of complete extensions of $\mathcal{M}_0$.[6]

There are two distinct uses to which *SV* models can be put. The first is to define notions of *supertruth* and *superfalsity*: a sentence φ of $\mathcal{M}$ is *supertrue* in the context c of an *SV* model $\mathcal{M}^*$ iff φ is true in all members c' of T such that $c \leq c'$; and φ is *superfalse* in c iff φ is false in all members c' of T that extend c. Furthermore, φ is said to be *supertrue/superfalse* in $\mathcal{M}^*$ iff φ is supertrue/superfalse in c_0.

For simple languages, like our language $\mathcal{L}$ of first order predicate logic, truth and falsity in partial models are *monotone*: if $c \leq c'$ and φ is true/false in c, then φ is true/false in c'.[7] Evidently, when truth and falsity are monotone, then for each c in C and sentence φ, if φ is true/false in c, then φ is supertrue/superfalse in c. However, the converse does not hold in general. For instance, every sentence of $\mathcal{L}$ that has the form of a tautology will be supertrue in any *SV* model $\mathcal{M}^*$ (in every c of $\mathcal{M}^*$), and every sentence that has the form of a classical contradiction will be superfalse. In particular, $P(a) \vee \neg P(a)$ will be supertrue and $P(a)$ & $\neg P(a)$ superfalse in all *SV* models $\mathcal{M}^*$, even when P is vague and a is in the truth value gap of P in the ground model. Note that supertruth and superfalsity lack many of the

[6] In such applications, the "intermediate models" of *SV* models, i.e., those $c \in C$ such that $c_0 < c < t$ for some $t \in T$, do not do any work and can be ignored. The result is a structure $\langle M_0, S\rangle$ of the kind just described.

[7] Truth for $\mathcal{L}$ in partial models $\mathcal{M}$ requires a "two-sided" recursion, with separate clauses for truth and falsity. For instance, the clauses for (i) atomic formulas of the form $P(\pi)$, (ii) negation, (iii) conjunction, and (iv) existential quantification must be stated as follows. (Throughout, g is an assignment of entities in the universe of $\mathcal{M}$ to the variables of $\mathcal{L}$, $g(\tau)$ is the value g assigns to the variable x if $\tau = x$, and the denotation of the individual constant c if $\tau = c$ and $g[d/x]$ is the assignment that is like g except that $g[d/x](x) = d$.)

(i) $[\![P(\tau)]\!]_{\mathcal{M},g} = 1$ iff $g(\tau) \in [\![P]\!]^+_{\mathcal{M}}$
$[\![P(\tau)]\!]_{\mathcal{M},g} = 0$ iff $g(\tau) \in [\![P]\!]^-_{\mathcal{M}}$

(ii) $[\![\neg\varphi]\!]_{\mathcal{M},g} = 1$ iff $[\![\varphi]\!]_{\mathcal{M},g} = 0$
$[\![\neg\varphi]\!]_{\mathcal{M},g} = 0$ iff $[\![\varphi]\!]_{\mathcal{M},g} = 1$

(iii) $[\![\varphi \;\&\; \psi]\!]_{\mathcal{M},g} = 1$ iff $[\![\varphi]\!]_{\mathcal{M},g} = 1$ and $[\![\psi]\!]_{\mathcal{M},g} = 1$
$[\![\varphi \;\&\; \psi]\!]_{\mathcal{M},g} = 0$ iff $[\![\varphi]\!]_{\mathcal{M},g} = 0$ or $[\![\psi]\!]_{\mathcal{M},g} = 0$

(iv) $[\![\exists x\varphi]\!]_{\mathcal{M},g} = 1$ iff there is some d in universe $U_{\mathcal{M}}$ of $\mathcal{M}$ such that $[\![\varphi]\!]_{\mathcal{M},g[d/x]} = 1$
$[\![\exists x\varphi]\!]_{\mathcal{M},g} = 0$ iff for all d in $U_{\mathcal{M}}$, $[\![\varphi]\!]_{\mathcal{M},g[d/x]} = 0$

compositionality properties of the classical notion of truth for first order logic. For instance, the supertruth of $P(a) \vee \neg P(a)$ does not entail the supertruth of one of its disjuncts, whereas the truth of a disjunction $p \vee q$ entails that either p or q must be true. In a typical *SV* model in which a is in the truth value gap of P in the ground model, there will be t in T where a is in P's positive extension and also t in T where a is in P's negative extension (thus $P(a)$, as well as its negation, would typically be neither supertrue nor superfalse). A similar deviation from what holds for truth in the absence of vagueness is found in its interaction with quantifiers, for example, an existential sentence can be supertrue without any of its instances being supertrue.

The notion of supertruth can be used to define logical validity:

(12) B is a *logical consequence* of Γ iff for every Supervaluationist vagueness model $\mathcal{M}^*$, if every premise A in Γ is supertrue in $\mathcal{M}^*$, then so is B.

The consequence relation defined in (12) turns out to be that of classical logic. This is one possible way of defending classical logic in the face of vagueness, but it is not the only one. A second definition will be given in (13) below.

Some of the criticisms of the supervaluation approach have targeted the notion of supertruth.[8] Supertruth, it is contended, is not really a notion of truth at all, which could serve as a proper explication of the informal notion of truth as we know and use it and that philosophy and logic should analyze and clarify. The factors that disqualify supertruth as a notion of truth include both the way supertruth is defined, involving a universal quantification over virtual models, which represent possible interpretations that *could* be assigned to the predicates in question, and certain formal properties of supertruth that are incompatible with those that any intuitively plausible notion of truth should have.

However, is this to be seen as a criticism of the supervaluation method as such? Not so, we think. Supervaluation and supertruth should not be conflated. It is important in this connection to note that the Supervaluation approach can be used to characterize logical validity without making use of supertruth. This is the second way we referred to above of making use of the same *SV* models $\mathcal{M}^* = \langle C, \leq, c_0, T\rangle$ that are also employed in the first use. We now define logical validity directly on the complete extensions of such models:

(13) The argument $\Gamma \models B$ is *supervalid* iff for every *SV* model $\mathcal{M}^*$ and every t in $T_{\mathcal{M}^*}$, if every A in Γ is true in t, then so is B.

This definition is like the one in (12) in that it too gives us classical logic. However, it does this in a somewhat different way. Technically, it is more

[8] Sorensen (2013) argues that when supertruth is accepted as the relevant notion of truth in the presence of vagueness, then the supervaluation account either commits us to the truth of the proposition that a one-year-old is not a child or else to the truth that a seventy-year-old person is a child. Neither is acceptable. So supertruth is not a good explication of truth.

"local" (see Williamson, 1994; Varzi, 2007; Cobreros, 2011). Rather than requiring, in the way of (12), the preservation of supertruth, which itself involves the idea of quantification over the complete models of particular *SV* models $\mathcal{M}^*$, it requires preservation of (classical) truth in each individual complete model of every *SV* model. But apart from formally circumventing the notion of supertruth, the definition also has an intuitive motivation that is not easy to recover from the definition in (12).

Logical deduction is a matter of form. We can engage in deduction even when we have no idea what some of the content words in the premises and conclusion of an argument mean; and *a fortiori* we can do so without knowing all there might be to know about those words. All that we need to assume in order to justify the deductive inferences we draw is that the accommodations made in order to obtain determinate truth conditions for the premises are the same as those that are made in order to obtain determinate truth conditions for the conclusion.

Within a Supervaluationist setting, it is also possible to define logical validity in yet other ways. Example (14) is one possible definition of an *internal logic*, which is based directly on the ground models of *SV* models and makes no reference to any extensions of it. So (14) is not really Supervaluationist in spirit. However, *SV* models suffice as its inputs.

(14) $\Gamma \models B$ is *internally valid* iff for every partial model $\mathcal{M}$, if every A in Γ is true in $\mathcal{M}$, then so is B.

This definition imposes stricter constraints on validity than supervalidity and defines a weaker logic, which is known as "Strong Kleene" (Veltman, 1984).[9] Example (14) is only one way in which the internal logic of partial models can be plausibly defined.[10] For someone who wants to advocate such an internal logic as the "true" logic of vague predication this presents a conceptual problem: How is he to argue for a motivated choice between these different options?

However, this also presents a problem for the advocate of (13): Is there a way to argue that definition (13) is conceptually superior to definition (14) or any of its variants? To use the argument we just gave in favor of (13) as definition of validity for a language of predicate logic with vague predicates seems persuasive. But not everybody will necessarily agree. Moreover, the issues change when we consider languages which include higher order vagueness.

[9] One salient difference between classical logic and Strong Kleene is that no classical tautology is valid in the Strong Kleene logic (in the sense of following logically from the empty set of premises).

[10] One alternative definition is given in (i):

(i) $\Gamma \models B$ is internally valid iff for every partial model $\mathcal{M}$ in which B is false, at least one of the premises in Γ is false.

The logic generated by this definition is different from the Strong Kleene logic generated by (14). It is known as LP. LP differs from Strong Kleene and is in this respect more like classical logic, in that it verifies all classical tautologies; but like Strong Kleene, it is a good deal weaker than classical logic. There are still other ways to define internal validity besides these two, which yield yet other logics. We refer to the literature for details (see in particular Varzi, 2007; Asher et al., 2009).

The distinction between the supervaluation approach (i) as a way of reanalyzing the concept of truth as supertruth and then defining logical consequence in terms of it and (ii) as a method for analyzing logical validity without making use of supertruth is important also for the account that Supervaluationism is able to give of the Sorites paradox. The standard supervaluation account, already mentioned above, is that some premise or premises other than the Base Premise is or are, contrary to appearances, false. For an argument of the form (8), this is the Inductive Premise. However, for arguments of the form (9), the account cannot be quite formulated in this exact form. To see this, consider a *SV* model $\mathcal{M}^*$, whose universe is the set of the positive natural numbers and suppose that P represents the predicate "is a number n such that n grains of sand can make a heap".

In keeping with our intuition that the Base Premise of (8) is definitely true, and assuming that its conclusion is definitely false, the positive extension of P in the ground model c_0 of $\mathcal{M}^*$ should be some segment $[k, \infty)$ that is neither too small nor too big (e.g., k is somewhere between 50 and 1,000,000), and the negative extension of P in the ground model should be some interval $[1, l]$, where $1 < l < k$. Furthermore, for each t in T, there is a number r in the interval $[l, k)$ such that the negative extension of P in t is the interval $[1, r]$ and the positive extension $[r + 1, \infty)$. Conversely, we assume that for each $r \in [l, k)$ there is a $t \in T$ in which P has the mentioned extensions. It is clear that in the ground model of $\mathcal{M}^*$, $P(1, 000, 000)$ is true and $P(1)$ false. Furthermore, the Inductive Premise of (8) is superfalse in $\mathcal{M}^*$. For let t be any precisification in T. Then for some $r \in [l, k)$, $P(r + 1)$ is true in t and $P(r)$ is false. So the conditional $P(r + 1) \rightarrow P(r)$ is false in t and, therefore, also the Inductive Premise, which is the universal quantification over such conditionals. So the Inductive Premise is false in every $t \in T$; that is, the premise is (super)false in $\mathcal{M}^*$. So $\mathcal{M}^*$ isn't a counterexample to the validity of (8). And since we may expect that any model which describes a Sorites situation yields this same conclusion, there is no reason here to doubt the validity of the argument.

We can argue in much the same way that arguments of the form (9) do not present countermodels to validity either, but to show this we have to proceed a little differently. This is because in a model like $\mathcal{M}^*$ none of the premises $P(r + 1) \rightarrow P(r)$ will be superfalse. However, even if none of these premises is superfalse by itself, the conjunction will be superfalse. Or, put only slightly differently, the set of these premises cannot be jointly true: there is no single complete model t in $\mathcal{M}^*$ such that all these premises are true in t. Thus, that a model like $\mathcal{M}^*$ is not a countermodel to (9) follows from the following principle:

(15) It is possible for a false conclusion to be validly deducible from a set of premises that cannot be jointly true.

Example (15) can also be used to explain why models like $\mathcal{M}^*$ are not countermodels to (8). In (8), the Inductive Premise does on its own the work that is jointly done by the Conditional Premises $P(r+1) \rightarrow P(r)$ in (9). So (15) can be applied to the case of (8) by taking the set of premises that cannot be jointly true to be the singleton set of which the Inductive Premise is the only member. This set "cannot be jointly true" in $\mathcal{M}^*$ because its one member is false in all members t of T. Of course, we can state this by saying that the Inductive Premise is superfalse in $\mathcal{M}^*$. However, we think enough has been said to make it clear that it is not just that the solution which the supervaluation method offers for the Sorites can be given without making reference to the notions of supertruth and superfalsity; in accounting for (9) these notions do not even deliver what is really needed. Here too we see that the supervaluation method is not wedded to the concept of supertruth.

These last considerations were aimed to show that the Supervaluationist resolutions of the Sorites paradox are coherent. The arguments are valid, but in models that capture our intuitions about the conditions in which their premises and conclusions get their truth values, the premises can never be all true. However, arguably coherence is not all that we want. Perhaps the strongest objection against the solution that Supervaluationism offers of the Sorites paradox is that it fails to do justice to the strength of our sense that the Conditional Premises of arguments of the form (9), and perhaps also the Inductive Premise of (8), are true. Consider once more one of the Conditional Premises in (9):

(16) If $n+1$ grains of sand can make a heap, then n grains can make a heap too.

The intuition that such a sentence is true is so strong, so the objection goes, because there is a dynamic aspect to its meaning: acceptance of the antecedent of (16) in a context c produces a context change from c to a new context c' in which n has become established as a member of the positive extension of the relevant predicate P. When, in this new context c', the question is raised whether P is true of some other number n' that stands in the tolerance relation to n, the answer can only be affirmative. Anything within the tolerance range of something that is an established member of the positive extension of P must also be classified as P. Dynamic approaches to the Sorites paradox are among the topics of the section on contextualism after the next one.

Subvaluationism

An approach to vagueness that has many formal features in common with Supervaluationism is **Subvaluationism**; the name has been chosen to emphasize these formal similarities. However, the informal motivation behind Subvaluationism is very different from that behind Supervaluationism. Conceptually, Subvaluationism is embedded within **Paraconsistency**, a general view of logic in the face of paradox (Priest, 1987). In paraconsistent logic, paradoxical combinations of sentences can be represented and adopted as premises without the consequence that everything becomes derivable.[11]

As regards vagueness, the core intuition of the paraconsistent approach is that when a is a borderline case of P, then $P(a)$ is *both* true and false (rather than neither true nor false, as in the Supervaluationist approach). One way to make this intuition explicit is something we could have done in our presentation of Supervaluationism too, but which doesn't seem quite as natural there: introduce a third "truth value", in addition to the truth values we already have – 1 for true (and not false) and 0 for false (and not true) – in order to cover such cases of joint truth and falsity. The new truth value can be denoted as "$(1, 0)$", so that the truth value space becomes $\{1, (1, 0), 0\}$. Three-valued models based on this truth value space for the language $\mathcal{L}$ described in the previous section will assign to predicates functions that map their application domain into $\{1, (1, 0), 0\}$. The borderline cases of P in such a model will now be those individuals which the function for P maps to $(1, 0)$. A three-valued truth definition, which closely resembles that for partial models given in footnote 7, then extends these truth value assignments to all sentences of $\mathcal{L}$.

It is possible to associate with such three-valued models sets of "complete" extensions in much the same way as that is done in the Supervaluationist approach. Going from $\mathcal{M}$ to one of its complete extensions now means that each entity a such that $P(a)$ has the value $(1, 0)$ in $\mathcal{M}$ gets either the value 1 or the value 0 in the extension. Evidently, the structures thus obtained are isomorphic to the vagueness models $\langle \mathcal{M}, S \rangle$ of the supervaluation approach. So exactly the same concepts can be defined from them. However, what concepts will seem useful will depend on the underlying philosophy, and in view of what it means for the Subvaluationist that a sentence has the value $(1, 0)$, it seems natural to introduce notions of subtruth and subfalsity as follows.

(17) Let $\mathcal{M}^{**}$ be a pair $\langle \mathcal{M}, S \rangle$ where $\mathcal{M}$ is a three-valued model and S is a set of complete extensions of $\mathcal{M}$. A sentence φ of $\mathcal{L}$ is *subtrue* in $\mathcal{M}^{**}$ iff there is some model $\mathcal{M}'$ in S such that φ is true in $\mathcal{M}'$. (And likewise for subfalsity.)

While the Supervaluationist approach has put a strong emphasis on the "outer logic" which can be defined using the complete extensions of *SV* models, the Subvaluationists have shown a preference for an internal logic, which can be defined directly on the three-valued models themselves (see Hyde, 2008, who endorses and later rejects an outer logic). The preference has been for the logic LP (see footnote 10), which has an independent motivation as a general logic of paradox. One of the uses of LP is in an account of the Sorites paradox. As this too is an account that advocates a change of

[11] An early formulation of formal logic with this property, known as LP, can be found in Priest (1979).

logic, we wait with the details until the following section, which is devoted to Sorites responses of this type.[12]

Contextualism

By Contextualism we here understand those approaches toward the Sorites problems that rely on the context dependence of vague predicates. We already noted the possibility of interpreting conditionals like $P(a_i + 1) \rightarrow P(a_i)$ as true because their consequent is true in the context established by their antecedent.

Actual situations in which the Sorites paradox can become an acute problem for participants in a discourse are referred to as **forced marches** (Horgan, 1994). A forced march arises when it is beyond question that an actual entity a_1 satisfies a predicate P, and it is equally beyond question that an actual entity a_N does not, and for $i = 1, \ldots, N - 1$, the actual entities a_i and $a_i + 1$ stand in the tolerance relation for P. It is obvious that our world is densely populated with such configurations. How much of a difficulty these situations actually do present to speakers who find themselves in them and want to talk about them is itself a topic of theoretical debate. But before anything can be said about this debate, we must first make more precise what the problem is supposed to be.

In the vagueness literature, the forced marches discussed have been mostly situations brought about in psychological experiments. Prominent among experiments that have actually been performed are those involving color predicates (see Raffman, 1994, 2005, 2014; Égré et al., 2013). Typically, the material consists of a series of N colored squares running from, say, an unequivocally red square a_1 to an unequivocally orange square a_N, while successive squares a_i and $a_i + 1$ look exactly the same color when placed next to each other. If we make the familiar and plausible assumption that any two color patches whose color shades cannot be told apart (by subjects with normal vision in normal viewing conditions) stand in the tolerance relation for ordinary color predicates like *red* and *orange*, and if it is strictly true that these color terms are governed by tolerance, then the judgment changes to which forced march experiments lead, more or less without exception, are violations of the semantics of those predicates. Either the subjects of forced march experiments violate the semantic rules of their language or else it is part of the semantics of tolerance-governed predicates that the tolerance principles governing them are not absolute, but capable of being overruled by other principles with a higher priority.

Support for this latter position can be found in the work of Sainsbury (1988). Sainsbury notes that there are situations in which it seems fully legitimate to adopt a sharp cut-off point for color terms and other vague

[12] We note that not all who endorse LP as a logic of vagueness are Subvaluationists, just as one does not have to be a Supervaluationist to endorse the Strong Kleene logic. For a different setting in which these logics arise, see Cobreros et al. (2012a).

predicates where there can be no doubt of their sensitivity to tolerance. An example is that of the owner of a paint shop who decides to store the reds on the top shelf and the oranges on the shelf below. This requires a decision, arbitrary to at least some extent, as to where the cut between the reds and the oranges should be made. Once that decision has been taken, it is better to stick to it for as long as one can, at least when it comes to restocking the shop. However, that does not diminish the freedom of choice that exists *at* the time when the decision is made. In the last analysis, there is nothing in the semantics of *red* and *orange* that prohibits such decisions. Furthermore, if that is so in the situation of the paint shop, why should it be so radically different in the situation of a forced march, where the price for sticking to the tolerance principle *à tort et à travers* is bound to get you into serious trouble?

What is it that countermands the power of tolerance in forced march situations? This is a question on which, we believe, no detailed answers currently exist. Certainly, there is no wide agreement on any particular answer (see Égré et al., 2013, for actual experimentation and discussion). We regard the task of finding a convincing answer as one of the most important for the theory of vagueness and tolerance.[13]

Another point about forced marches is that the linguistic resources involved can be extremely simple. Typically, in a forced march experiment the only sentences ever uttered are those occurring in question–answer pairs like: A: *Is this red?*; B: *Yes/No/I am not sure*. These are just atomic predications. None of the logical constructs – conjunction, conditionals, universal quantification – that occur in the Sorites arguments on which so much of the Sorites literature has focused play any part here. When this point is appreciated, the challenges that are presented by Sorites arguments in their traditional forms, as in (8) and (9), take on a new complexion. In these arguments, logical constructs play a central part, for it is they that permit, or seem to permit, the deduction of the conclusions from the premises. So the focus has to be on the way these constructs behave in the presence of vagueness. The Supervaluationist response meets the challenge by modeling

[13] Raffman (1994) diagnoses the judgment changes that occur in the course of forced marches as a species of Gestalt switch, akin to what can be observed when subjects are made to stare at a Necker cube or certain other ambiguous images. On this view the judgment switch occurs when the new pair (a_i, a_{i+1}) is submitted to the subject's judgment after a_{i-1} has been removed. Once the Gestalt switch takes place, *neither* member of the pair (a_i, a_{i+1}) will look unequivocally red to the subject any longer; and when the experimenter then returns to the pair (a_{i-1}, a_i), then the Gestalt switch that has just occurred will tend to have the effect that now neither element of this pair, a_{i-1} no more than a_i, seems to support an unequivocal judgment of "red".

Of course, even if it is true that Gestalt switches lead to the changes in the judgments subjects actually express, this does not prove that the *semantics* of *red* and other color predicates is compatible with such changes. There might be a fundamental rift between our understanding of how such predicates should work and what is dictated by our color experiences in forced march situations.

Cobreros et al. (2012b) advocate tolerance as a soft and defeasible constraint, and Raffman (2014) even considers the necessary category-switch in forced marched Sorites as a primitive datum for an adequate theory of vagueness. She would, therefore, rather ask what makes the power of tolerance so appealing in Soritical contexts, despite its being doomed to be given up.

vagueness in such a way that the classical semantics of the constructs can be preserved and resolves the paradox by arguing that the premises cannot be jointly true. But if one is not prepared to place the blame as squarely as that on the truth values of the premises, then it is no longer clear whether the classical semantics of the logical operators can be upheld. Contextualist approaches to the Sorites differ on this point, as we will see next.

Dynamic contextualist accounts

As we see it, the dominant trend within contextualism is dynamic, and the core of dynamic accounts is what we just surmised about the mechanisms involved in forced march conversations: the extensions of vague predicates are in general only partially determined, and the extent to which they are determined varies with the context. More specifically, the participants in a conversation can agree to treat entities mentioned in the conversation, or those newly brought into it, as positive or negative instances of P, thereby changing the context into one of which this commitment is part. If, moreover, P is governed by tolerance, then such contextual changes may have a secondary effect: for an entity b with regard to which it was previously undecidable whether it should be counted as P, it may now be possible to answer this question, because the new context carries the commitment that some individual a that stands in the tolerance relation to b belongs to, say, the positive extension of P; in that case, assuming that the tolerance principle is in force, $P(b)$ should be regarded as true. However, that means that if in the given context someone asks whether $P(b)$, and the participants act according to the dictates of tolerance and jointly accept the truth of $P(b)$, then that will lead to yet another context, in which there is a commitment that b now also belongs to the positive extension of P.

In this way, the interaction between context-dependent truth judgments and the context-modifying commitments that arise when these judgments are expressed and acknowledged as correct will propel contexts and judgments onwards, and to eventual disaster if nothing puts a stop to it. Exactly what the stopping mechanism is, what triggers it, and what this entails for the semantics of tolerance-governed predicates is part of the open question mentioned above.[14]

[14] Soames (2002) describes the dependence of the extensions of vague predicates on context as a form of indexicality. This has been criticized by Stanley (2003) as untenable because soritical situations can be described also in a form like that in (i):

(i) If a_1 is a heap, then a_2 is too, and if a_2 is, then a_3 is, and if a_3 is, then a_4 is, ... and then a_N is.

It is a feature of indexical expressions (such as first or second person pronouns and deictic demonstratives) that they cannot change reference between two occurrences one of which is overt while the other is part of the tacit material that is missing from an ellipsis construction like VP Deletion or Gapping. So if *heap* was indexical in the sense that its extensions were indexically determined, then there could be no relevant change in context between the antecedent of the first conditional in (i) and all the following clauses (each of which is elliptical). Clearly, the context dependence at issue does not follow the principles that, essentially following Kaplan (1989b), are assumed for indexicals. In fact, other contextualist proposals for dealing with vagueness do not make the assumption that the context dependence of vague predicates is a form of Kaplanian indexicality.

Whether and how this might affect the semantics of operators like &, $\rightarrow$, and $\forall$ is still open. For example, should $A \rightarrow B$ now be defined as true in a given context c iff B is true in the context $c + A$ (the context that results when the commitments involved in accepting A are incorporated into c)? Furthermore, there are now also different ways – dynamic as well as static ones – of defining logical consequence. Different ways of settling the semantics of the operators and of defining the consequence relation can be expected to yield different logics, with different implications for our assessment of classical formulations of the Sorites paradox such as (8) or (9). A proper exploration of the various possibilities is not possible within the spatial limits of this survey. For some of the options, see Kamp (1981a) and Shapiro (2006).

We conclude this subsection by repeating and stressing its main methodological point. Whether and how logical operators are to be reinterpreted in the presence of tolerance-governed predicates must be clearly distinguished from the contextualist claim that the dynamic context dependence of such predicates is responsible for the paradoxical aspects of forced march conversations. We need an account of what happens in such situations, and why, irrespective of what we then go on to say about Sorites arguments.

Non-dynamic contextualist accounts

Not all contextualist approaches to the Sorites are dynamic. There is another group of proposals that is based on a combination of the following two linguistic phenomena. The first is most often observed in connection with nouns, though it seems applicable to predicates of natural language more generally: a noun typically contributes to the noun phrase of which it is the head not just its own, context-independent extension, but a restriction of that extension, which is obtained by intersecting it with a set that can be recovered from context (see Section 14.2).

The second phenomenon is that the contextual restriction imposed on a particular use of a tolerance-governed predicate P can render it immune to forced marches because the restricted application domain contains gaps which exceed the "span" of the tolerance relation $\sim_P$ that governs P: that is, the application domain of the predicate can be divided into two parts, P_1 and P_2, so that (i) the positive extension of P is included in P_1, (ii) the negative extension of P is included in P_2, and (iii) no member of P_1 stands in the relation $\sim_P$ to any member of P_2. Let us call such gaps *tolerance-trumping gaps* (*for* a given predicate P with tolerance relation $\sim_P$).

The central goal of the proposals that exploit gaps is more modest than that of the contextualist responses to the Sorites discussed above. Rather than trying to make sense of uses of vague tolerance-governed predicates in forced march situations, these proposals are aimed primarily at safeguarding uses in which the dangers connected with forced marches are blocked by the presence of a tolerance-trumping gap (thus countering the global pessimism of Dummett (1975b), which seems to declare the very notion of observational and other tolerance-governed predicates as incoherent).[15]

A recent proposal of this sort is that of Pagin (2010a,b). Pagin introduces the notion of a **central gap**. The assumption here is that the context in which a tolerance-governed predicate *P* is used must select one of the gaps in the actual (contextually restricted) application domain of *P* as "central gap" and that the borderline between the (actual, contextually restricted) positive and negative extensions of *P* runs through this gap. In situations with no tolerance-trumping gap in the contextually determined application domain of *P*, there is no central gap for the context to select. In such cases the use of *P* is unwarranted. These cases are beyond the proposal's reach.[16]

One of the apparent consequences of this proposal is that it declares as incoherent even those uses of a tolerance-governed predicate *P*, in which the application domain of *P* does contain one or more Sorites series, but where the use of *P* remains very local, thereby avoiding the pitfalls connected with those series. Suppose, for instance, that I produce a clearly red color chip and you describe it as red. Is your description of the chip to be considered incoherent just because it belongs to an actual Sorites series? For instance, I could have the other chips of such a series in my pocket, but you do not know that, and I never produce them or refer to them, so they never become part of the topic of conversation.

Perhaps an advocate of Pagin's proposal would argue that so long as I do nothing to bring the other chips into play, this Sorites series is not part of *red*'s application domain in the context of our exchange. But then what happens to the application domain when I do produce the other chips? If this does change the application domain, and with it the context that is supposed to determine it, then what happens in the course of a conversation can apparently change the context. And that gets us back to the dynamic dimension of the context dependence of vague predicates, something that the appeal to tolerance-trumping gaps in stating the semantics of Sorites-prone predicates may have been intended to obviate.

14.3.3 Denying the validity of Sorites arguments: changing the logic via multi-valued truth or multiple notions of truth

In this section, we look at a few proposals for dealing with the Sorites paradox by adopting a logic in which Sorites arguments are no longer valid. In

[15] Wright (1975) can be read as largely endorsing Dummett's position, but in later work he stresses that such a radically skeptical position flies in the face of the fact that speakers do make use of tolerance-governed predicates successfully in expressing information and communicating it, and the task of semantic theory is to account for this (Wright, 1987).

[16] Earlier proposals in a similar spirit are Manor (2006) and Gaifman (2010). These differ from Pagin's (2010a,b) proposal in that they do make provisions for uses of *P* in which the assumption of a tolerance-trumping gap is not satisfied. For Manor, all sentences containing *P* are false in such situations. Gaifman assumes that in such sitations *P* behaves as a sharp predicate. These assumptions may have certain technical advantages, but it is not easy to see a plausible linguistic motivation for them.

each of these, the change in logic is the result of a revision of the classical semantics of one or more of the operators of first order logic. We have already mentioned a few such proposals in passing, but without providing any details. In what follows, we look at some further proposals of this kind. We will consider two ways in which such logics can be characterized, that of **multi-valued semantics**, in which use is made of more than two truth values, and that of introducing several **notions of truth** and combining these in definitions of logical validity.

Multiple truth values

Many model theories for alternative vagueness logics work with more than two truth values. However, as far as known to us, the systems of multi-valued semantics that have been discussed in connection with vagueness are all conservative with respect to classical two-valued semantics in the sense that if all atomic constituents of a complex sentence φ have values from the set $\{0, 1\}$ (i.e., from the set consisting of falsity and truth) then φ has the value that we would obtain if we evaluated φ in a two-valued model.

Multi-valued semantics offers flexibility for defining consequence relations at two levels. First, additional truth values create room for new definitions of the logical operators, and, second, the possibility for defining logical consequence as necessary preservation of truth can now be varied by allowing for different sets of "designated truth values": for any proper non-empty subset T of the truth value space, we can define logical consequence as preservation of having some truth value or other within T.

In the spirit of our remarks about conservativity of multi-valued model theories, it is natural to require that 1 must belong to T and that 0 must not. But even then there exists the possibility for more than one definition of the consequence relation even when the total number of truth values is just three. An illustration of this is implicit in Section 14.3.2, at the part devoted to Subvaluationism. There it was observed that the Subvaluationist semantics can be set up as a three-valued system. Moreover, this set-up can be used to reformulate the partial semantics that we made use of to present the Supervaluationist approach. When that is done, then, as far as the semantics is concerned, the only differences that remain between Subvaluationism and Supervaluationism are conceptual. However, a difference returns when this semantics is used to define a relation of logical consequence. When logical consequence is defined as preservation of truth in partial models, then the resulting logic is Strong Kleene; if consequence is defined as converse preservation of falsity – B is a logical consequence of Γ iff in each partial model in which B is false, at least one of the sentences in Γ is false – then the logic is LP.

Another way to obtain these same two logics within the three-valued setting is to fix the definition of logical consequence as preservation of designated values while varying the set T of those values: if T is chosen to be the singleton set $\{1\}$, the resulting logic is Strong Kleene; if T is chosen to be $\{1, (1, 0)\}$ (where as before $(1, 0)$ is the third value), then the resulting logic is LP. With larger truth value sets, the range of possible logics rapidly increases.

Fuzzy Logic

A very different kind of multi-valued semantics and logic is Fuzzy Logic (Zadeh, 1965). The truth value space of Fuzzy Logic is the closed interval $[0, 1]$ of real numbers. The basic intuition is that the numbers in this interval represent degrees of truth, with 1 representing the maximum degree of complete, unequivocal truth and 0 representing the minimal degree of total, unequivocal falsity. The sense in which these numbers are to be thought of as degrees is visible from Zadeh's truth value rules for negation, conjunction, and disjunction.

(18) a. The complement rule for $\neg$: $[\![\neg p]\!]_t = 1 - [\![p]\!]_t$.
b. The minimal-degree rule for $\wedge$: $[\![p \wedge q]\!]_t = \min([\![p]\!]_t, [\![q]\!]_t)$.
c. The maximal-degree rule for $\vee$: $[\![p \vee q]\!]_t = \max([\![p]\!]_t, [\![q]\!]_t)$.

The clauses (18b) and (18c) indicate that Fuzzy values are not meant to be probabilities. One way to see this is to assume that p has the value 0.5. Then $\neg p$ also has the value 0.5. However, then it follows from (18b) that $[\![p \wedge p]\!] = [\![p \wedge \neg p]\!] = 0.5$ and from (18c) that $[\![p \vee p]\!] = [\![p \vee \neg p]\!] = 0.5$. In probability logic, these results would be wrong: $[\![p \wedge p]\!]$ and $[\![p \vee p]\!]$ should be 0.5 if $[\![p]\!] = 0.5$, but $[\![p \wedge \neg p]\!]$ should be 0 and $[\![p \vee \neg p]\!]$ should be 1. In fact, these results point toward a deeper and more general problem. There is a strong intuition that $p \wedge p$ and $p \vee p$ should get the same truth value as p – as far as that is concerned, the predications made by (18b) and (18c) are right. But when the arguments of $\wedge$ and $\vee$ are distinct from each other, then, one cannot help feeling the degree of truth of their conjunction or disjunction depends on more than just the truth degrees of the conjuncts or disjuncts. For instance, if the conjuncts are mutually exclusive (in the way that for instance p and $\neg p$ are), then their conjunction should get the value of absolute falsity, i.e., 0. No definition for conjunction, as a function from the truth degrees of p and q to the truth degree of $p \wedge q$, can meet all these requirements, because the truth degrees of p and q have next to nothing to say about any logical connections between them. The same problem arises for disjunction.

Fuzzy Logic has made a virtue of this impossibility, of defining binary connectives as degree functions in such a way that all the mentioned desiderata are met, by simply setting these qualms aside and introducing various degree-based connectives for special purposes, often in the context of particular applications. In a sense this is also true of the application of Fuzzy Logic to the Sorites paradox (Goguen, 1969). One analysis of arguments like

(8) and (9) makes use of the following Fuzzy definition of the conditional connective $\rightarrow$:

(19) $[\![A \rightarrow B]\!] = \min(1, 1 - ([\![A]\!] - [\![B]\!]))$

Suppose that $a_1, \ldots, a_N$ form a Sorites series and that $[\![.]\!]$ is a Fuzzy valuation of the atomic sentences of $\mathcal{L}$, which is a monotonically descending function on the series of sentences $P(a_1), P(a_2), \ldots, P(a_N)$ in the sense that if $i < j$, then $[\![P(a_j)]\!] \leq [\![P(a_i)]\!]$, but in which the difference between any two successive elements in this series is small. That is, there is some small number $\epsilon > 0$ such that for all $i = 1, \ldots, N-1$, $[\![P(a_i)]\!] - [\![P(a_i+1)]\!] \leq \epsilon$. Then, with (19) as clause for $\rightarrow$, for all $i = 1, \ldots, N-1$, $[\![(P(a_i) \rightarrow P(a_i+1))]\!] = \min(1, 1 - ([\![P(a_i)]\!] - [\![P(a_i+1)]\!])) \geq 1 - \epsilon$. So according to such a valuation, the Conditional Premises in (9) will all have a high degree of truth – not that of absolute truth perhaps, but certainly a value close to that. Since the first premise is supposed to be unequivocally true and the conclusion unequivocally false, we may assume that $[\![(P(a_1)]\!] = 1$ and $[\![(P(a_N)]\!] = 0$. This means that in this interpretation all the premises have a value close to truth, whereas the conclusion is plain false. That may not be quite as dramatic as when the conclusion is unequivocally false while all the premises unequivocally true. However, it is still a reason why (9) should not be logically valid. So what does Fuzzy Logic have to say to that? The matter turns on the status of *Modus Ponens*.

In Fuzzy Logic, there is an aspect to MP and other inference rules that does not come up in other logical systems. Here the "validity" of an inference rule can be a matter of degree too. When the degrees of A and $A \rightarrow B$ are less than 1, then the degree of B can be less than both of those degrees. Because of this, repeated applications of MP to premises with degrees less than 1 may reduce the trustworthiness of a deduction step by step, so that in the end no constraints on the degree of truth of the conclusion are left. And that is what happens when MP is applied to the premises of (9) as many times as is needed to arrive at the conclusion $(P(a_N))$. The same considerations apply to arguments of the form (8).

Fuzzy Logic thus adds a distinctive new element to the explanation of the apparent soundness and actual unsoundness of Sorites arguments: Arguments proceeding from less than perfectly true premises may gradually deteriorate so that eventually they will provide no support for the conclusions reached. (Note too that classical axioms and rules are verified by the truth definition of Fuzzy Logic, so long as we restrict attention to the extreme degrees 0 and 1.)

There are two aspects to the general set-up of Fuzzy Logic and its application to vagueness, however, that can be seen as problematic. The first is the problem we already mentioned about defining the semantics of connectives as functions from and to degrees of truth. That problem arises for conditionals as well: Suppose that the degree of A is 0.5. What should then be the value of "if A then A" and of "if A then not A"? What justification is there for insisting that these values must be the same; and how plausible is a clause like (19) in the light of these considerations? The second problem concerns the actual numerical values of the degrees of atomic sentences of the form $P(a)$. For these sentences the truth degree clearly derives from the degree to which the argument term satisfies the predicate. However, what can be said about the numerical values of the satisfaction degrees of vague predicates?

This of course is an issue that does not just arise for Fuzzy Logic. It arises just as much for a probabilistic semantics, in which truth and satisfaction are replaced by probabilities.[17] In neither case is the impossibility of assessing values very precisely necessarily a serious objection. Exact degree values do not matter when it comes to articulating and justifying the general principles of Fuzzy Logic. Here certain assumptions about relations between the truth degrees of different sentences will suffice. Moreover, even in discussions of particular valuations that reflect our intuitions about Sorites scenarios, rough estimates of degrees are often all that is needed, as we did above where we used the parameters ϵ and δ for "small numbers > 0".

Fuzzy Logic was the first framework to offer a degree-based account of Sorites problems, but subsequently there have been a number of other degree-based proposals that start from somewhat different conceptual assumptions. Prominent have been approaches that assume a close connection between the satisfaction degrees of vague predicates and degrees of belief, or "credences" (Edgington, 1995a, 1996; Smith, 2008). These approaches would deserve a discussion in their own right, but for reasons of space we refrain from doing so here.

Multiple notions of truth

A comparatively recent approach to the semantics and logic of vagueness is that of Cobreros et al. (2012a,b). These authors define three notions of truth for sentences containing tolerance-governed predicates. They do this on the basis of a largely traditional model theory, in which models assign complete extensions to a tolerance-governed predicate P but contain, in addition, (sharp) extensions for the tolerance relation $\sim_P$; Cobreros et al. refer to such models as "T-models". In a T-model $\mathcal{M}$ (i) $P(a)$ is *classically true* iff $a \in [\![P]\!]_{\mathcal{M}}$ (the extension of P in $\mathcal{M}$), (ii) $P(a)$ is *tolerantly true* iff there is some b such that $b \sim_P a$ and $b \in [\![P]\!]_{\mathcal{M}}$, and (iii) $P(a)$ is *strictly true* iff for all $b \in [\![P]\!]_{\mathcal{M}}$ such that $b \sim_P a$, $b \in [\![P]\!]_{\mathcal{M}}$. These three notions of truth can then be extended to all sentences of the language $\mathcal{L}$ by a simultaneous recursion.[18] The authors show that a number of familiar logics, as well as some novel ones, can

[17] Kamp (1975) offers a probabilistic reinterpretation of truth degrees as probabilities.

[18] Simultaneous in that the strict truth of $\neg\varphi$ is defined in terms of the tolerant truth of φ and the tolerant truth of $\neg\varphi$ in terms of the strict truth of φ. For the "positive" operators &, $\vee$, $\exists$, and $\forall$, tolerant truth of the compound is defined in terms of the tolerant truth of its immediate constituents and strict truth in terms of their strict truth. The truth clause for the conditional $\varphi \rightarrow \psi$ is the one we obtain by identifying $\varphi \rightarrow \psi$ with $\neg\varphi \vee \psi$; that is, $\varphi \rightarrow \psi$ is tolerantly true iff either φ is strictly false or ψ is tolerantly true; and $\varphi \rightarrow \psi$ is strictly true iff φ is tolerantly false or ψ is strictly true.

be obtained by means of the standard definition of logical consequence, repeated in (20), by (independently) varying the interpretation of *true* in the antecedent and consequent of the conditional in the definiens.

(20) B is a *logical consequence* of Γ iff for every model $\mathcal{M}$, if all A in Γ are true in $\mathcal{M}$, then B is true.

When the two occurrences of *true* are interpreted in the same way, the logics are (more or less) identical to logics that we have already mentioned. On the classical interpretation of both occurrences of *true* the result is, obviously, Classical Logic; if both occurrences are interpreted as "strictly true", we get Strong Kleene; and if both are interpreted as tolerant truth, we get the Logic of Paradox LP.[19]

Here are some of the things that can be said about forced march situations and soritical reasoning in this setting. Let $\mathcal{M}$ be a T-model which describes a Sorites situation involving a tolerance-governed predicate P and a Sorites series $a_1, \ldots, a_N$ for P. Let us assume that the extension of the tolerance relation $\sim_P$ in $\mathcal{M}$ consists merely of the identity relation on the Universe of $\mathcal{M}$ together with the pairs $\langle a_i, a_{i+1}\rangle$ and $\langle a_{i+1}, a_i\rangle$ for $i = 1, \ldots, N-1$. In $\mathcal{M}$ each of the conditionals $P(a_i) \rightarrow P(a_{i+1})$ will be tolerantly true; but one conditional – the one for which i is such that $a_i \in [\![P]\!]_{\mathcal{M}}$ and $a_{i+1} \notin [\![P]\!]_{\mathcal{M}}$ – will be classically false; and both this conditional and the next one, $P(a_{i+1}) \rightarrow P(a_{i+2})$, will be strictly false.[20] Furthermore, we assume that $P(a_1)$ is strictly (and thus classically and tolerantly) true in $\mathcal{M}$ (which entails that $a_2 \in [\![P]\!]_{\mathcal{M}}$) and that $P(a_N)$ is strictly (and thus classically and tolerantly) false (which entails that $a_{N-1} \notin [\![P]\!]_{\mathcal{M}}$).

As far as soritical reasoning is concerned, first consider the logic $\models^{tt}$ obtained by interpreting both occurrences of *true* in (20) as "tolerantly true". For this logic, *Modus Ponens* is not valid. This has to do with the fact that a conditional $A \rightarrow B$ is tolerantly true iff either A is strictly false or B is tolerantly true. Again, let $\mathcal{M}$ be a model in which the line between the positive and the negative extension of P in $\mathcal{M}$ runs between a_i and a_{i+1}. Then $P(a_{i+1})$ will be tolerantly true because of the fact that $a_i \sim_P a_{i+1}$ holds in $\mathcal{M}$ while a_i belongs to the extension of P. But $P(a_{i+1})$ is strictly false because $a_{i+1} \sim_P a_{i+1}$ and a_{i+1} does not belong to the extension of P; and because of this $P(a_{i+1}) \rightarrow P(a_{i+2})$ is also tolerantly true. But $P(a_{i+2})$ is not tolerantly true, since none of the entities that are $\sim_P$ – related to a_{i+2} — a_{i+1}, a_{i+2}, and a_{i+3} – belongs to the extension of P. This refutes MP for $\models^{tt}$ and by implication for the weaker logics $\models^{tc}$ and $\models^{ts}$, in which the second occurrence of *true* in (20) is interpreted as "classically true" and "strictly true", respectively.

[19] The qualifier *more or less* indicates that the statement in the text may have to be qualified if the language includes the identity symbol $=$ as well as a relation symbol to denote the tolerance relation.

[20] To see that $P(a_i) \rightarrow P(a_{i+1})$ is not strictly true, consult the truth conditions for $\varphi \rightarrow \psi$ in footnote 18 and observe (a) that since $P(a_i)$ is classically true, it cannot be tolerantly false and (b) that since $P(a_{i+1})$ is classically false, it cannot be strictly true.

For the logic $\models^{ss}$ on the other hand MP is valid, and by implication the same is true for the stronger logics $\models^{sc}$ and $\models^{st}$.[21] So the argument in (9) can be verified by a valid deduction in those logics. But for these logics the response to the Sorites paradox is, once again, that in models describing Sorites situations not all the premises are strictly true.

These observations are meant to give a first impression of the range of options that the multiple-notions-of-truth approach makes available. Remarkable about this approach when compared with the other approaches reviewed in this section is the diversity of responses to the Sorites that it covers. Depending on what option is chosen, the resolution of the Sorites involves the verdict either that some premise of the Sorites arguments cannot be (jointly) true or else that the logic that comes with the given option does not support the inference principles needed to derive the conclusions of Sorites arguments from their premises.

That the multiple-notions-of-truth approach offers such a variety of possible responses to the Sorites could be seen as an advantage that it has over the approaches discussed earlier. However, there is arguably also a downside to this. More than any of the other approaches we have considered, this one leaves us with an *embarras du choix*: Which of all the different options on offer with this approach is the right one is a question that cannot be avoided.[22]

14.4 Vagueness and grammar: additional challenges

Any theory of vagueness will ultimately have to answer the following questions:

1. What are the connections between vagueness and morphological gradability?
2. What are the connections between vagueness and imprecision?
3. What are the consequences of vagueness for the architecture of grammar?

Let us discuss these issues one by one.

14.4.1 Gradability

There is a strong and widespread intuition that vagueness is connected with gradability. We encountered this idea in the discussion of Fuzzy Logic

[21] Suppose that A and $A \rightarrow B$ are both strictly true. For $A \rightarrow B$ to be strictly true, it must be that either A is tolerantly false or B is strictly true. But if A is strictly true then A is not tolerantly false. So the strict truth of A and $A \rightarrow B$ entails the strict truth of B.

[22] Cobreros et al. (2012b, 2015) elect one specific consequence relation as the right candidate, namely strict-to-tolerant (st) consequence, on several grounds (including, for example, validation of tolerance, together with maximum preservation of classical inferences, except for the meta-inferential property of transitivity).

in Section 14.3.3: What makes a predicate vague is that its satisfaction conditions are not black and white but allow for shades of grey; an entity *a* can satisfy a vague predicate *P* to various extents, or various *degrees*, with perfect satisfaction at one end of the spectrum and complete non-satisfaction at the other. So far we have said little about what justifies such intuitions – we looked at only the implications of assuming graded satisfaction for an account of the Sorites. In fact, for all that has been said so far, justification for this assumption might vary from one type of vague predicate to the next (to the extent that a justification can be given at all).

Relative adjectives connected with measuring procedures

There is one category of vague predicates for which the notion of graded satisfaction conditions has very strong and unequivocal support, and some of these predicates have been prominent in the preceding sections. These are relative adjectives that have a direct connection with measuring procedures, such as *tall*, *long*, *short* (all connected with the procedures for measuring length), *heavy*, *light* (connected with the procedures for measuring weight), *late* (connected with the procedures for measuring time), or *hot* and *cold* (connected with the procedures for measuring temperature).

Measurement of physical magnitudes is a complex topic, with significantly different stories for the different measurable magnitudes,[23] but for purposes of linguistic analysis many of the details do not matter. So we follow the literature on adjectives in simply assuming that with these magnitudes, and with the adjectives that English and other natural languages use to refer to them, are associated *measure functions* f_M, which assign to each entity that can be assessed for the given magnitude M a certain value. We assume that when an adjective is connected with a given magnitude M (in the sense in which *tall* and *short* are connected with the magnitude of length), then the application domain of the adjective consists of those entities that can be assessed for the connected magnitude M. Thus, the application domains of *tall* and *short* both coincide with the domain of the function f_{length}.

A standard assumption about physical measurement is that functions f_M assign real numbers modulo some *unit of measurement*. Any entity within the domain of the magnitude can be chosen as unit of measurement for that magnitude. Choosing it means that this entity, and all those for which the measurement function returns the same result, are assigned the number 1 and all other entities a number corresponding to this assignment of 1.[24] For some magnitudes, mostly those that play an important role in our daily lives, more than one unit is in actual use, in large part for the purpose

[23] For a general discussion of the mathematical properties of measurement, see Krantz et al. (1971a,b,c).

[24] The correspondences are fixed because each of the physical magnitudes in question has the property that the measure procedures for it reflect proportional relations between the values assigned to different entities. Such scales with fixed proportions are known as ratio scales (Krantz et al., 1971a); but see Sassoon (2013b) for linguistic evidence against ratio scale representations in some of these adjectives.

of keeping numerical values within a range with which most of us are conversant (e.g., so that we do not have to deal with very large numbers of millimetres or very small numbers of kilometres). However, for the present discussion this variation is of no consequence. So we assume that one unit of measurement is given as part of the measure function f_M and thus that the values assigned by f_M are positive real numbers.[25]

For adjectives A that have a measure function f_A connected with them, there is a very simple answer to a question that we have hardly touched upon so far, namely the semantics of *comparatives*. In many languages, comparatives are expressed with the help of special morphology that is combined with the morphologically simple form of an adjective. English has the suffix *-er* to form the comparatives of simple, monosyllabic adjectives, e.g., *tall*, *short*, *smart* as well as a few polysyllabic ones, e.g., *heavy*, while the comparatives of all other adjectives are formed with the help of the modifier *more* (e.g., *more intelligent*, *more educated*). In other languages the details of comparative morphology differ. But a cross-linguistic generalization with few exceptions is that comparative forms are morphologically more complex than the so-called positive forms. This fact suggests that the comparative is more complex than the positive semantically as well as morphologically and that it can be obtained from the positive by application of a certain operator -ER, which English expresses either as *-er* or as *more* (Klein, 1991; Bobaljik, 2012).[26] How can we account for this?

Here is the simple answer: Assume that the basic meaning of an adjective A connected with a measurement procedure simply is the associated measure function f_A (see Venneman and Bartsch, 1972; Kennedy, 1999, 2007b). Then the semantics of the comparative form of A (to which for simplicity we will refer as "A-ER" irrespective of the form of A) can be given as in (21).

(21) A-ER(a, b) (paraphrase: "a is A-er than b") iff $f_A(a) > f_A(b)$

Example (21) is appealing for several reasons: It is simple, it is pretty obviously right, and it conforms to the intuition that the semantics of the comparative of an adjective is derived from its basic meaning. However, it leaves us with one question and one problem. The problem is that there is only a handful of adjectives that have a measure function associated with them. The vast majority of adjectives that allow for the formation of comparatives

25 In the standard degree approach (see Venneman and Bartsch, 1972; von Stechow, 1984a,b; Kennedy, 1999, 2007b; Heim, 2000; Fox and Hackle, 2006; Landman, 2010; Beck, 2011; Solt, 2015a, and references therein), the set of degrees is not equated with the set of real numbers but is assumed to be isomorphic to it. It is thought of as dense, continuous, linearly ordered and supporting operations of addition, substruction, and scalar multiplication (von Stechow, 1984a,b).

26 The traditional morphological analysis of adjectives distinguishes three forms: positive, comparative, and superlative. There appears to be general agreement that the superlative can be semantically derived from the comparative. That is not to say, however, that all questions about superlatives have been answered once an analysis of the comparatives is in place (see Teodorescu, 2009, and references therein). However, in this section we focus exclusively on the latter.

do not, and for all of those the story about their comparatives must therefore be a different one. But before we turn to the problem, we first consider what f_A tell us about those uses of A in which it appears in its simplest form, that is, in its positive uses.

The following answer is typically given within the degree approach (see Kennedy, 1999, 2007b). We must distinguish between the adjective as lexical item and the use of its positive form, just as we have already distinguished between the lexical item and its comparative use. In the case of the positive, this distinction may be less obvious, since morphologically the positive cannot be distinguished from the lexical item as such (any more than, say, the first person singular present tense form *walk* can be distinguished from the way we identify the lexical verb *walk*; but this analogy can be seen as a warning against taking sameness of surface morphology at face value (see Fox, 2003)). Once the distinction between the adjective as such and its positive form is accepted, the task one faces is to provide a semantics of the Positive as an operator POS which transforms the basic meaning of an adjective A, f_A, into the meaning POS(A) of its positive form.

But what could the semantics of POS be? Kennedy (2007b) argues that the semantics of the positive form sets a threshold (standard) for satisfaction, with the stipulation that an entity satisfies the adjective's positive form only when it exceeds that standard to a significant extent. Thus, in effect, this approach appeals to two ways in which the satisfaction conditions of adjectival positives depend on context. First, the context c determines a *standard of comparison* st_c, and second, it determines a *significance margin* ϵ_c. Assuming that the lexical semantics of A is given by f_A, both st_c and ϵ_c must be real numbers; and the satisfaction condition for POS(A) can then be given as in (22).

(22) $\mathrm{POS}(A)(a)$ (paraphrase: "a is A") iff $f_A(a) > \mathrm{st}_{A,c} + \epsilon_{A,c}$

The, context-dependent, parameter st_c in (22) renders the positive uses of relative adjectives sensitive to the class of objects that is being talked about, within which the adjective is meant to make a significant cut. The parameter ϵ_c establishes a significance margin. For a motivation of these parameters, see, e.g., Kennedy (2007b) and van Rooij (2011a). A large amount of literature is devoted to the question of how these parameters are determined (Rips and Turnbull, 1980; Fara, 2000; Rotstein and Winter, 2004; Kennedy and McNally, 2005a; Syrett, 2007; Schmidt et al., 2009; Lassiter, 2011b; McNally, 2011; Toledo and Sassoon, 2011; Solt, 2012, 2015a; Solt and Gotzner, 2012; Lassiter and Goodman, 2013). There are various factors that influence their setting. For instance, the determination of $\epsilon_{A,c}$ has been claimed to be affected by the interests and desires of the discourse participants (Fara, 2000; Kennedy, 2007b).

We conclude the present section with two questions. First, how can a gradable notion of satisfaction be generalized to adjectives for which no obvious measurement procedures exist? The second question relates to vagueness.

The predicate *tall* and likewise compound predicates like *tall man*, *tall basketball player*, *tall six-year-old*, or *tall building* are generally perceived as vague even when they are used in contexts that are fully transparent to the interpreter. How can that intuition be squared with the condition in (22)? The only possibility, it would seem, is to assume that typical contexts, and perhaps all contexts, do not determine the standard and/or significance margin for *tall* completely, but only constrain it within certain limits, and that that is so not only when *tall* occurs on its own but also in adjective–noun combinations like *tall man* or *tall building*.

Relative adjectives without measurement functions

The main problem with the proposal of the last section is that, as we noted, there is only a fairly small set of adjectives that are straightforwardly associated with measure functions (such as f_{length}). Most adjectives, including those with grammatical comparatives, have no such semantic foundation.

Attempts to address this question go back to the early history of the theory of vagueness. Kamp (1975) noted that a supervaluation treatment of vagueness creates room for the definition of degrees of satisfaction as "probability measures" over the space of all admissible precisifications of a given ground model. But the paper described this merely as a formal possibility; hardly anything was said about which probability measures among the uncountably many that are formally possible capture the actual semantics of particular predicates (for a promising recent development in this direction, however, see Douven et al., 2013; Decock and Douven, 2014).

Another point in Kamp (1975) is that when an adjective occurs prenominally, then the context in which it is to be interpreted will be determined, wholly or largely, by the noun that follows it. This suggestion was part of the endeavor of that paper to analyze prenominal occurrences of adjectives as vague predicates whose interpretation shows a strong dependence on the context provided by the following noun, rather than as functors operating on the nouns they precede, as proposed in Montague (1970a) and other publications from that time. This idea can also be used as the starting point for a definition of satisfaction degrees, but here the story is a good deal more indirect. What follows is an outline of how this story goes.

Klein (1980) makes an explicit proposal for how the nouns preceded by prenominal occurrences of adjectives determine their extensions. The central idea of the proposal is that of a *Comparison Class*. Relative adjectives like *tall*, *heavy*, *impressive*, or *trustworthy*, Klein assumes, are typically interpreted in the context of some class X, consisting of entities that are conceived as possible candidates for the application of the adjective. The point of using such an adjective A in the context provided by X is typically to make a meaningful distinction within X, in the sense that both the set of entities in X that satisfy A and the set of entities in X that do not satisfy A are substantial portions of X. Klein captures this intuition by putting the central idea of Supervaluationism, namely that a vague predicate partitions its application domain into positive extension, negative extension, and truth value gap, to a new use. In this use, it is the given comparison class X that plays the part that was ascribed in Section 14.3 to the application domain of A, and the semantics of A is given by the way in which A partitions different "application domains". That is, it takes the form of a function g_A that assigns to each non-empty set X of entities to which the adjective is applicable in principle, a partition into one, two, or three subsets.[27]

In other words, $g_A(X)$ is of one of three following forms: (i) X or (ii) $\langle X^+, X^- \rangle$ or (iii) $\langle X^+, X^?, X^- \rangle$ (where the sets X, X^+, X^-, $X^?$ are non-empty). The function g_A from comparison classes X to extensions provides information about a reflexive partial order relation $\leq_A$ on the set X: in case $g_A(X) = X$, all elements of X stand in the relation $\geq_A$ to each other in both directions (so $\geq_A$ is the universal relation on X); in the other two cases – $g_A(X) = \langle X^+, X^- \rangle$ and $g_A(X) = \langle X^+, X^?, X^- \rangle$ – the information about $\geq_A$ is that for each $x \in X^+$ and $x' \in X^-$, $x \geq_A x'$ and not $x' \geq_A x$.[28] As made fully explicit in van Benthem (1982), natural assumptions about how the values $g_A(X)$ are related to each other for different classes X guarantee that the relation $>_A$ (defined by: $x >_A x'$ iff $x \geq_A x'$ & $\neg x' \geq_A x$) is a strict weak order. This means that for any comparison class X, the relation $\approx_{A,X}$ as defined in (23) is an equivalence relation and a congruence relation with respect to $\geq_A$.[29]

(23) For all $x, x' \in X$, $x \approx_{A,X} x'$ iff $x \geq_A x'$ & $x' \geq_A x$.

Thus, if the relation $>_A$ is used to give the semantics of A-ER, the comparative of A, as in (24), then, modulo van Benthem's assumptions, A-ER will denote a strict weak order as well.

(24) For all a, b in the application domain X_A of A, A-ER(a, b) iff $a >_A b$.

We can make this characterization look even more like (21) by introducing an abstract notion of "degree of satisfaction of A". That is, we define the *satisfaction degrees* for A on X as the equivalence classes, $[x]$, generated on X by the relation $\approx_{A,X}$ (such that $[x]_{\approx_{A,X}} = \{x' \in X \mid x \approx_{A,X} x'\}$). Since $\approx_{A,X}$ is a congruence relation with respect to $>_A$, the relation $>'_A$ defined in (25) is properly defined, and it is a strict linear order on the set $\{[x]_{\approx_{A,X}} \mid x \in X\}$ of satisfaction degrees for A on X (see Cresswell, 1976). Thus, we can restate (24) as (26), taking the comparison class X to be the application domain X_A of A, and writing "$\mathrm{Deg}_A(a)$" for "$[a]_{\approx_{A,X_A}}$" in case $a \in X_A$.

(25) For all $x, x' \in X$, $[x]_{\approx_{A,X}} >'_A [x']_{\approx_{A,X}}$ iff $x >_A x'$.

27 This is a simplification of the analysis that Klein (1980) actually presents, which considers the possibility of multiple criteria for adjectives such as, e.g., *clever*.

28 The cases in which the "division" leads to a single set X do not play any direct role in Klein's proposal. Nonetheless, to capture several cases, such as comparison classes of equally tall entities, the formulation has to include them (see Landman, 2005).

29 The equivalence relation R is a *congruence relation* with respect to the binary relation S iff for all x, y such that xRy, if ySz then xSz and if zSy then zSx.

(26) For all a, b in the application domain X_A of A: A-ER(a, b) iff $\text{Deg}_A(a) >'_A \text{Deg}_A(b)$.

The only difference that remains between (26) and (21) is that in (21) the degrees $f_A(.)$ are real numbers, while the degrees $\text{Deg}_A(.)$ in (26) are equivalence classes (sets of entities which are equally A). We could make this look like a perfect similarity by restating (21) also in terms of equivalence classes. In this case, the equivalence classes are those generated by the relation $\equiv_A$, defined by: $a \equiv_A b$ iff $f_A(a) = f_A(b)$ and the linear order $>''$ between them is given by: $[a]_{\equiv_A} >''_A [b]_{\equiv_A}$ iff $f_A(a) > f_A(b)$ (see Bale, 2011). But of course that is little more than cosmetics.

There are three morals we want to draw from the Klein–van Benthem proposal. The first is that a partial semantics for vague predicates in the spirit of Supervaluationism can be used as the basis for the semantics of the comparatives of adjectival predicates. All that is needed is to exploit the idea that adjectives are vague predicates which are context-dependent in the sense that their ability to partition their application domain varies as a function of the way that domain is determined in any given context through the restrictions that the context imposes on it. In this sense, the ordering relations used to interpret comparatives can be seen as emerging from an underlying capacity on the part of the adjective to partition different application domains in different but structurally connected ways. And note that this capacity is the very same that Supervaluationism appeals to in its account of the vagueness of the positive use of adjectives. The difference between Supervaluationism and Klein–van Benthem is that Supervaluationism does not exploit the *connections between* the ways in which such vague predicates partition *different* possible application domains.

The second moral concerns the notion of degree. It is a trivial and long familiar fact from the theory of relations that ordering relations with the right properties allow the definition of equivalence relations that are congruence relations with respect to those ordering relations and that these equivalence relations can then be used to define "degrees", namely as the equivalence classes they generate. This enables us to see adjectives supported by measure functions – the degree approach's point of departure – as forming a special case of the more general and abstract construction that we have just gone through.

The third moral arises from juxtaposing the first two. When it comes to the question of the status of degrees in the semantics of adjectives, it is important to distinguish between the following sub-questions: (i) Do we need degrees in the semantics of adjectives? (ii) To the extent that degrees are needed or wanted, where do they come from? Do we assume them as primitives – something for which we seem to have good evidence only in those cases in which the semantics of the adjective is rooted in a procedure of measurement – or are they to be defined in terms of something else? And (iii) if degrees have to be justified through definition, in terms of *what* are they supposed to be defined? It is in connection with this last question that the juxtaposition of the first two morals is relevant. A distinction that we believe the literature on vagueness and gradability does not always make as clearly as it should is that between definitions of degrees and definitions of ordering relations. Once we have an ordering relation with the right properties, defining a corresponding notion of degree is, we noted, straightforward. But obtaining an ordering relation out of a plausible characterization of the semantics of certain types of predicates, which doesn't build the order into the definition of the predicate in some obvious way from the start, is a less trivial challenge. However, it is one that we think Klein and van Benthem have met in an interesting way.

Two questions remain when the approaches of this and the previous section are laid side by side. The first has to do with the interpretation of the positive forms of adjectives. We observed at the end of the last section that positives are vague and that this remains true also when the adjective is followed by a noun that provides the intended comparison class. The account of this section provides a marginal improvement on this by imposing the following requirement: In a context c in which the comparison class is the set X, the standard $\mathrm{st}_{A,c}$ must be such that a significant part of X comes out as satisfying the positive of the adjective and some other substantial part as definitely not satisfying it. But at the same time, we are now also faced with a new problem, which has to do with the significance margin $\epsilon_{A,c}$.

In (22) $\mathrm{st}_{A,c}$ and $\epsilon_{A,c}$ were both real numbers, and ϵ_A could be thought of as a significance *interval*. In this present more general setting, it is hard to see the difference between this proposal and one according to which the context determines an interval $(\mathrm{st}^-_{A,c}, \mathrm{st}^+_{A,c})$ such that the positive extension in c consists of those members a of X such that $\mathrm{Deg}_A(a) >_A \mathrm{st}^+_{A,c}$ and the negative extension of those a such that $\mathrm{Deg}_A(a) <_A \mathrm{st}^-_{A,c}$, whereas the truth value gap consists of the remaining members of X (for an analysis of the standard as an interval, see von Stechow, 2009a).

The second question has a more specifically cognitive dimension. Is it right to attribute to adjectives supported by measure functions the role of paradigms for our understanding of adjectival comparatives in general? Do we, as language users, "model" our semantic conception of adjectives that are not supported by measurement "on" those that have such support? One assumption that might be seen as lending support to this view is that even our use of adjectives without associated measure functions reflects some kind of metric on their satisfaction degrees, and not just an ordering relation. Solt and Gotzner's (2012) experimental results suggest that changing the degrees of entities matters (affects the standard), even when the ordering between them is preserved. Perhaps this kind of study can be used to examine adjectives which are not associated with measurement procedures in order to test the generality of the hypothesis that degrees play a fundamental role in their semantics.

Both questions may also be looked at from a somewhat different perspective, in which the definition of degrees as equivalence classes is not warranted. Van Rooij (2011a) has argued that because of tolerance the order $>_A$ an adjective A imposes on its application domain – informally: in the sense that $x_1 >_A x_2$ iff x_1 satisfies A to a higher degree than x_2 – is a semi-order but in general not a weak order.[30] One way to obtain semi-orders is to take a measure function f and a real number ϵ (an "error margin") and to define $>_{f,\epsilon}$ on the domain of f by: $x_1 >_{f,\epsilon} x_2$ iff $f(x_1) > f(x_2) + \epsilon$. In general, $>_{f,\epsilon}$ will then be a semi-order but not a weak order. For a semi-order obtained in this way, the relation $\sim_{f,\epsilon}$ given by: $x_1 \sim_{f,\epsilon} x_2$ iff $\neg(x_1 >_{f,\epsilon} x_2)$ & $\neg(x_2 >_{f,\epsilon} x_1)$ will hold iff $|f(x_2) - f(x_1)| \leq \epsilon$. (This is what justifies calling ϵ the "tolerance margin" for $>_{f,\epsilon}$.)

Suppose that f is the measure function f_A associated with some adjective A. Then we can think of the relation $>_{f_{A,\epsilon}}$ as that of being "significantly A-ER than" and of the relation $\sim_{f_{A,\epsilon}}$ as the tolerance relation for A. (So if A is tall, "$x_1 >_{f_{A,\epsilon}} x_2$" could be paraphrased as "x_1 is significantly taller than x_2" and "$x_1 \sim_{f_{A,\epsilon}} x_2$" as "$x_1$ is neither significantly taller than x_2 nor significantly shorter than x_2".) It is clear from the definition of $\sim_{f,\epsilon}$ that a relation of this form is reflexive and symmetric but (with few, marginal exceptions) not transitive, and thus not an equivalence relation that could be used to define degrees as equivalence classes.

Van Rooij argues that for various aspects of the semantics of an adjective A with associated measure function f_A, the relations $>_{f_{A,\epsilon}}$ and $\sim_{f_{A,\epsilon}}$ are the determining factors. This is so, for instance, for the truth of "x_1 is A as compared with x_2" and also for the truth of "x_1 is A" in a context c in which the standard of comparison st_c is instantiated by an entity x_0 (in which case "x_1 is A" is true in c iff $x_1 >_{f_{A,\epsilon}} x_0$). However, for other semantic functions of A, a semi order $>_{f_{A,\epsilon}}$ and the associated tolerance relation $\sim_{f_{A,\epsilon}}$ will not be enough, and a weak order relation $>_A$ and corresponding equivalence relation $\sim_A$ will be needed instead (as in, e.g., "x is Aer than y"). What properties the relation $>_A$ has will typically depend, however, on the context c, which determines what factors are to be taken as relevant to assessing to what extent an entity satisfies A, and with that determines the "coarse"- or "fine"-grainedness of the comparison between how well two entities x_1 and x_2 satisfy A. In particular, it will generally be possible to move from a context c, in which $>_{A,c}$, the "comparative satisfaction relation for A in c", is a semi-order but not a weak order, to a context c' in which the satisfaction criteria for A are enriched and/or refined in such a way that $>_{A,c'}$ is a weak order. When A is used in a setting in which its semantics presupposes a weak ordering relation and for the given context c $>_A$ is not a weak ordering, then determining the semantic contribution that is made by A to its

[30] A semi-order $>$ is a binary relation which is irreflexive – $\forall x, \neg(x > x)$, satisfies the interval order constraint – $\forall x_1, x_2, x_3, x_4((x_1 > x_2 \ \& \ x_3 > x_4) \to (x_1 > x_4 \vee x_3 > x_2))$, and is semi-transitive – $\forall x_1, x_2, x_3, x_4((x_1 > x_2 \ \& \ x_2 > x_3) \to (x_1 > x_4 \vee x_4 > x_3))$. (Note that irreflexivity and semi-transitivity together entail transitivity.)

sentence may require a more "fine-grained" context c' in which $>_A$ is a weak ordering.

In this discussion of semi-orders and weak orders and of the indifference relations that can be defined in terms of them, we have for the most part been talking about adjectives that have associated measure functions. However, the structural properties of order and indifference relations have been stated in terms that are independent of this assumption; relations with such properties can be induced by adjectives without measure functions too. So what we have said about the role of the relations $>_{f_{A,\epsilon}}$ and $\sim_{f_{A,\epsilon}}$ in shaping the semantics of A can be seen as a sub-case of the more widely applicable notion of a semi-order.

The dynamic interplay between semi-orders (which cannot be used to define degrees as equivalence classes) and weak orders (which can) is important because degrees are often assumed to be indispensible for a compositional account of comparatives and other constructions with a gradable semantics (for a well-developed view of the syntax−semantics interface of these constructions, see Heim's work in, e.g., Heim, 2000, and as reviewed in Beck, 2011; see also Landman, 2010, and others). However, analogous accounts within the comparison class approach have recently emerged as well (see discussion of the syntax−semantic interface in a degree-free account in Doetjes et al., 2010). Instead of using degree variables, these accounts make use of comparison class variables in logical forms (as well as expressions of more complex types involving such variables). As in the degree approach, though, a difference is assumed to exist between the meaning of an adjective (a function from comparison classes to extensions) and the meaning of its positive form. The latter effectively provides a comparison class variable for the adjective to operate on in order to yield a set of entities.

Developmental and cross-linguistic findings (in, e.g., Ravid et al., 2010; Beck et al., 2010; Tribushinina, 2013; Solt, 2015a) make it tempting to think that the coarse-grained interpretations of positive forms are at the bottom of some kind of hierarchy of different morpho-syntactic constructions in which adjectives can appear and get increasingly complex interpretations. However, we have to be careful with such speculations. It may well be that the adult speaker of a language like English, who has mastered all these strategies, has a different semantics for positive adjectives than the child that is on the bottom rung of this developmental ladder. Possibly, it is by climbing the ladder that the language learner arrives at the mature understanding of forms and some different initial understanding is needed to set him off on his ascent.

Absolute adjectives

This section moves on to discuss the difference between relative adjectives, like *tall*, *heavy*, or *smart*, that is, those that were the topic of Section 14.4.1 and (22), and absolute adjectives like *flat* or *wet*. Example (27) reveals some ways in which the latter are judged to behave differently from the former in comparison constructions, but these examples also show that *flat* and *wet* differ from relative adjectives in different ways.[31,32] (27b) shows that, conceptually at least, there is a maximum to the degrees to which something can be flat, and that the positive form *flat* indicates that maximal degree. When something qualifies as flat, then there cannot be anything else that qualifies as flat to an even higher degree. In that sense *flat* is a maximum-criterion absolute adjective. On the other hand, the acceptability of (27a) indicates that *not flat* is not used to describe a maximal degree of non-flatness, presumably because no such maximum is conceptually available. With *wet*, things are the other way around. There is no maximal degree to which a thing can be wet, which is why (27d) is unproblematic. However, *not wet* is absolute and has a maximum criterion: If something is claimed to be not wet, then it is inconsistent to add that something else is even less wet (i.e., that the first thing is wetter than that second thing, see (27c)). The degrees to which things can be wet can be seen as "bound from below", although in this case the bounding degree is not a degree of wetness, but the maximal degree of being not wet, or dry. As shown by the acceptability of both (27e) and (27f), the degrees of a relative adjective like *tall* are bound in neither direction (van Rooij, 2011b).

(27) a. The desk is not flat, but it is flatter than the pavement.
  b. #The pavement is flat, but the desk is flatter.
  c. #The desk is not wet, but it is wetter than the pavement.
  d. The pavement is wet, but the desk is wetter.
  e. Bill is not tall, but he is taller than Mary.
  f. Bill is tall, but Mary is taller.

Adjectives of the type of *flat* are called *total absolute adjectives* and those of the type of *wet* are called *partial absolute adjectives*.

The semantic connection between the positive and the comparative forms of a relative adjective A that we discussed in the last section was this: the relation expressed by the comparative A-ER holds between two objects a and b in the application domain of A iff the A-degree of a is bigger than the A-degree of b (however A-degrees may be defined or construed and barring for now the generalization from weak orders to semi-orders); and in a given context c, a satisfies the positive POS(A) of A iff the A-degree of a equals at least $\mathrm{st}_c(A) + \epsilon_c(A)$ (with $\mathrm{st}_c(A)$ the standard of A in c and $\epsilon_c(A)$ A's significance margin in c). Since relative adjectives involve neither maximal nor minimal standards, there will, conceptually speaking, be, for any context c, both bigger A-degrees and smaller A-degrees than $\mathrm{st}_c(A)$, and the same will be true for $\mathrm{st}_c(A) + \epsilon_c(A)$. For a total adjective A the relation between the positive and

[31] Speakers vary in their judgments regarding the examples in (27), and we are not sure how reliable and widely shared these judgments are.

[32] And recall the examples in (4) of Section 14.2.1, which also show differences between absolute adjectives of the *flat* type and those of the *wet* type.

the comparative forms of A is clearly different. Now the degree scale of A has a maximal element and that, intuitively, is the standard that a should live up to in order to qualify as satisfying POS(A).

It has been stressed, in particular by Unger (1975), that when this is taken literally, it puts the satisfaction level for POS(A) at an impossibly high level, which can never be attained in actual practice. If we were to stick to such levels, the positive forms of absolute adjectives would be useless: any assertion of the form 'a is A' would be false. As it is, we do make such statements: *This desk is flat*, *This towel is dry/not wet*, *This glass is full/empty*; and so forth, and we succeed in conveying genuine information by them. What is it that makes this possible?

Intuitively the answer would seem to be obvious, especially in light of what has been said about the positives of relative adjectives. The context also affects the interpretation of absolute adjectives, though the way in which it does so differs from how it affects the interpretation of relative adjectives. Its primary role is to fix the standard of A in a "realistic" manner so that objects in the application range of A have a chance of meeting it. We can think of this element of context dependence as given by the lower bound $\mathrm{lb}_c(A)$ of a tolerance interval whose upper bound is the context-independent standard Max(A). In other words, a qualifies as an instance of the positive form of A in c iff the A-degree of a lies within the degree interval $[\mathrm{lb}_c(A), \mathrm{Max}(A)]$. If A is associated with a measure function f_A, then this can be stated as in (28).

(28) (POS for total absolute adjectives A)
$\mathrm{POS}(A)(a)$ iff $\mathrm{lb}_c(A) \leq f_A(a) \leq \mathrm{Max}(A)$

However, this cannot be all. If justice is to be done to the observation that (27b) is ill-formed, then the determination of $\mathrm{lb}_c(A)$ also must have a further effect: The ordering imposed by f_A should be made inaccessible to the semantics for the values of f_A in the closed interval $[\mathrm{lb}_c(A), \mathrm{Max}(A)]$. One way to do this is to count all objects a such that $f_A(a)$ belongs to $[\mathrm{lb}_c(A), \mathrm{Max}(A)]$ as having the same A-degree. This renders sentences like (27b) trivially false (see also Rotstein and Winter, 2004).

These stipulations make the semantics of the positive and comparative forms of total absolutes come out the way we want. However, as things stand there is a lack of uniformity between these principles and the ones put forward in the previous sections for the positives and comparatives of relative adjectives. Perhaps the difference between these two adjective types just does not admit of a more unified treatment than the one we have sketched (see also van Rooij, 2011a,b; McNally, 2011; Burnett, 2014). However, the possibility of a unified account should not be given up too easily. We leave this for further reflection, and conclude the discussion with one last comment on the possible role of the dynamic shifting of granularity levels between contexts.

One way to think of the "loose" interpretations of the positive forms of absolute adjectives is in terms of partitions of associated scales into segments. For a total adjective, the partition should be such that its positive extension consists of those objects that fall within the highest segment of the partition – the one that has the maximum of the scale as its upper bound. Suppose, for example, that the semantics of the total adjective *flat* is given by a flatness scale. This scale can be partitioned into adjacent segments in various ways. Some of these will be coarse-grained, involving only few largish segments, others more fine-grained, with more but smaller segments. Part of what is involved in the interpretation of an occurrence of *flat* is to choose a partition of the scale or to find out from the context what the intended partition is. Positive occurrences of the adjective will show a preference for coarse-grained partitions. In order to satisfy the positive form, the object of the adjective being predicated must fall within the "top" segment, and that will only be the case if this segment is big enough. Thus, for instance, for the sentence *The pavement is flat* to come out as true, the partition must be such that the pavement has a degree of flatness that falls within its top segment. To accommodate what they perceive to be the intentions of the speaker, interpreters will often go for such coarse-grained partitions, thereby justifying the speaker's claim.

However, while positive occurrences of a total positive adjective push us in the direction of coarse-grained partitions, occurrences in comparison constructions push us toward fine-grained ones, which can capture the degree distinctions that are involved in the semantics of these constructions. For instance, the statement *The desk is flatter than the pavement* may be true, and recognized as such, even though the difference between them is only slight (Kennedy, 2007b; van Rooij, 2011a,b).

This tension between the need for coarse-grained partitions for the interpretation of positive forms and for fine-grained partitions for the interpretation of comparison constructions manifests itself dramatically when the two conflicting needs arise in connection with a single sentence like (27b). Here the truth of the first conjunct requires a coarse-grained partition which enables the pavement to make it into the top segment, whereas the second conjunct requires a partition that is fine-grained enough to draw a distinction between the pavement and the desk, and that one must be such that the pavement does *not* end up in its top segment. Clearly a single partition cannot deliver on both fronts. It is our impression that if the two conjuncts were further away from each other, for instance if they were separated by another clause or sentence, then the awkwardness of (27b) would be mitigated; however, more empirical work is needed to confirm this.

A more general question for empirical research is how interpreters navigate between partitions of different granularity when interpreting the different forms of the different types of adjectives (for additional data points and different theoretical perspectives, see Unger, 1975; Rotstein and Winter, 2004; Kennedy, 2007b; Syrett, 2007; McNally, 2011; Sassoon, 2012).

Additional types of adjectives

The distinction between relative and absolute adjectives is not the only one that is relevant for a semantic theory of adjectives. Adjectives such as *tall* and *heavy* are *one-dimensional* in that their satisfaction degrees are given by a single measurement function – height for *tall* and weight for *heavy*. But such adjectives are comparatively rare. Far more often, there are several criteria that are relevant to how well an object instantiates a given adjectival predicate (Kamp, 1975; Klein, 1980; Murphy, 2002; Sassoon, 2013a,b). A classical example from the literature is *clever*: whether someone is to count as clever, and how clever, may depend on different kinds of skills, from mathematical problem solving to such social skills as persuasiveness or successful manipulation of others (see Grinsell, 2012 and Canonica, 2014 for discussion of vagueness in sets of criteria used in classification under adjectives).

For an adjective like *clever*, the context is important for more than one reason – not only because it may fix the set of categorization criteria and the standard of application for those criteria but also because it determines the way in which the different criteria combine to create a single categorization criterion. The dimensional criteria can be conjoint or disjoint; alternatively, context may single out one of them as the only one that is relevant, or it may impose a certain weighting between them. This kind of "multi-dimensionality" is extremely common. We find it, for instance, also with *flat*: How do we compare the flatness of a very smooth flat surface with one small bump and that of a surface that has a pattern of tiny ribs all over it? Which of the two is the flatter one?

One reason why the difference between one-dimensional and multi-dimensional adjectives is important is that they have different "logics". For a one-dimensional adjective, the positive is dependent on context, but the comparative is not. For such an adjective *A*, it will invariably be the case that if *a* and *b* are both in the application domain of *A*, then we have the following:

(29) Either *a* is *A*-er than *b* or *b* is *A*-er than *a* or, thirdly, *a* and *b* are equally *A*.

For multi-dimensional adjectives, the comparative will in general depend on context as well as the positive. The context may influence the comparative of a multi-dimensional adjective by, for instance, selecting one of its dimensions rather than another. If the context doesn't provide the right information, then the disjunction in (29) need not hold.

What we see here is a further twist to the "logic of vagueness" discussed in Section 14.3: It is not just vagueness as such that raises questions about logic (that is, about the logic of languages with predicates that are vague in whatever way and for whatever reason). The questions we have just raised concern the vagueness-related semantic structure of particular types of predicates and the logical implications of such structures. Some such predicates have a comparatively simple semantic structure, which supports logical laws and inferences that do not hold for predicates with a more complex structure. However, those with more complex structures may license other logical principles in their turn.

Not all that much seems to be known at this point about how the semantic structure of vague predicates may vary and what implications that may have for the logic of those predicates. Further distinctions have been noted in the literature between different types of adjectives, but we cannot go into more detail about this here (see Kamp and Partee, 1995; Morzycki, 2015; McNally, Chapter 15, and references therein). Nevertheless, the topic is important, and it is important in particular for natural language predicates that take the form of adjectives. Here the relations between meaning, logic, and form have a special linguistic importance, since in many languages adjectives can occur in a rich variety of morpho-syntactic constructions that reflect their semantic and logical properties (positives, comparatives, equatives, and more). The study of the variety of semantic types of adjectives is therefore as important for the linguist as it is for the logician. However, this point extends far beyond the category of adjectives. For a discussion of different types of nouns and verbs in a similar range of constructions, see, for example, Wellwood et al. (2012), Bochnak (2010, and references within).

We have just argued that questions about the logic of different types of vague adjectives (as well as of other types of vague expressions) differ from those that were touched upon in the discussions of the logic of vagueness in Section 14.3. In fact, investigations of the logic of different types of adjectives and other vague predicates should *build* on a general logic of vagueness (whatever that logic is taken to be). The logical principles that are specific to particular types of predicates should be cast in such a form that they can be incorporated into such a general logic, for instance as axioms that are restricted to the predicates of the type in question (see van Rooij, 2011a,b; Burnett, forthcoming).

14.4.2 Imprecision and approximation

Our discussion of total absolute adjectives like *flat*, *dry*, or *clean* suggests the following picture: These words are predicates with a well-defined semantics, but one which in practice no object can ever meet (e.g., nothing is ever completely flat). So in order to be able to make a meaningful use of such a predicate A, we always relax the degree to which they should be satisfied, and this relaxation varies as a function of context: in any such context c, the 'de facto extension in c' consists of all objects whose satisfaction degree lies within the interval $[\mathrm{lb}_c(A), \mathrm{Max}(A)]$.

However, absolute adjectives are not the only expressions for which an account of this sort suggests itself. Some others are on display in (30) (Lasersohn, 1999; Krifka, 2002).

(30) a. Mary arrived at three o'clock.
b. Mary arrived one minute after three o'clock.
c. The distance from Amsterdam to Vienna is 1000 km.
d. The distance from Amsterdam to Vienna is 965 km.
e. In decimal notation π is 3.14.
f. In decimal notation π is 3.1415926538.

The time-denoting NPs *three o'clock* in (30a) and *one minute after three o'clock* in (30b) are often, and plausibly, said to denote instants of time, which occupy infinitesimal parts of the timeline. But if that is so, then it is hard to see how (30a) or (30b) could be really true. For how could the events described in those sentences be that narrowly confined in time? So, if there are to be situations that these sentences describe correctly, then that must be either because the described events stand to the denoted instants in some other relation than temporal identity (i.e., identity of the time of the event with the denoted instant) or because the temporal adverb makes available something other than an instant, such as an interval surrounding it, within which the event e must be temporally contained. We do not know how much there is to choose between these options, but we follow Lasersohn (1999) and Krifka (2002, 2007) in pursuing the second.

According to this second option each context c for the use of *three o'clock* must determine an interval, and it seems obvious that that interval should include the instant t denoted by the phrase. A further natural assumption is that c determines an interval that has t as its center point. That is, c determines a temporal distance ϵ_c such that (30a) is acceptable in c only if the described event is temporally included in the interval $(t - \epsilon_c, t + \epsilon_c)$.

Example (30b) is like (30a) except that we tend to allow for more tolerance in the case of the "round" time-denoting phrase *three o'clock* than with the phrase *one minute after three o'clock*, which is "not round". For instance, when nothing more is said and Mary arrived between two and three minutes past three o'clock, then (30b) would normally be regarded as wrong, but (30a) might well be considered acceptable.

Sentences (30c)–(30f) serve to illustrate much the same points as (30a) and (30b). Krifka (2002) notes that if the distance between Amsterdam and Vienna is in fact 972 km, then (30c) might be accepted but not (30d), in spite of the fact that the discrepancy between the actual distance and the one mentioned in (30d) is less than that between the actual distance and the one mentioned in (30c). The sentence pair (30e),(30f) illustrates another instance of the same phenomenon. 3.1415926538 is closer to the true value of π (of which the first ten decimals are 1415926535 rather than 1415926538) than it is to 3.14. Yet our convention about decimal approximations qualify (30e) as right but (30f) as not: what matters according to that convention is that those decimals must be correct which are explicitly given. In science this principle governing the interpretation of decimal approximations is generally accepted and rigidly observed. The principle that round numbers guide us toward more tolerant contexts is less rigid and not as easily stated, but it is in the same spirit.

In our comments on the examples in (30) we have been anxious to avoid the use of the words *true* and *false*. For instance, we did not say that (30e) is true and (30f) false, though that might be thought to be a perfectly correct description of the difference between them. In avoiding *true* and *false* we have tried to remain consistent with Lasersohn's discussion of these phenomena. According to Lasersohn, both (30a) and (30b) are false when Mary arrived at two minutes past three, even if the context places the event *e* of Mary's arrival within the halo of *three o'clock* but not within that of *one minute after three o'clock* (where the halo of *three o'clock* might be, say, the period from two minutes before three o'clock to two minutes after three o'clock and that of one minute after three o'clock the period from 30 seconds after three o'clock till 90 seconds after three o'clock). We cannot see any compelling reason, however, against describing (30a) as true in this setting and (30b) as false (see the discussion of absolute adjectives in the last section). This point of view regarding the use of *true* and *false* is compatible with the approaches developed in Lewis (1979c), Rotstein and Winter (2004) and McNally (2011).

Krifka accounts for the "round number" effect as the result of a competition between the demand for precision on the one hand and a preference for short expressions on the other: the phrases for round numbers tend to be simpler and shorter than those for numbers that are not round, and the advantage of brevity will often outweigh the striving for precision. It is not clear, however, that brevity is always the reason why a speaker chooses a round number phrase instead of a longer but more accurate one. It is not just that round number phrases come with an implication of greater tolerance – something that only involves a "halo-ish" interval around their precise denotation – but, more globally, their use relates to a certain coarse granularity that extends to the entire numerical domain. For instance, the use of the phrase *1000 km* in (30c) suggests a context in which distances are assessed as multiples of, say, 50 km intervals (see Krifka, 2007 for an elaborate discussion).

Canonica (2014) argues that such coarse granularities are advantageous from a computational perspective, especially in relation to statements that involve quantification over the given numerical dimension. Shifting to a coarser granularity makes it possible to switch from infinite to finite domains when evaluating such statements. In a similar vein, Solt et al. (2014) argue that coarse and approximate interpretations reduce processing costs. Vagueness and approximation are useful for reasons of politeness and diplomacy as well, for example, describing a strictly speaking *incorrect* utterance of a speaker as *roughly correct* can help to save his or her face. Fixing an appointment for *the afternoon* is less committal than fixing it for *4:00 o'clock*, meaning that the chance one has of arriving "on time" increases (van Deemter, 2010). Rather than being viewed as mere deficiencies of natural language expressions (Frege, 1903; Russell, 1923), vagueness and imprecision, on these accounts, have a purpose.

Perhaps most importantly, speakers themselves often have only approximate knowledge of the facts they want to communicate. I do not know exactly how far it is from Amsterdam to Vienna, but I do know it is about 1,000 km. I could of course convey this approximate knowledge by saying something like *The distance from Amsterdam to Vienna is roughly 1,000 km*. However, in view of the round number convention (30c) will usually do just as well, and in the choice between these two potions brevity can easily have its way, for in this case no alternative benefits are competing with it. Furthermore, even when I do know that the distance from Amsterdam to Vienna is 972 km, I may nevertheless prefer to say *The distance from Amsterdam to Vienna is 1,000 km*, as a way of conveying that the imprecise information this formulation conveys is all that I take to matter.

To conclude this section, is imprecision of the kind illustrated by the sentences in (30) a form of vagueness or isn't it? Perhaps it is impossible to answer this question without some measure of legislation. It should be clear from what we have said that we do see imprecision of this kind as a form of vagueness. One justification for this that we have not drawn attention to so far is the following: this kind of imprecision shares some of the features that we find with prototypical examples of vague predicates, such as *bald* or *heap* and that are seen by many as the hallmarks of vagueness: they too give rise to Sorites problems – if a belongs to the halo of x and b is only marginally different from a, how could b fail to belong to the halo as well? There are means of contextual resolution (through contraction of halos), but without a genuine prospect that this will ever ban the dangers of the Sorites altogether.

14.4.3 Vagueness as an aspect of grammar?

In the course of this survey, we have run more than once into sentences of doubtful grammaticality. Their grammaticality appeared to depend on how the adjectives contained in them were to be classified. For instance, in both Section 14.2 and Section 14.4.2 we noted that certain adjectival modifiers can be applied to adjectives of one kind (e.g., relative adjectives) but not to adjectives of other kinds (total or partial absolute adjectives). The grammaticality judgments of such sentences tend to be controversial, and for all we can tell this may be because speakers are not all that firm and consistent in their classifications of the adjectives in question. But whatever the precise reasons for these uncertainties and inconsistencies, it very much looks as if aspects of vagueness affect the syntax of the language, and not just its semantics.

That grammar should be "vague" in this sense is nothing new. Various suggestions have been made over the years to the effect that it is often vague whether something that looks like a possible word is in fact a word of the language, or whether a noun phrase with a given head noun can occur as argument to a certain verb, or whether a certain construction is a genuine part of the grammar or only something that people use under pressure because there is no grammatically perfect way of saying what they want to express. For such reasons grammar has long been seen by many as inherently “fuzzy” (see Aarts et al., 2004, and multiple references within).

In fact, such fuzziness seems to go hand in hand with language change. To give just one anecdotal example, one of us still remembers being somewhat bewildered quite a few years ago when hearing for the first time an American waiter speak the word(s) “Enjoy!”, evidently as an encouragement to enjoy the food he had just placed on the table. One gets used quickly enough to such innovations, but even today *enjoy* doesn’t seem a very good paradigm of an intransitive verb. “After they enjoyed, the men withdrew to the smoking room for port and cigars” seems a strange way of saying “after they enjoyed the meal”, and not just because of a clash of cultures. On the whole, grammaticalization is a complex process, involving slow and tentative progress through many gradations of rejection, uncertainty and acceptance. It seems plausible to say that something like vagueness or indeterminacy governs the intermediate stages of such processes.

The case for a deep interaction between vagueness and grammar has recently been made by Chierchia (2010) in connection with the distinction between mass and count nouns. This distinction, Chierchia argues, has profound consequences for the grammars of many languages, English among them. The syntactic structure of noun phrases (the various syntactic projections of the category *N*) depends crucially on the properties of the nouns that act in them as “lexical heads”. In particular, the syntactic rules that govern the well-formedness of noun phrases are sensitive to whether or not the noun’s extension is built from **atoms**. For example, the count noun *apple* has an extension that is built from atoms. The *apple*-atoms are the individual apples, and the extension of the plural *apples* consists of all mereological sums that can be formed out of these. Typical examples of mass nouns, such as *mud* or *air*, are widely seen as the exact opposite of this; for instance, what counts as an atomic quantity of mud is completely undefined. However, in between these conceptually clear cases there are many nouns – both mass and count – that cannot be characterized straightforwardly in these simple terms. For example on the one hand, *furniture* is a “fake mass noun” in that its extension clearly does have atomic elements (e.g., individual pieces of furniture in a room). On the other hand, *segment* is a count noun, but in the extension segments typically contain smaller segments as parts, so many elements of the singular noun *segment* are not atoms. Other nouns can be used both as mass nouns and as count nouns – e.g., *stone*, *rope*, *rock*, *beer*, *vice* – and it is often unclear whether their extensions are built from atoms or not. Also, it is sometimes not clear if a noun does have both uses (is there a use of *string* as count noun, with the meaning “piece of string”? And what about *yarn*?).

Chierchia proposes to deal with these and other problems in the syntax and semantics of noun phrases by assuming that the notion of an "*N*-atom" (where *N* is a noun) is vague but that its vagueness can often be resolved in context. Furthermore, the formation rules for noun phrases built from *N* as lexical head refer to *N*-atomicity and thus are sensitive to the indeterminacies of this notion, with the result that the notions of well-formedness and Logical Form themselves become indeterminate. Often, Chierchia goes on to argue, the context will make clear which parts of the extension of a noun are to be treated as atoms so that counting elements of the extension will become possible in that context, and with it the evaluation of noun phrases containing numerals, such as *three portions of ice cream*.

Chierchia is certainly right that contextual information of this sort is often needed and that the given context will often supply it. What is not so clear is whether the indeterminacy of atomhood is to be treated as an instance of vagueness and dealt with formally in terms of supervaluation, as Chierchia proposes.[33] Whether supervaluation is the right tool or model here, one thing seems fairly certain: indeterminacy of N-atomhood does not give rise to the Sorites. Is that enough to disqualify it as a case of "genuine" vagueness, though? We do not know how to answer this question.

However, has there got to be an answer? There are a number of characteristics that we have come to associate with the notion of vagueness in an intuitive and informal manner. A closer and more systematic study will be needed to show how these characteristics are logically related, and thus which combinations of them are logically possible. Furthermore, a closer investigation into the nature of language and thought can reveal which of those combinations are in fact realized there. In this survey, we have tried to give an impression of the considerable progress that has been made on both these fronts. Nevertheless, the subject is far from exhausted – partly, no doubt, because there are many aspects of vagueness that are still hidden from view, but also because it is so hard to combine the insights gained through work in different disciplines into a single coherent picture.

Acknowledgments

Both authors have worked on vagueness on their own for many years at different but extended periods of time. We have both been influenced extensively and decisively by many of our teachers, colleagues, and students and much of that influence – probably much more than we are aware of ourselves – has gone into this chapter, even though its principal task and aim is an even-handed presentation of some of what the rich and diversified literature on vagueness has to offer. We both feel a deep gratitude to all whose influence we have wittingly or unwittingly profited from, but we see no way

[33] See Rothstein (forthcoming) for data and an alternative account in terms of implicit atom-set arguments of count nouns.

of turning this general sense of indebtedness into individual acknowledgments. Nevertheless, during the process of writing this chapter, each of us has recognized the profound impact that certain individuals have had on its outcome, and we would therefore like to mention them explicitly.

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15

Modification

Louise McNally

15.1 Introduction

The term *modifier* (and modification, the function a modifier carries out) is difficult to define in intuitive terms. A first informal approximation might be, for example, to say that a modifier adds additional, non-essential descriptive content to that contributed by the expression that it combines with; in this respect, a modifier would contrast with an *argument*, which would provide descriptive content that is somehow required by the expression it combines with. For instance, one could try to argue that in (1), the content contributed by *delightful* is less essential to determining the referent of the whole nominal than that contributed by *of Susan*, and thus we could conclude that the former is a modifier, while the latter is an argument:[1]

(1) the delightful mother of Susan

However, this sort of reasoning has long been known to be problematic, as the large literature on the argument/nonargument distinction in the argument structure literature makes clear.[2] For example, consider (2):

(2) the younger sister of Susan

[1] Dowty (1989) argues that, despite appearances, as a rule no nouns have arguments. I will not make this assumption here.

[2] See especially Dowty (1982, 1989, 2003) for insightful discussion of the problem of distinguishing arguments from modifers. In this article, the terms *argument* and *modifier* will be used to characterize expressions exclusively in terms of their compositional semantic effect. The terms *complement* and *adjunct*

If Susan has two sisters, the content contributed by the adjective is arguably as important as that contributed by the prepositional phrase for identifying the referent of the nominal. However, such adjectives are universally treated as modifiers, not arguments. A classic example from the verbal domain involves the verbs *buy*, *sell*, *rent*, and *lease*: Money is an essential participant in the situations these verbs describe, and yet the *for*-phrase in (3) is not treated as an argument (see, e.g., Jackendoff, 1972, for an early discussion of this problem):

(3) We sold the car (to the dealer) for 2000 euros.

Syntactic obligatoriness is even more problematic as a criterion for defining modifiers, as many expressions that linguists would agree are arguments are syntactically elidable (such as *to the dealer* in (3)), and sometimes modifiers are obligatory, if arguably only for pragmatic reasons (see, e.g., ??*a built house* vs. *a well-built house*, Goldberg and Ackerman, 2001). Consequently, in this article, *modifier* and *modification* will be defined in strictly formal terms.

The notion of modification cannot be understood without the prior assumption, at least as old as Aristotle, that language makes a distinction between the basic entities we ascribe properties to and the properties that we ascribe to them via predication. Assume that the fundamental distinction between these basic entities and properties is that the former are *saturated*, that is, semantically complete in some sense, while the latter are *unsaturated*, that is, semantically incomplete (see Frege, 1892a; Strawson, 1959, and, for more recent discussion in the context of contemporary syntactic and semantic theory, Chung and Ladusaw, 2004). If we make this assumption, we can define *modifier* as in Definition 15.1.1:[3]

Definition 15.1.1 (Modifier) An expression that combines with an unsaturated expression to form another unsaturated expression of the same type.

Modifiers can thus be contrasted with arguments, which saturate (i.e., reduce the valence of) the expressions they combine with, and (main) predicates, which as a rule combine with saturated expressions to yield expressions of a different type.[4]

will be used to characterize expressions in terms of their syntactic relation to the head of a phrase. Though in most cases, (syntactic) complements are (semantic) arguments, and (syntactic) adjuncts are (semantic) modifiers, it has been argued that sometimes this parallelism breaks down (see, e.g., Chung and Ladusaw, 2004; Espinal and McNally, 2011; see also brief comments in Section 15.2.4 and 15.3.2).

[3] See Dowty (2003) for a fundamentally similar definition. This discussion assumes basic familiarity with type theory as it is generally applied to natural language semantics; see, e.g., Dowty et al. (1981) and Gamut (1991) for accessible introductions, as well as Pagin, Chapter 3. Except where crucial, all denotations are treated extensionally in this article, and the basic domain of individuals will be assumed to include entities, events, and kinds of objects and events (see Carlson, 1977a; Landman and Morzycki, 2003), but not properties or propositions, as in, e.g., Chierchia (1984), though what is said in this article could be adapted to the sort of ontology Chierchia adopted.

[4] One sort of potential complication for this definition will be set aside here. For example, on some analyses, verbs like *seem* are analyzed as semantic type $\langle\langle e,t\rangle,\langle e,t\rangle\rangle$, that is, as functions from properties to properties (see, e.g., Jacobson, 1990), despite the fact that, in this instance, this semantic type is generally understood

On this view, we could conclude that the adjectives in (1) and (2) are modifiers but that *of Susan* is not, as follows. Assume that *mother* is a relational noun of type $\langle e, \langle e, t\rangle\rangle$. Assume that *of* is contentless and that *of Susan* denotes an entity (type *e*). When *of Susan* combines with *mother*, the result, *mother of Susan*, is of type $\langle e, t\rangle$ and thus of a lower valence, and correspondingly of a different semantic type, than *mother*. In contrast, adjectives are generally assumed to denote properties of individuals or functions from properties to properties (that is, types $\langle e, t\rangle$ or $\langle\langle e, t\rangle, \langle e, t\rangle\rangle$, respectively). The issues involved in choosing one or the other type of denotation for the adjective will be discussed in Section 15.3.1, below; for now, assume the adjective denotes a function from properties to properties. With this denotation the adjective combines with the $\langle e, t\rangle$-type expression *mother of Susan*, and the result will be another $\langle e, t\rangle$-type expression – in other words, the adjective does not affect the valence of the expression it combines with. In the case of the *for*-phrase in (3), one need only assume (as indeed is standardly the case in the argument structure literature) that the verb *sell* denotes a three-place relation to the exclusion of the money exchanged; as a result, whatever the contribution of the *for*-phrase, it will not involve saturation.

In what follows, the definition of *modifier* in 15.1.1 is assumed, though some questions concerning its adequacy will be raised below. In order to provide a broad vision of modification, the following section presents an overview of the most important families of modifier typologies that have been proposed in the literature, with a principal (though not exclusive) focus on adjectives and adverbs. Some of the key issues raised by modification for semantic theory are then presented in 15.3.

15.2 Typologies of modifiers

15.2.1 Morphosyntactically based typologies

Modifiers have been classified in quite different ways in the philological tradition and within formal linguistic theories, depending on the phenomena the classification was intended to explain. One well-known typology classifies modifiers according to the morphosyntactic categories they belong to and those they combine with. Perhaps the most familiar example of this sort is the characterization, typically found in descriptive or pedagogical grammars, of adjectives as modifiers of nominals and adverbs, as modifiers of non-nominal categories (particularly verbs, adjectives, and clauses). See, e.g., Siegel (1976) and Levi (1978) on the former and Jackendoff (1972), Thomason and Stalnaker (1973), McConnell-Ginet (1982), Ernst (1984), Wyner (1994) and Eckardt (1998) on the latter; these works also discuss the semantic correlates of morphosyntactic classifications. These definitions are intended to

to correspond to a relation between an entity and a property, rather than a modifier of a property. Of course, whether this semantic type is really the best option for such verbs, and whether it is really correct to think that *seem* is relational in a way that other modifiers are not, are open questions.

account, among other things, for basic facts about the distribution of the two categories, such as the contrast in (4) and (5) (though see Payne et al., 2010, and below for counterexamples).

(4) a. the patient's complete/*completely recovery
  b. The patient has completely/*complete recovered.

(5) a. an unfortunate/*unfortunately accident
  b. Unfortunately/*Unfortunate, there was an accident.

Though there is almost certainly some role for syntax in characterizing the distribution and behavior of modifiers, strictly syntactic classifications have at least two limitations. First, it is difficult to find an elegant, strictly morphosyntactic characterization of what can be a modifier and what cannot. For example, in English, nouns can be modified by expressions of almost any syntactic category, including nouns, pronouns, proper names, untensed verb phrases, and even entire clauses (6); perhaps the only exceptions are tensed verb phrases and determiners (7), which cannot function as modifiers at all:[5]

(6) a. a quality product
  b. an all-or-nothing situation
  c. the "it" girl
  d. a Jane Doe production
  e. the rapidly disappearing coastline
  f. a to die for dress
  g. an I-told-you-so look

(7) a. *a rapidly disappears coastline
  b. (?)an "each" situation

Morphosyntactically, neither those expressions that can modify nor those that cannot form a natural morphosyntactic class.

Second, similar problems arise in characterizing the morphosyntactic categories that specific modifiers combine with. For example, the claim that adjectives only modify nouns is questionable. Adjectives are used as verb phrase and sentential modifiers in depictive ((8a); Dowty, 1972; McNally, 1994) and absolute constructions ((8b); Stump, 1985):

(8) a. The children came home from camp happy.
  b. Hoarse, the instructor cancelled class.

Though it might be argued that such adjuncts and absolutes are syntactically distinct from simple adjective phrases (e.g., that they are covert clauses

[5] With respect to determiners, the question is complicated by the complexities of the category itself. For example, numerals occur in a modifier-like position in expressions like *the/every two weeks*, but, unlike, e.g., *each*, they are also sometimes argued to have an adjectival syntax and semantics. Note also that (7b) might be interpretable along the lines of (6b) as "a situation where each of something (as opposed to some other quantity or distribution) is involved".

of some sort), it is far from obvious that this is the case. It therefore does not seem possible to classify modifiers cleanly according to the morphosyntactic categories they combine with.

In addition to failing to explain these sorts of facts, the classification of modifiers in strictly morphosyntactic terms arguably emphasizes their differences over their similarities. While the morphosyntactic properties of different types of modifiers should be taken into account, the range of facts mentioned in this section points to the need to classify modifiers along other parameters.

15.2.2 Notionally based typologies

What we might call notionally based typologies classify modifiers according to aspects of their descriptive content or, loosely speaking, semantic function; such classifications can be found in descriptive grammars and the philological tradition more generally. A typical example is the typology in Picallo (2002), used specifically for adjectives (for other typologies see, e.g., Dixon, 1982; Huddleston and Pullum, 2002; Dixon and Aikhenvald, 2004; Demonte, 2008). Picallo divides adjectives into three classes. *Qualitative* adjectives (e.g., *male*, *sick*, *red*, *good*) denote properties or qualities of some entity. *Relational* adjectives (e.g., *technical*, *solar*, *molecular*; term due to Bally, 1944) are typically identified morphologically as being denominal; semantically, they contribute a property which somehow relates the individual described by the noun they modify to the sort of object described by their nominal root (for instance, a *parliamentary decision* is a decision by a parliament). The remaining adjectives are classified as *adverbial*, a heterogeneous class that Picallo divides into subclasses of modal (e.g., *possible*), aspectual (e.g., *frequent*), and circumstantial (e.g. *fast*) adjectives.

Notional typologies of adjectives have been used to account for various kinds of data.[6] For example, relational adjectives have among the strongest distributional identifiers of any subclass of adjectives (Boleda, 2007). Not only are they often identifiable by their denominal structure, they also stand out, for instance, as being the only class of adjectives in Spanish and Catalan that are systematically restricted to postnominal position (McNally and Boleda, 2004).

Notional typologies for adverbs and other verb phrase and sentence modifiers look superficially rather different and are equally diverse. A typical example, taken from Huddleston and Pullum (2002), sorts adverbs into thirteen categories, according to whether they provide information about, for instance, manner (e.g., *skillfully*), degree (e.g., *very*), modality (e.g., *necessarily*), and so on.[7] As is the case with notional typologies of adjectives, these

[6] In fact, they are really more about the adjectives themselves than about adjectives as modifiers, and thus they have also been used to account for phenomena not involving modification, such as what the inventory of adjectives is across languages (see, e.g., Dixon, 1982), and whether or not the adjective can have a predicative use (see, e.g., Levi, 1978, on relational adjectives, though she does not use that term).

[7] Despite the traditional classification as adverbs, degree words like *very* have been argued by Kennedy (1999) not to be adjuncts/modifiers (though Kennedy and McNally, 2005b, resuscitates such an analysis,

adverbial subcategories are motivated both by basic semantic intuitions and, more importantly, by distributional tendencies: for instance, manner adverbs tend to appear towards the end of the verb phrase in English, whereas modal adverbs tend to appear close to the auxiliary verb, if there is one, or preceding the main verb.

Though clearly useful in predicting distributional patterns, notionally based typologies of modifiers suffer from at least two weaknesses. First, it is difficult to determine exactly how many categories of modifiers are necessary, as attested by the lack of agreement among the different proposals. Second, as the category names themselves indicate, the specific notional categories are quite different for adjectives vs. adverbs, making such typologies less useful for capturing similarities between the two categories of modifiers. Moreover, though it remains to be demonstrated, notional typologies may prove to be superfluous, a by-product of the meanings of the roots and derivational morphemes making up the modifiers, including, in particular, their semantic type.

15.2.3 Entailment-based typologies

The most prevalent typology of modifiers in the formal semantics tradition classifies them according to the sorts of inferences they license, as accounting for inference in language is, of course, a central concern of formal semantic theories. The standard classification, originating in work by Parsons (1970b) and Kamp (1975), consists of three categories, one of which in turn divides into two subcategories.[8]

The first category is the *intersective* modifiers. If α is an expression consisting of an intersective modifier β and a modified expression γ, then for any entity x, if x is α, then x is β and x is γ. This inference pattern (and the term *intersective*) reflects the fact that with such modifiers, α's satisfaction conditions amount to the intersection of β's and γ's satisfaction conditions. This is illustrated in (9) below.

(9) a. Robin is a male nurse.
b. $\models$ Robin is a nurse.
c. $\models$ Robin is male.

Some other relatively clear examples of intersective adjectives include shape adjectives such as *circular*, so-called minimum-standard gradable adjectives such as *sick* (see Kennedy and McNally, 2005a, and below for discussion), and color adjectives such as *red*.

and see also Katz, 2005 and McNally and Kennedy, 2013, for discussion of degree interpretations of manner adverbs). Instead, they have been treated as a special subcategory of word that serves as the head of a degree phrase taking a gradable adjective phrase as its complement; the degree word denotes a function from the adjective denotation, which is recast as a measure function or relation between individuals and degrees, to a property of individuals (see also Corver, 1997, on DegP). See Section 15.4 for further discussion.

[8] As already observed by Parsons (1970b), this classification can apply to adverbs as well as adjectives, but it will be illustrated here only with adjectives.

In contrast, when a complex expression α consists of a *subsective* modifier β and a modified expression γ, then for any entity x, if x is α, then x is γ, but we cannot conclude that x is β. Subsective modifiers are thus so called because they serve to pick out a subset of individuals within the extension of the expression they modify, as in (10). Note that not only is β not entailed to hold of x, but it cannot even be meaningfully applied to x in some cases, such as (10c).

(10) a. Andrea is a molecular biologist.
  b. $\models$ Andrea is a biologist.
  c. $\not\models$??Andrea is molecular.

Subsective modifiers are arguably the largest class, and the sources of the subsectivity are varied. In the case of relational adjectives such as *molecular*, subsectivity is due to the fact that the adjective establishes a relation between the kind of entity determined by the adjective's root (in (10), molecules), and the kind of entity the modified noun describes, but crucially not the entity x itself. Thus, as a rule it makes no sense to ascribe the relational adjective to x directly (though see, e.g., McNally and Boleda, 2004, and Section 15.3.2 below for counterexamples).

Another important source of subsectivity is due to the fact that many modifiers characterize the sort of individual described by the modified expression not directly, but rather only indirectly in virtue of characterizing some event or some other individual related to it, as happens on one reading of (11) (due to Siegel, 1976, and discussed extensively in, e.g., Larson, 1998; see also Pustejovsky, 1995, for other sorts of examples).

(11) a. Olga is a beautiful dancer (read: beautiful as a dancer).
  b. $\models$ Olga is a dancer.
  c. $\not\models$ Olga is beautiful.

On the indicated reading of (11a), *beautiful* characterizes Olga's dancing. We therefore cannot infer that Olga herself is beautiful, which is the most natural interpretation of (11c) out of context. We return to this sort of example and its implications in Section 15.3.2.

A third source of subsectivity, often cited in textbooks (e.g., Chierchia and McConnell-Ginet, 2000), involves the comparison class that is used to determine whether certain gradable adjectives hold of their arguments, as illustrated in (12):

(12) a. Lobsters are large crustaceans.
  b. $\models$ Lobsters are crustaceans.
  c. $\not\models$ Lobsters are large.

On the most natural reading of (12a), the sentence is true if lobsters are large taking into account the comparison class of crustaceans. In contrast, the most natural reading of (12c) out of context ascribes largeness to lobsters taking into account a more general comparison class, such as perhaps animals in general. Since these comparison classes are different, the inference from (12a) to (12c) does not automatically go through. Nonetheless, there is a strong intuition that the comparison class is easily controlled for; indeed, the comparison class can be analyzed as an argument of the adjective itself (see, e.g., the discussion in Klein, 1980, though Klein ultimately does not adopt such an analysis; see Solt, 2011, for more recent discussion). Moreover, in contrast to what happens with relational adjectives and those like *beautiful* in (11), gradable adjectives as used in (12) are clearly directly ascribed to the individual that is the argument of the modified nominal. Thus, once the comparison class is taken into account and given a fixed value, gradable adjectives such as *large* are arguably better characterized as intersective rather than subsective.[9]

Continuing with the entailment-based typology of modifiers, when a complex expression α consists of an *intensional* modifier β and a modified expression γ, then for any entity x, if x is α, we cannot infer that x is γ (or, indeed, we may be able to infer that it is *not* γ), nor can we conclude that x is β. This class includes the so-called *privative* modifiers such as *fake*, *former*, and *spurious*, which get their name from the fact that they license the inference to "not γ":

(13) a. Martina is a former star athlete.
b. $\models$ Martina is not a star athlete now.
c. $\not\models$??Martina is former.

It also includes modifiers such as *alleged*, *suspected*, and *possible*, which license no entailments at all concerning whether or not x is γ:

(14) a. That politician is an alleged crook.
b. $\not\models$ That politician is a crook.
c. $\not\models$??That politician is alleged.

These modifiers are termed *intensional* because they compose with and operate on the noun's *intension* (understood here as a function from possible circumstances/times to sets of individuals): it is not clear how they could be given an analysis in a semantics on which there is no information about the set of individuals denoted by the unmodified nouns at different times or in different possible circumstances.

The intensional modifiers constitute a comparatively very small class, and, as Landman (2001) observes (citing unpublished work by Irene Heim), the sorts of meanings intensional adjectives can have are not random. Specifically, it seems that even if, in terms of the general schema used above, we cannot infer that x is γ at a given time or in a given circumstance of evaluation, it must be the case that x is γ at some time or in some possible circumstance of evaluation. Moreover, privative adjectives have predicative

[9] See Kamp and Sassoon, Chapter 14, for further discussion of gradability in relation to vagueness.

uses which would be difficult to account for if the subject were not simultaneously describable by the noun and the (predicative) adjective (see (15)).

(15) a. This gun is fake.
b. The counterexample was spurious.

These facts have motivated some preliminary attempts to provide intensional adjectival modifiers with a special sort of subsective semantics (Landman, 2001; Partee, 2010; Asher, 2011) or even an intersective semantics (e.g., Larson, 1998, whose approach is sketched below).

It is not clear that the entailment-based typology is much more useful than the notionally based typology for explaining linguistic phenomena such as the syntactic distribution of modifiers. In particular, it has little to say about the diverse behavior of the different subclasses of subsective modifiers, for example, the special properties of the relational adjectives, where notionally based typologies fare better. However, the entailment patterns motivating this typology have had important consequences for the analysis of modification in formal semantics, as will be discussed in Section 15.3.

15.2.4 Pragmatic/discourse-related typologies

Finally, modifiers are sometimes characterized according to pragmatic or discourse-related aspects of their interpretation. The most general, and most important, of these is the division of modifiers into those that contribute to the "at issue" content of the utterance in which they appear vs. those that do not. The latter constitute a diverse group that includes nonrestrictive relative clauses and nonrestrictively used adjectives (including expressive adjectives), and what will (somewhat loosely) be referred to as speaker-oriented adverbials, illustrated in (16a–b), (16c–d), and (16e–g), respectively.[10]

(16) a. The candidate, whom we interviewed yesterday, has a Ph.D.
b. (All the words were unsuitable, and) every unsuitable word was deleted. (Larson and Marušič, 2004)
c. We visited spectacular Mount Ranier.
d. I left my damn keys in the car. (Potts, 2007)
e. Unfortunately, they had to leave.
f. In my opinion, this is ridiculous.
g. Wisely, they said nothing.

[10] Each of these classes of modifier has an independent history of study, though with the exception of speaker-oriented adverbials, they have received comparatively little attention in formal semantics until recently. See Potts (2005) for the most complete overview of these modifiers and an attempt to unify their analysis in terms of the notion of at-issue content. For further discussion of the semantics of nonrestrictive relatives, see Del Gobbo (2003), Schlenker (2010b, 2013), and references cited therein. On the semantics of expressives, see, e.g., Macià (2002), Potts (2007), Schlenker (2007). Finally, on speaker-oriented adverbials, see, in addition to the references on adverbs cited in Section 15.2.1, Bartsch (1976), Mittwoch (1977), Bonami and Godard (2008), Morzycki (2008), Wyner (2008), and references cited therein. See also Schlenker, Chapter 22.

Though syntactically these expressions are usually treated as adjuncts,[11] it is less obvious that their semantics conforms to Definition 15.1.1 of *modifier*. The expressions in (16a–d) have been treated as contributing a property ascribed to the entity picked out by the nominal with which they combine, resulting in a proposition independent of that denoted by the sentence in which they appear. For example, paraphrasing, an utterance of (16c) asserts that we visited Mount Ranier and contributes an additional proposition which is not, however, at issue, namely that Mount Ranier is spectacular. The expressions in (16e–g) have been given a similar treatment, on which they constitute an independent proposition "whose predicate (the adverb) evaluates the fact, event, or state of affairs denoted by S (sentence without the adverb)" (Bellert, 1977, p. 342). However, as will be shown in Section 15.3.3 below, the semantics of these expressions can ultimately be reconciled with Definition 15.1.1.

15.3 Issues in the compositional semantics of modification

15.3.1 Modification and modes of composition

Among the issues modification raises for semantic theory, perhaps the most basic is how best to capture the flexibility of most expressions to function both as modifiers and as predicates of individuals, illustrated in (17) and (18).

(17) a. a male nurse
b. The nurse was male.

(18) a. the cookies on the table
b. The cookies are on the table.

There are three general approaches to capturing this dual function.[12] The first and perhaps most widely assumed is to treat adjectives like *male* as ambiguous (or systematically type-shiftable) between a property of individuals denotation (type $\langle e, t\rangle$) and a function from properties to properties (type $\langle\langle e, t\rangle, \langle e, t\rangle\rangle$); see Siegel (1976) for an early proposal. On this view, the denotation for the adjective as used in (17b) would be as in (19):

(19) $\lambda x[\mathbf{male}(x)]$

The semantic representation for the adjective when used attributively as in (17a) would be as in (20a), which could be guaranteed via its satisfaction conditions to be equivalent to (20b); the modified nominal could thus be represented as in (20c).

[11] An exception is the analysis of adjectives in Larson and Yamakido (2008). See footnote 13.

[12] As elsewhere, the discussion is developed using only adjectives for illustration, though the same issues apply to other categories as well. See, for example, Davidson (1967a), Parsons (1990), and Landman (2000) for relevant discussion in relation to adverbs.

(20) a. $\lambda P \lambda x[(\mathbf{male}(P))(x)]$
b. $\lambda P \lambda x[\mathbf{male}(x) \wedge P(x)]$
c. $[\![\text{male nurse}]\!]$: $\lambda x[\mathbf{male}(x) \wedge \mathbf{nurse}(x)]$

The second approach, advocated by, for example, Larson (1998) and Chung and Ladusaw (2006), among others, is to treat the relevant modifiers unambiguously as first-order properties and adopt the assumption that natural language uses not just functor-argument application to compose meanings, but also other modes of composition, such as the intersective composition operation **MODIFY**, proposed in Chung and Ladusaw (2006):[13]

(21) $\mathbf{MODIFY}(\lambda x[\mathbf{nurse}(x)], \lambda y[\mathbf{male}(y)]) = \lambda x[\mathbf{male}(x) \wedge \mathbf{nurse}(x)]$

On the third approach, attributed to Parsons (1970b), Montague (1970a), and Kamp (1975), all adjectives unambiguously denote functions from properties to properties; in sentences like (17b), the adjective is assumed to modify a null or elided nominal rather than to be predicated directly of the subject argument. As this latter approach runs into some empirical difficulties and is not currently widely assumed in the semantics literature, it will not be discussed further here.

The choice between the other two approaches is an example of the typical trade-off that must be made in linguistic analysis: simplification in one area entails complication in another. In this case, a smaller inventory of composition rules requires more complex assumptions about lexical items; a more parsimonious lexicon requires a richer inventory of modes of composition. The ambiguity approach has the important advantage that, when developed in an intensional version, it accounts for the fact that some adjectives have only predicative uses (such as *adrift*). It also allows for a fully general semantics for all modification constructions, as observed in, e.g., Parsons (1970b), since it is not obvious how to extend the sort of intersective analysis in (21) to subsective and intensional modifiers; at least some adjectives, such as *former* and *mere*, lack predicative uses altogether and thus would seem difficult to analyze as properties of individuals. However, the second-order property analysis of modifiers has been criticized, notably by McConnell-Ginet (1982) (for adverbs) and Larson (1998) (for adjectives) on both conceptual and empirical grounds. Larson concludes that the key to understanding apparently anomalous predicative uses of adjectives, including ones like *former*, involves understanding the sortal conditions they impose on the individuals to which they can apply, an issue to which we now turn.

[13] Some sort of intersective analysis is also an obvious choice for restrictive relative clauses, though see Bach and Cooper (1978) for an alternative analysis on which relative clauses substitute for free property-type variables in the denotations of determiners; see Larson and Yamakido (2008) for an updated version of this analysis on which modifiers within the determiner phrase are explicitly treated as oblique arguments to the determiner. Though it is less commonly posited than the analyses discussed in this article, Larson and Yamakido present an interesting argument in favor of this analysis based on so-called *Ezafe* morphology in Persian and similar adjectival inflection in Greek and Japanese.

15.3.2 Subsective modification and semantic sort

Larson's reanalysis of attributive adjectives builds on the intuition that the semantics of nouns is more complex than it initially appears and that, in particular, nouns make available more than one variable that can be targeted by the adjective.[14] Larson specifically extends to nouns Davidson's analysis of verbs as relations involving events (1967a) and proposes that nouns systematically make available an event variable for adjectival modifiers, assuming a rule similar to that in (22a). Thus, the intuition is that on the subsective reading of the nominal *beautiful dancer*, *beautiful* describes events of dancing associated with the dancer; the representation for the nominal on this reading would thus be as in (22b), in contrast to the representation for the reading on which *beautiful* describes the dancer herself, as in (22c):

(22) a. If $[\![\mathrm{N}]\!]$ is $\lambda x \lambda e[\mathbf{N}(x, e)]$ and $[\![\mathrm{AP}]\!]$ is $\lambda e[\mathbf{A}(e)]$, then $[\![\mathrm{AP\ N}]\!]$ is $\lambda x \lambda e[\mathbf{N}(x, e) \wedge \mathbf{AP}(e)]$
b. $[\![$beautiful dancer$]\!]$: $\lambda x \lambda e[\mathbf{dancer}(x, e) \wedge \mathbf{beautiful}(e)]$
c. $[\![$beautiful dancer$]\!]$: $\lambda x \lambda e[\mathbf{dancer}(x, e) \wedge \mathbf{beautiful}(x)]$

This analysis has the virtue of correctly predicting that subsective adjectives should also have predicative uses on the relevant readings, as in (23), assuming a variant of the rule in (22a) for copular constructions.

(23) Olga is beautiful (as a dancer).

Moreover, as Larson suggests, this general approach can be extended to other sorts of nonintersective adjectives besides those that describe eventualities. McNally and Boleda (2004) apply it to the analysis of relational adjectives. They propose that relational adjectives generally denote properties of kinds rather than of token entities and argue that the logical representation for the noun's semantics contributes a variable corresponding to the kind of entity the noun describes. This kind is then related via Carlson's (1977a) realization relation R to the set of token entities in the extension of the noun and serves as the argument to the adjective, as in (24).

(24) $[\![$logistical problem$]\!]$: $\lambda x_k \lambda y_o[R(y_o, x_k) \wedge \mathbf{problem}(x_k) \wedge \mathbf{logistical}(x_k)]$

The intuition behind this analysis is that one of the principal functions of relational adjectives is to form subkind descriptions from kind descriptions (e.g., *technical problem* and *logistical problem* describe subkinds of *problem*).

Among McNally and Boleda's arguments for this analysis is the fact that in the Romance languages relational adjectives have a distribution resembling that of intersective adjectives, rather than that of intensional adjectives like Catalan *presumpte* 'alleged'; for example, they only occur postnominally, a

[14] These ideas also play a key role in Pustejovsky's (1995) analysis of modification, but technically Pustejovsky treats adjectives as properties of properties.

position shared by intersective adjectives, whereas intensional adjectives occur only prenominally, as the contrasts in (25) illustrate.

(25) a. un presumpte assassí
a alleged murderer
'an alleged murderer'
b. *un assassí presumpte
c. un problema logístic
a problem logistical
'a logistical problem'
d. *un logístic problema

In addition, contrary to what is sometimes claimed, relational adjectives can be used predicatively not only in Romance but also in, for example, English when the predication involves classifying some individual or kind of individual to a subkind, as seen in the contrast in (26).

(26) a. That problem is logistical.
b. ??Alex is logistical.

Such facts recast the anomaly of sentences such as (26b) as a problem of sortal incompatibility between a (first-order) predicate and its argument, rather than as a problem of using a second-order predicate where it is not licensed. In fact, Larson suggests that the intersective analysis could even be used to account for intensional adjectives like *former*, a suggestion initially supported by contrasts like that in (27), discussed in Higginbotham (1985) and Bouchard (2002):

(27) a. ??The thief was alleged.
b. His Communism was alleged.

One important concern raised by this sort of approach to subsective modification is that it can easily lead to a proliferation of variables in the representation for the modified expression, even though there is little or no evidence that so many variables are actively available, and if they are, they cannot all have the same status (see McNally, 2006, for discussion of this point). For example, while (23) suggests that the event variable in *dancer* can be targeted for predication, this is not systematically possible for the kind variable proposed by McNally and Boleda, as the unacceptability of (28b) shows.

(28) a. a logistical specialist
b. ??That specialist is logistical.

Alternatively, one might try to maintain the intersective analysis for attributive modification and argue that in predications such as (23), the property contributed by the adjective is ascribed directly to the subject referent, for which it is sortally appropriate in any case, and that the way in which the property is manifested remains underspecified.

Despite this concern, the intersective approach to subsective modification is very appealing for one type of modification in particular, namely the sort of incorporation constructions discussed in, e.g., Farkas and de Swart (2003) for Hungarian, Chung and Ladusaw (2004) for Chamorro and Maori, and Espinal and McNally (2011) for Catalan and Spanish; see (29) for an example from Chamorro.

(29) Man-gäi-ga' häm.
Agr-have-pet we
'We have pets.'

Though there are important differences of detail between the analyses, all of these authors argue that, in the respective languages, certain kinds of bare nominals do not saturate the verbs they co-occur with but rather effectively function as intersective modifiers. One of the various arguments offered in support of a modifier analysis is based on the fact that, in some languages, including Chamorro, the presence of the incorporated nominal is compatible with the presence of an independent "doubling" nominal with the same referent ("L" indicates linking morphology). For example, in (30), the incorporated nominal *ga'* 'pet' is doubled by *un ga'lagu* 'a dog'.

(30) Gäi-ga' un ga'lagu ennao na patgun.
have-pet a dog that L child
'That child has a pet dog.'

If the incorporated nominal saturated the verb, Chung and Ladusaw (2004) argue, it would not be possible to semantically compose the doubling nominal with the rest of the sentence. Note the similarity between the composition rule **RESTRICT** that Chung and Ladusaw propose for combining verbs and incorporated nominals and their **MODIFY** rule, presented in (21):

(31) $\mathbf{RESTRICT}(\lambda y \lambda x[\mathbf{V}(x, y)], \lambda z[\mathbf{NP}(z)]) = \lambda y \lambda x[\mathbf{V}(x, y) \wedge \mathbf{NP}(y)]$

Such an analysis is, arguably, intuitively more appealing than the alternative of treating the nominal as a second-order property of eventuality descriptions (as was proposed in de Hoop, 1992, for so-called weak Case nominals). Moreover, all of the above-mentioned authors show that incorporation constructions can contain not only lexical nouns but also syntactically complex nominals, rendering implausible a lexical ambiguity analysis of the sort used by Siegel for adjectives.[15]

The best way to leverage sortal restrictions in order to account for cases of subsective and intensional modification remains an unresolved issue

[15] See also Dayal (2003), who treated similar cases in Hindi as (first-order) property-type arguments to the verb with the ultimate semantic effect of second-order verbal modification. This analysis constitutes another strategy for capturing the modifying effect of the nominal without treating it formally as a second-order property. See Dayal (2011) for additional discussion.

and poses important technical and conceptual challenges; see Asher (2011) for a particularly cogent discussion and a rich alternative analysis. These challenges affect not only the questions of how best to represent lexical meaning and what the inventory of composition rules should look like but also very fundamental questions involving the semantics/pragmatics distinction, such as the possible indeterminacy of meaning in predications like (23) or the treatment of nonrestrictive, expressive, and speaker-oriented modifiers, to which we now turn.

15.3.3 Modification and the contribution of non at-issue content

Recall that nonrestrictive, expressive, and speaker-oriented modifiers are widely claimed to contribute a proposition ancillary to the denotation of the clause in which they appear, composed of a predicate contributed by the modifier and an argument which is retrieved in one of various ways. A significant point of debate has been exactly what the semantics and pragmatics of this ancillary proposition are – specifically, whether the proposition constitutes a presupposition, a conventional implicature, or something else, and whether or not its interpretation justifies the use of a multi-dimensional logic (see notably the debate between Potts and Schlenker in the references cited in Section 15.2.4, but also the other references cited there). As this debate is addressed in Schlenker, Chapter 22, the discussion here will focus specifically on semantics of the predicate contributed by the modifier and its implications for a general semantic theory of modification and, to a lesser degree, for a theory of natural language ontology. As the discussion must be brief, at the risk of some oversimplification, many points of detail will be glossed over in order to provide a general overview of the issues.

In this discussion it will be assumed, as the evidence suggests, that the proposition constructed from these modifiers does not form part of the at-issue content of the sentence in which they appear. For example, when someone asserts (32a), the assertion cannot be rejected on the grounds either that *spectacular* does not describe Mount Ranier (32b) or that it is unsurprising that Mount Ranier hasn't been climbed (32c):

(32) a. Surprisingly, nobody has ever climbed spectacular Mount Ranier.
b. ??That's false: Mount Ranier is not spectacular.
c. ??That's false: It's not surprising at all.

Thus, focusing on *spectacular*, the representation of (32a) could be as in (33), setting aside the adverb for the moment; with minor modifications, the same sort of analysis extends to nonrestrictive relative clauses and at least a subset of expressives.[16]

(33) $(\mathbf{no}x : \mathbf{person}(x))[\exists e[\mathbf{climb}(e, x, \mathbf{mr})]] \wedge \mathbf{spectacular}(\mathbf{mr})$

[16] Some expressives combine compositionally with property-type nominals and behave, modulo their special pragmatic characteristics, essentially like other subsective modifiers.

Though analyses differ on exactly how the information corresponding to the second conjunct is passed up in semantic composition to permit conjunction (or a parallel but independent interpretation) with the main clausal proposition, locally, the modifier is effectively treated as a function from entities to entities.[17] For example, on Potts's (2005) analysis, when a nonrestrictive modifier is attached to an entity-denoting nominal, two kinds of content result: On the one hand, the entity denoted by the nominal is passed up for further semantic composition, while, on the other, the property that Potts takes as the relative clause denotation is predicated of that entity to form a proposition that constitutes conventionally implicated content, which for Potts is ontologically distinct from at-issue content. Del Gobbo (2003) does not distinguish between at-issue and non at-issue content, but treats nonrestrictive modifiers as t-type sisters to an e-type expression; the nonrestrictive modifier is eventually restructured in the syntax to form a sister to the main clause, leaving the e-type expression as it originally was to undergo semantic composition.

The analysis of speaker-oriented modifiers like *surprisingly* has been similar: They have generally been analyzed as functions from propositions to propositions, as in (34).[18]

(34) $(\mathbf{no}x : \mathbf{person}(x))[\exists e[\mathbf{climb}(e, x, \mathbf{mr})]]$
$\wedge\ \mathbf{surprising}((\mathbf{no}x : \mathbf{person}(x))[\exists e[\mathbf{climb}(e, x, \mathbf{mr})]])$

Again, the differences usually involve the status of the conjoined proposition containing the adverbial. Potts (2005) adopts essentially the same approach for these adverbials as for nonrestrictive modifiers. Bonami and Godard (2008) argue for a richer model of discourse in which the distinction between at-issue and conventionally implicated content is not ontological but rather a matter of how these contents are distributed in a formal model of dialogue of the sort developed by Ginzburg (see, e.g., Ginzburg, 2012, and Ginzburg, Chapter 5). In part, then, a decision between the analyses of these modifiers involves a decision about whether or not the different sorts of content communicated in an utterance should be distinguished ontologically or through some other formal mechanism. Notably, however, as was the case for nonrestrictive modifiers, the adverbial modifier has no effect on the semantic type of the main clause.

Definition 15.1.1 of *modifier* is not immediately reflected in the diverse semantic analyses that have been proposed for these expressions. Modifiers were defined as expressions that combine with an unsaturated expression

[17] Except for certain well-defined exceptions – see, e.g., Del Gobbo's (2003) discussion of examples due to Sells (1985) – nonrestrictive modifiers systematically combine with entity-type nominals.

[18] An exception is Wyner (2008), who argues that factive adverbials like *stupidly* formally denote functions from properties of events to propositions and effectively contribute a conjunctive condition on the fact described by the event predicate they combine with. Thus, for instance, Wyner's analysis of (32a) would be paraphrased as "There is a fact that corresponds to nobody ever having climbed spectacular Mount Ranier, and that fact is surprising."

to form another unsaturated expression of the same type. Since entities and (at least extensionalized) propositions are not unsaturated types, on this definition they fall out of the domain of modification altogether; however, it also seems intuitively wrong that only for that reason we cannot provide additional, non-essential descriptive content about the sorts of things these types of expressions refer to. The definition was formulated this way in order to permit a clear distinction between predication and modification, which can become blurred particularly when representing sentences as the following alongside those like (32a):

(35) It is surprising that nobody has ever climbed spectacular Mount Ranier.

The main predicate in (35) also appears to denote a function from propositions to propositions. How, then, can it be distinguished semantically from a propositional modifier? A simple way to distinguish them would be to provide the main predicate in (35) with an eventuality argument or similar, so that it would denote a relation between a proposition and the state of being surprising. If we do so, a more generalized definition of *modifier* could be formulated as follows:

Definition 15.3.1 (Modifier) An expression which combines with another expression to produce a result with the same semantic type.

This definition covers modification of entity- and proposition-denoting expressions.

It is a striking fact that entity- and propositional modifiers, that is, modifiers of saturated expressions, systematically fail to contribute at-issue content.[19] Why should this generalization hold? For example, why couldn't a modifier of an entity-denoting expression, such as the relative clause in (36a), in principle have the same pragmatic status as the first clause of (36b)?

(36) a. The candidate, who was very popular, won by a wide margin.
b. The candidate was very popular, and she won by a wide margin.

Though it does not appear to follow from any deep property of modifiers of saturated expressions, the generalization is very much in tune with the intuitive definition of modifier mentioned at the beginning of this article, namely that a modifier adds additional, non-essential descriptive content to that contributed by the expression that it combines with. For example, since a modifier of an entity-denoting expression does not play any role in determining the reference of that expression, it will play no role in

[19] Those sentence adjuncts that do contribute at-issue content make other sorts of semantic contributions, for example as sortal properties of times or locations, as in (ia), or as restrictions on sentential quantifiers, as in (ib), in which the free adjunct restricts the domain of the modal *can* (Stump, 1985).

(i) a. Tomorrow it will rain.
b. Standing on a chair, the child can reach the shelf.

determining the proposition formed when a predicate combines with the expression, either. If that proposition is what is put forward as at issue, the information contributed by the modifier will necessarily be left out.

15.4 Degree modification

Within the body of research on modification, so-called degree modifiers have received particular attention and merit their own section. Pre-theoretically speaking, a degree modifier combines with an expression describing a gradable property and provides information about the degree to which that property holds of its argument. Typically, the gradable property is contributed by an adjective or adverb, though degree modification also appears to be possible with verbs (37b), prepositions (39b), and nouns (41). Examples of the varied sorts of expressions that have been claimed to serve as degree modifiers include measure phrases, intensifiers, certain manner adverbs, comparative and related constructions, and adjectives indicating some sort of extreme size. These are illustrated in (37)–(41), respectively.[20]

(37) a. **6 feet** tall
b. to like **a lot**

(38) a. **very**/**slightly** warm

(39) a. **extremely**/**terribly**/**surprisingly** quickly
b. **well** above average

(40) a. bigg**er**/**more** difficult **than we expected**
b. **as** happy **as we are**
c. **less** necessary **than many other things**
d. the new**est**/the **most** interesting **of the bunch**
e. **so** tiny **that it cannot be seen**
f. expensive **enough that almost nobody would buy it**

(41) a **huge**/**tremendous** idiot

[20] The literature on degree modification, even just for English, to say nothing of other languages, is too large to do justice to here. A comprehensive descriptive overview of degree expressions in English is provided in Bolinger (1972b). Early semantic analyses of degree modifiers of adjectives appear in Wheeler (1972) and Klein (1980). For more recent discussion of both the syntax and semantics of such modifiers, see, e.g., Kennedy (1999), Neeleman et al. (2004), Rotstein and Winter (2004), Kennedy and McNally (2005a), Kennedy and McNally (2005b), Katz (2005), and McNally and Kennedy (2013). Bresnan (1973) presents an early, highly detailed account of the syntax of English comparative constructions; see, e.g., Bhatt and Takahashi (2011) for a recent analysis in a cross-linguistic context and extensive references. A thorough review of the classic semantic analyses of comparatives appears in von Stechow (1984a); see also Klein (1991) and Beck (2011) for an updated overview. On superlatives, see, e.g., Sharvit and Stateva (2002) and references cited therein; on comparisons involving *so*, *too*, and *enough*, see Meier (2003). For comparison of degree modification across different categories, see, e.g., Doetjes (1997, 2008) and Bochnak (2010); for such modification in nominals specifically, see Morzycki (2009) and Constantinescu (2011). For a typological overview of comparison constructions, see Stassen (1985). See also the references cited in all of these works.

The existing analyses of these expressions are almost as varied as the expressions themselves. Let us once again use adjectives to illustrate. Throughout this survey, adjectives have been represented as denoting simple one-place properties of individuals, as in (42a). However, as mentioned in Section 15.2.3, on some analyses gradable adjectives have been given semantic representations that include reference to extents or degrees (see Seuren, 1973; Cresswell, 1976; Hellan, 1981; von Stechow, 1984a; Heim, 1985; Bierwisch, 1989; Kennedy, 1999, *inter alia*). The implementations of this latter idea differ in detail, but (42b) will serve as a starting point. Though **tall** looks superficially similar in the two representations in (42), in (42b) it is not a property of individuals (type $\langle e, t\rangle$) but rather a *measure function* (type $\langle e, d\rangle$): It applies to an entity x and returns a degree d, specifically, the degree to which x is tall (or, more precisely, has height). It will be true that x is tall if the value of x on this measure function is greater than or equal to some reference degree d provided by context or linguistic material; this degree is typically referred to as the *standard*.

(42) a. $\lambda x[\mathbf{tall}(x)]$
b. $\lambda d \lambda x[\mathbf{tall}(x) \geq d]$

However, the adjective is sometimes taken to contribute only the measure function to (42b). On these analyses degree morphology, instantiated either as a null positive form morpheme (usually represented as *pos*) or as an overt degree expression, typically contributes both the degree argument and the relation betwen the value of the measure function on x and the degree in question (see Bartsch and Vennemann, 1972a; Cresswell, 1976; von Stechow, 1984a; Kennedy, 1999; see Neeleman et al., 2004, for comparison of different approaches to introducing the degree). On such approaches, a degree expression (e.g., *6 feet* in (43a)) denotes a function from measure functions (such as that denoted by *tall*, see (43b)), to properties of individuals (e.g., the property of being 6 feet tall in (43d)). The representation for the entire sentence in (43a) is thus as in (43e).

(43) a. John is 6 feet tall.
b. $[\![$tall$]\!]$: **tall**, a function from individuals to degrees
c. $[\![$6 feet$]\!]$: $\lambda G \lambda x[G(x) \geq \mathbf{6ft}]$, G a function of type $\langle e, d\rangle$
d. $[\![$6 feet tall$]\!]$: $\lambda x[\mathbf{tall}(x) \geq \mathbf{6ft}]$
e. $[\![$John is 6 feet tall$]\!]$: $\mathbf{tall}(\mathbf{j}) \geq \mathbf{6ft}$

An exactly analogous treatment can be given to the (null) positive form morpheme, as illustrated in (44). The only difference involves the standard: instead of being numerically specified, either it is contextually determined by a comparison class (as is the case for *tall*) or, in some cases, it is fixed independently of a comparison class, typically as the minimum or maximum degree to which the property can be held (as is the case with, e.g., *open* and *closed*, respectively).[21]

(44) a. $[\![pos]\!]$: $\lambda G\lambda x[G(x) \geq d_{\mathbf{s}(G)}]$, $\mathbf{s}(G)$ the standard for G
b. $[\![pos(\text{tall})]\!]$: $\lambda x[\mathbf{tall}(x) \geq d_{\mathbf{s}(\mathbf{tall})}]$

Intensifiers and other adverbs have been analyzed in a similar fashion; they differ only in the nature of the specific conditions they place on the standard for the adjective they combine with and on the standard for the resulting modified expression. For example, the standard for an adjective modified by *very* is determined by considering the comparison class of individuals that satisfy the positive form of the adjective (Wheeler, 1972; Klein, 1980; the specific formulation in (45) is based on Kennedy and McNally, 2005a).

(45) a. $[\![\text{very}]\!]$: $\lambda G\lambda x[G(x) \geq d_{\mathbf{s}(\{y:pos(G)(y)\})}]$
b. $[\![\text{very tall}]\!]$: $\lambda x[\mathbf{tall}(x) \geq d_{\mathbf{s}(\{y:pos(\mathbf{tall})(y)\})}]$

Kennedy and McNally (2005a) show that only those interpretations of adjectives on which the standard is determined by a comparison class in the first place (as opposed to being lexically determined) are compatible with *very*. In contrast, the degree modifier *much* only combines with adjectives whose standard is a minimum degree; other degree modifiers are similarly selective.

Finally, comparatives, equatives, and similar constructions can be assigned the same general semantics, varying only in the fact that the standard is introduced by a comparative phrase or clause (e.g., *than Bill* in (46a)) and in the nature of the relation to the standard (e.g., $>$ in (46b), rather than $\geq$ as in previous examples):

(46) a. taller than Bill
b. $[\![\text{-er} \ldots \text{than Bill}]\!]$: $\lambda G\lambda x[G(x) > G(\mathbf{b})]$
c. $[\![\text{taller than Bill}]\!]$: $\lambda x[\mathbf{tall}(x) > \mathbf{tall}(\mathbf{b})]$

Note that on all of the analyses in (43)–(46), the expressions we have referred to as degree modifiers do not comply with Definitions 15.1.1 or 15.3.1 because all of them are type changing, rather than type preserving: they turn measure functions into properties of individuals. This is a direct consequence of the proposal to treat adjectives as measure functions (or as relations between individuals and degrees) rather than as properties of individuals. This proposal, however, is not uncontroversial: see, for example,

[21] See Kennedy (2007b) for this formulation of the semantics for *pos*; see this work and Kennedy and McNally (2005a) for detailed discussion of the standards for positive form adjectives. These works refer to adjectives whose standard is determined by a comparison class as *relative*, and to those whose standards are determined independently of a comparison class, as *absolute*. These terms are also used by extension to characterize the standards themselves. See McNally (2011) for the argument that color terms and certain other adjectives can be interpreted with a standard that is absolute but neither a minimum nor a maximum value on a scale.

Klein (1980), Bale (2006), and van Rooij (2011c); see also Kennedy (2007a) and Beck (2011) for discussion of the possibility that languages may vary in their use of degrees. Were the simple property analysis of adjectives to be maintained, an alternative analysis for degree expression on which they were type preserving could, in theory, be pursued.

This situation naturally brings into question whether degree expressions in fact behave like other modifiers. The preceding analyses predict that they should not. However, this prediction is only partially borne out. The most obvious difference that is predicted between degree expressions as analyzed here and other modifiers is that only the latter should be iterable. Since the result of adding a modifier to some expression is another expression of the same type, this result can, in turn, combine with additional modifiers, as illustrated in (47).

(47) long, sunny, pleasant days

In contrast, if a degree expression turns a word or phrase denoting a measure function into one denoting a property of individuals, the resulting modified phrase will not be of the appropriate type to combine with additional degree expressions. This is certainly the case for many combinations of degree expressions, as (48) illustrates.

(48) a. *Alice is more very happy than is her brother.
b. *Andrea is 6 feet very tall.
c. *Alex is very 90 years old.

However, some combinations of degree expressions are possible, perhaps most notably iterations of comparison constructions as in (49a) (Bresnan, 1973; Bhatt and Pancheva, 2004; Kennedy and McNally, 2005b), but also the addition of measure phrases or intensifiers to comparatives to express differential degree ((49b) and (49c), respectively).

(49) a. John is (much) taller than Mary than Bill is.
b. John is 2 inches taller than Mary than Bill is.
c. John is very (much) taller than Mary than Bill is.

Whether intensifiers are genuinely iterable or not is less clear. Clearly, they can be reduplicated, as in (50a). However, some combinations of different itensifiers are odd (e.g., (50b)).

(50) a. very, very happy
b. ??very quite happy

Moreover, when such combinations are acceptable it can be difficult to determine whether the outermost intensifier has combined with the entire phrase, as in (51a) or just with the first intensifier, as in (51b).

(51) a. [quite [very happy]]
b. [[quite [very]] happy]

Uncertainties in the data notwithstanding, these sorts of facts have led to some analyses on which not all degree expressions are assigned the same semantic type. For example, von Stechow (1984a) analyzes intensifiers as modifiers of adjectives that have already combined with *pos*, while giving comparatives a (still type-changing) analysis that, unlike the analysis in (46), builds in the possibility of selection for a differential degree expression. Kennedy and McNally (2005b), taking the iterability of comparatives at face value, propose that they denote modifiers of adjectives prior to the addition of degree morphology, assigning them to type $\langle\langle d, \langle e, t\rangle\rangle, \langle d, \langle e, t\rangle\rangle\rangle$. The function of comparatives on this view is to manipulate the minimum or maximum degree[22] to which an individual can stand in relation to the relevant property. For example, while the minimum degree to which an individual can stand in the relation denoted by *tall* will be the smallest degree above zero, the minimum degree to which an individual can stand in the relation denoted by *taller than Mary* will be Mary's height. This analysis, like von Stechow's, allows for the subsequent addition of measure phrases and intensifiers.

As this brief discussion should make clear, degree modification is an exceptionally complex phenomenon that requires continued research. Much of the literature on degree expressions has developed independently of the literature on modification as a whole. This is in part because of the affinities between certain sorts of degree expressions, such as measure phrases, and quantifiers, particularly determiners. However, there are also cases of degree modification, notably those involving the adverbs in (39) and the adjectives in (41), that arguably have at least as much in common with canonical modification as they do with quantification. A closer approximation between the study of degree expressions and the study of other modifiers would no doubt contribute to a better understanding of the variety of strategies human language provides for expressing the gradability, comparison, and measurement of properties.

15.5 Conclusions

Modification remains one of the most difficult semantic phenomena to model because it makes particularly evident the need for a sufficiently rich theory of lexical meaning and for a model that can integrate conventionalized propositional content with discourse-related aspects of meaning and, ultimately, world knowledge. The definition of a modifier as a word or phrase that combines with an expression to yield another of the same semantic type is perhaps the best definition currently available. However, a fully adequate theory of how best to explain the division of labor between

[22] The effect will be on the minimum for "more" comparatives and on the maximum for "less" comparatives.

the semantics of the modifier and modifiee, the semantic composition rules, and context remains to be developed.

Acknowledgments
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Part IV

Intensionality and force

16

Negation

Henriëtte de Swart

16.1 Introduction

Horn's *A Natural History of Negation* (1989) opens with the following statement: "All human systems of communication contain a representation of negation. No animal communication system includes negative utterances, and consequently, none possesses a means for assigning truth value, for lying, for irony, or for coping with false or contradictory statements." It is therefore not surprising that the expression and interpretation of negation in natural language has long fascinated philosophers, logicians, and linguists. This chapter reviews a number of key issues that have been discussed in the literature. We start with the treatment of negation in classical logic and show that the asymmetry between positive and affirmative sentences can be handled in the pragmatics. Natural languages express negation by means of negative particles and negative quantifiers. This complicates the grammar (position of the negative particle with respect to the verb) and correlates with semantic issues concerning scope, negative polarity, and negative concord.

16.2 Negation in classical logic

In classical logic, negation is a truth-functional operator, usually written as the connective $\neg$. $\neg$ reverses the truth value of the statement to which it is attached, that is $\neg p$ is true if and only if p is false. If we assume that the assignment of truth values to propositions p is handled by a valuation function V in a model M, $V(\neg p) = 1$ iff $V(p) = 0$. Under this semantics, negation relates the propositional operators $\wedge$ (conjunction) and $\vee$ (disjunction) through the De Morgan Laws:

(1) De Morgan Laws

$\neg(p \wedge q) = \neg p \vee \neg q$ not (p and q) = (not p) or (not q)

$\neg(p \vee q) = \neg p \wedge \neg q$ not (p or q) = (not p) and (not q)

Because of the truth-reversing nature of $\neg$, double negation is equivalent to the original proposition. Given that $\neg\neg p$ is true iff $\neg p$ is false, $\neg\neg p$ is true if and only if p is true. There are many non-classical logics that reject the truth-conditional equivalence between $\neg\neg p$ and p (see Priest, 2008, for an introduction to non-classical logics). In linguistic semantic theories, $\neg$ is usually maintained, and the difference in meaning between $\neg\neg p$ and p is taken to reside in the pragmatics (see 16.3 below).

The connective $\neg$ creates an opposition between the two propositions p and $\neg p$. Since Aristotle, it is customary to distinguish several types of oppositions, and Horn (1989, Chapter 1) discusses them extensively. Contrariety and contradiction both come into play in the study of negation. Contrariety is a relation between two opposites, e.g., *good* and *bad*. Nothing can be good and bad at the same time, along the same dimension, but something can be neither good nor bad. Contradiction is a relation between members of a pair such that it is necessary for one to be true and the other false (the law of the excluded middle). Negation and affirmation are contradictions in this sense. The notions of contradiction and contrariety come into play in the square of oppositions for the first-order quantifiers exemplified in (2).

(2) a. All students are happy.
b. No students are happy.
c. Some student is happy.
d. Not all students are happy.

The universal and existential quantifiers are duals, in the sense that they are defined in terms of each other plus negation:

(3) a. $\forall x P(x) = \neg\exists x \neg P(x)$
b. $\exists x P(x) = \neg\forall x \neg P(x)$

The pairs $\forall/\neg\forall$ and $\exists/\neg\exists$ are contradictories, because in any state of affairs, one member of the pair must be true, and the other false. $\forall$ and $\neg\exists$ are contraries, which cannot both be true at the same time. $\exists$ and $\neg\forall$ are

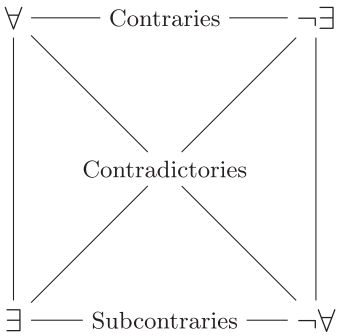

Figure 16.1 *Square of oppositions for first-order quantifiers*

subcontraries; as existentials they cannot both be false at the same time. Figure 16.1 illustrates these relations.

As the definition of duals in (3) and the square of oppositions in Figure 16.1 indicate, negation takes internal or external scope with respect to other scope-bearing operators such as quantifiers. The differences in scopal configuration have truth-conditional impact. Natural languages generally have expressions that correspond to the connective $\neg$, but not all languages have expressions that denote the quantifier $\neg\exists$. Some languages use multiple occurrences of what looks like a negative quantifier, to spread the negative meaning over different nominal expressions in the sentence (negative concord involving *n*-words). The denotation of such *n*-words is difficult to fix in terms of the square of oppositions. As we will see in Section 16.7 below, *n*-words are analyzed in terms of $\exists$, $\neg\exists$, $\forall$, or $\neg\forall$, depending on the various theories.

We can build similar squares of opposition for other scope-bearing operators such as necessity and possibility modals. If $\Box$ and $\Diamond$ are defined as duals, $\Box/\neg\Box$ and $\Diamond/\neg\Diamond$ are contradictions, and $\Box/\neg\Diamond$ and $\Diamond/\neg\Box$ are contraries. In natural language: *you should go* and *you are not allowed to go* are contraries, whereas *you must go* and *you do not have to go* are contradictions. Löbner (1987) and ter Meulen and Smessaert (2004) build extended squares with aspectual adverbs (*still/yet/not yet*), and a range of other natural language expressions.

16.3 Pragmatics of negation

Horn's generalization that all natural languages have an expression for propositional negation leads to a formal contrast between affirmation (4a) and negation (4b).

(4) a. It is raining. p
    b. It is *not* raining. $\neg p$

Dahl (1979) also takes negation to be a universal category of natural language. Greenberg (1966) and Givón (1979) observe that negation typically receives an overt expression, while affirmation usually has zero expression. Whether we are only dealing with a morphosyntactic asymmetry, or whether the formal asymmetry is mirrored in interpretation is a matter of debate. A semantic asymmetry is not supported by the standard interpretation of negation in (two-valued) classical logic. Here, the propositions p and $\neg p$ have the same status, and we can go back and forth between $\neg\neg p$ and p without any change in meaning. However, double negation sentences in natural language multiply the markings and have a more complex structure than plain affirmative sentences; see (5):

(5) a. Carol does not believe that Phil does not play chess.
b. Carol isn't unhappy.

Negation in (5a) is truth-functional but interacts with a scope bearing intensional verb in ways that its simple affirmative counterpart does not. In (5b), the double negation comes with a special communicative effect not present in its affirmative counterpart, which is known as the rhetorical figure of litotes. Pragmatic accounts of litotes are found in Horn (1989, 2001), van der Wouden (1997), and Blutner (2004). Postal (2004) is also concerned with syntactic and prosodic features of double negation in English. The experiments carried out by Huddlestone (2010) and Espinal and Prieto (2011) show that double negation interpretations of potentially ambiguous sentences in Afrikaans and Catalan respectively require strong prosodic clues. These results support the markedness of double negation meanings as compared to single negation.

Pragmatic problems with negation also arise in the presence of presupposition triggers (definite descriptions, factive verbs, aspectual verbs; see Schlenker, Chapter 22, for more extensive discussion of the semantics–pragmatics interface). It is difficult to assign a truth value to (6a), because there is no (current) king of France. We cannot therefore take the sentence to be true, but we cannot very well qualify it as false either, because that would incorrectly make its negation in (6b) true:

(6) a. The King of France is bald.
b. The King of France is not bald.

The claim that a King of France exists is somehow part of the meaning of the sentence, but is not included in the assertive content. Presupposed material is taken for granted and is projected even when embedded under operators like negation, as illustrated by Example (6b). Some analyses adopt the Strawsonian line and take the truth value of the sentence to be undefined when the presupposition is not met. Nowadays, most authors preserve the standard truth-conditional treatment of natural language negation and develop a pragmatic or dynamic account of presupposition, focusing on cancellation and local updates of partial information states (see Beaver and Geurts, 2011, for a recent overview).

Negation itself can also be viewed as a presupposition trigger. With narrow focus negation, stress is on the part of the sentence that is affected by negation. Consider the contrast between (7a) through (7d), where capitals indicate stress, and the parts between brackets give possible continuations:

(7) a. SARA didn't buy a blue sweater, [her sister did].
b. Sara didn't BUY a blue sweater, [she stole it].
c. Sara didn't buy a BLUE sweater, [she bought a red one].
d. Sara didn't buy a blue SWEATER, [she bought a blue vest].

With emphatic stress on one particular constituent, the scope of negation is narrowed down to that constituent, and the rest of the sentence becomes background information. If Sara is taken to be the focus of negation in (7a), the rest of the sentence is presupposed, and de facto outside of the scope of negation, thus leading to the interpretation under which someone bought a blue sweater, but it was not Sara (contrastive reading). The continuations in (7b)–(7d) spell out various narrow scope interpretations of negation, depending on focus. This behavior of negation relates to other focus-sensitive expressions such as *even* and adverbs of quantification like *always* (see Beaver and Clark, 2008, and references therein). In Germanic languages, the position of negation is flexible in the so-called Mittelfeld (see Jacobs, 1991, for German). In such cases, linear order has implications for the focus of negation:[1]

(8) a. daß *nicht* viele Linguisten freiwillig jeden zweiten Tag duschen
that SN many linguists voluntarily every second day shower
b. daß viele Linguisten *nicht* freiwillig jeden zweiten Tag duschen
c. daß viele Linguisten freiwillig *nicht* jeden zweiten Tag duschen
d. daß viele Linguisten freiwillig jeden zweiten Tag *nicht* duschen

Jacobs represents the meaning of the sentences in (8) as in (9):

(9) a. not (viele linguisten (freiwillig (jeden zweiten tage (duschen))))
b. viele linguisten (λx (not (freiwillig (jeden zweiten tage (x duschen)))))
c. viele linguisten (λx (freiwillig (not (jeden zweiten tage (x duschen)))))
d. viele linguisten (λx (freiwillig (jeden zweiten tage (not (x duschen)))))

There is a strong correspondence between the linear order of constituents in (8), and the scope of negation in (9). When syntactic and semantic scope align, we are dealing with direct scope.

Languages that have a designated focus position in their syntactic structure, such as Hungarian, also display an interaction between word order and scope of negation. Whereas (10a) conveys standard clausal negation,

[1] Throughout the chapter, SN is used to gloss sentential negation.

the agent is outside the scope of negation in (10b); in (10c), however, it is the focus of negation (examples from Payne and Chisarik, 2002):

(10) a. Nem olvasta el János a könyvet.
SN read PERF János ART book.ACC
'János didn't read the book.'
[Hungarian]
b. JÁNOS nem olvasta el a könyvet.
János SN read PERF ART book.ACC
'It was János who didn't read the book.'
c. NEM JÁNOS olvasta el a könyvet, hanem PÉTER
SN János read PERF ART book.ACC, but Péter
'It wasn't János who read the book, but Péter.'

Focus in Hungarian is typically interpreted as exhaustive, as indicated by the use of cleft constructions in the English translation of (10b) and (10c) (see É. Kiss, 2010, and references therein).

Issues concerning double negation, presuppositions, and focus show that the negation marker in natural language is more than a truth-functional connective and interacts with prosody, information structure, and presuppositions. This observation extends the study of negation to pragmatics.

16.4 Negation in natural language

There is little controversy about the characterization of sentences like those in (4b) as negative. However, as Horn (1989, pp. 31 sqq.) reminds us, it is not always easy to draw the line between affirmative and negative sentences. Consider the pairs of examples in (11) and (12).

(11) a. Mary did not manage to secure her job.
b. Mary failed to secure her job.

(12) a. Claire didn't leave long ago.
b. Claire left not long ago.

The different forms in (11) and (12) can be truthful descriptions of the same situation with slightly different nuances of meaning. This highlights the impossibility of characterizing (extra-linguistic) situations as either positive or negative. It is not easy to determine whether sentences like (11b) and (12b) are affirmative or negative in nature. Certain verbs contribute an inherently negative meaning. *Fail* in (11b) patterns with *deny*, *refuse*, *reject*, *dissuade*, *doubt* in this respect. Horn (1989, pp. 522 sqq.) treats inherent negation as pragmatically more complex, because it relies on propositions evoked in earlier discourse, or presupposed in the context (see Section 16.2).

Klima (1964) provides some diagnostics that come in useful in the distinction between sentence negation and constituent negation relevant to (12).

The (a) examples in (13) and (14) pass the test for sentential negation; the (b) sentences contain constituent negation.

(13) *Either* vs. *too* tags:
a. Mary isn't happy, and John isn't happy either.
b. Mary is unhappy, and John is unhappy {*either/too}.

(14) positive vs. negative tag questions:
a. It isn't possible to solve that problem, is it?
b. It is impossible to solve that problem, {#is it/isn't it}?

Additional tests have been proposed in the literature. Horn (1989, p. 185) warns that the tests sometimes give conflicting results, so uncertainties remain.

Payne (1985), Mitchell (2006), and Kaiser (2006) show that some languages realize negation by means of negative verbs and auxiliaries. Most languages are like English, though, and realize sentence negation by means of a negative particle such as *not*. The main syntactic issue discussed in the typological literature on negative particles concerns the position of negation with respect to the verb (Greenberg, 1966; Dahl, 1979; Dryer, 1988, 2009). Examples of negation in preverbal and postverbal position respectively are in (15) and (16):[2]

(15) a. Maria *non* parla molto.
Maria SN talks much
'Maria doesn't talk much.'
[Italian]

b. ʔəli *ma*: ra:ħ lidda: ˀirə.
Ali SN went to the office
'Ali didn't go to the office.'
[Baghdad Arabic]

c. O Jánis *dhen* irthe.
the Jánis SN came.INDIC.3SG.
'Jánis didn't come.'
[modern Greek]

(16) a. Maria a parla *nen* tant.
Maria CL talks SN much
'Maria doesn't talk much.'
[Piedmontese]

b. Maria praat *niet* veel.
Maria talks SN much
'Maria doesn't talk much.'
[Dutch]

[2] For Italian (15a) and Piedmontese (16a), see Zanuttini (1991, 1997). The Baghdad Arabic example in (15b) is from Payne (1985), the Greek example in (15c) from Giannakidou (1998). The Gbaya Kaka example (16c) (a Niger-Congo language) is from Dryer (2009).

c. Mi-zɔk wi ndɔng *na*.
1SG-see person that SN
'I do not see those people.'

[Gbaya Kaka]

There is an overall tendency for the negative marker to precede the verb. Out of 345 languages in his sample, Dryer (1988) finds that 227 (70%) place the negation marker before the verb. Jespersen (1917) was the first to identify a strong tendency "to place the negative first, or at any rate as soon as possible, very often immediately before the particular word to be negated (generally the verb)" (Jespersen, 1924, p. 4). Horn (1989, pp. 292–293) uses the term *NegFirst* for this tendency. NegFirst is motivated by communicative efficiency, i.e., to "put the negative word or element as early as possible, so as to leave no doubt in the mind of the hearer as to the purport of what is said" (Jespersen, 1924, p. 297), quoted by Horn (1989, p. 293). Although the majority of languages have a preverbal marker of sentential negation, as in (15), the examples in (16) indicate that NegFirst is not an absolute rule. The preference for NegFirst is mirrored by the tendency of FocusLast, where new information is placed later in the sentence (see Section 16.3 for more on focus and negation).

Jespersen (1917, 1924) describes the relation between preverbal and postverbal negation patterns in diachronic terms. He points out that preverbal negation is in a position where it can be phonologically weakened. When that happens, the postverbal expression of negation strengthens the negative meaning. The postverbal marker eventually replaces the preverbal one to convey semantic negation on its own. The trajectory of the Jespersen cycle is well documented for English (Horn, 1989; Mazzon, 2004; Wallage, 2008), French (Bréal, 1900; Horn, 1989; Godard, 2004), Dutch/Flemish (Hoeksema, 1997; Zeijlstra, 2004; Breitbarth and Haegeman, 2010), German (Jäger, 2008, 2010) and Greek (Kiparsky and Condoravdi, 2006).

This process is reflected in an intermediate stage of discontinuous negation, in which two "bits" of form, which appear in two different positions in the sentence, together convey semantic negation. (17) provides examples of discontinuous negation.[3]

(17) a. *Ne* bið he *na* geriht.
SN is he SN righted
'He is not/never set right (=forgiven)'

[Old English]

b. Elle *ne* vient *pas*.
she SN comes SN

[written French]

[3] Example (17a) is from Mazzon (2004, p. 27), (17c) is from Borsley and Jones (2005), (17d) is from Dryer (2009), (17e) is from Huddlestone (2010, p. 5). With discontinuous negation, SN appears twice in the gloss.

c. *Ni* soniodd Sioned *ddim* am y digwyddiad.
SN mention.PAST.3SG Sioned SN about the event
'Sioned did not talk about the event.'
[formal Welsh]

d. baba *wo*-shìi nai tapa *u*.
father SN-he smoke tobacco SN
'My father does not smoke tobacco.'
[Kanakuru]

e. Haar suster het *nie* haar verjaarsdag vergeet *nie*.
her sister has SN her birthday forgotten SN
'Her sister didn't forget her birthday.'
[Afrikaans]

f. Pas op dat ge *niet en* valt *nie*!
fit on that you SN SN fall SN!
'Take care that you don't fall!'
[Brabantic Belgian Dutch]

Even though there are two negative markers in the syntax, there is only one negation in the semantics, that is, all the sentences in (17) express a proposition of the form $\neg p$, with p an atomic proposition. The two markers are often different lexical items, e.g., (17a)–(17d), though not always, e.g., (17e)–(17f). The analysis of discontinuous negation raises important problems for the principle of compositionality of meaning. This foundational principle states that the meaning of a complex whole is a function of the meaning of its composing parts. If a sentence contains two negation markers, how can the sentence convey a single negation meaning? Maybe one of the two expressions is not actually a semantic marker of negation, but, for example, a scope marker? (see Godard, 2004, for such an analysis of French *ne*). But then what about triple (17f) or even quadruple negations (van der Auwera, 2010; Devos et al., 2010)? Compositionality problems surface with negative indefinites as well, as we will see in Section 16.8.

16.5 Negative quantifiers and scope

In logic as well as linguistics, the analysis of sentence negation is closely intertwined with the treatment of quantifiers (see Figure 16.1 in Section 16.1 above). If negation affects an indefinite pronoun or NP, negation may be incorporated into the indefinite, as in English (18a), (18b), (18c):

(18) a. No one came.
$\neg\exists x \mathrm{Came}(x)$
b. No student danced.
$\neg\exists x(\mathrm{Student}(x)\ \&\ \mathrm{Dance}(x))$
c. Western Prince whale watching: we saw no orcas, for all they looked, but the crew felt worse than we did.

d. Monterey Whale Watching: disappointing because we didn't see any whales.

In preverbal position, incorporation of negation into the indefinite is the norm in English, but inverse scope constructions, like (27d) below, are possible with heavier nominal constituents. In postverbal position, the *do*-support construction in (18d) is more frequent than the negative incorporation in (18c). The preference for a position of negation early in the sentence is possibly due to NegFirst (Section 16.4). Semantically, sentences involving *not* and *no one*/*no student* are variants on the expression of truth-functional negation. Syntactically *no one* and *no student* are pronominal or nominal constituents, so they denote generalized quantifiers, in the sense of Barwise and Cooper (1981) (see Section 16.6 below and Westerståhl, Chapter 7.1, on generalized quantifier theory).

For propositional operators like negation or quantification, their semantic scope is defined as the proposition the operator is prefixed to. Quantificational NPs give rise to scope ambiguities when they interact with other quantifiers, or when they are embedded under intensional verbs. In these contexts, we find the so-called "split" readings of negative quantifiers besides the familiar wide and narrow scope readings. For the German example in (19) (adapted from Jacobs, 1991), the split reading is paraphrased in (19c). For Rullmann's (1995) Dutch example in (20), the split reading is the one in (20c).

(19) Hanna sucht kein Buch.
Hanna seeks no book
[German]
a. There is no book x such that Hanna seeks x. (*de re*)
b. The object of Hanna's seeking is no book. (*de dicto*)
c. It is not the case that Hanna is seeking a book. (split)

(20) Iedereen is geen genie.
everyone is no genius
[Dutch]
a. The property that everyone has is to be no genius (narrow scope of *geen*)
b. There is no genius x so that everyone is identical to x (wide scope of *geen*)
c. It is not the case that everyone is a genius (split)

General mechanisms of dealing with scope ambiguities such as quantifying-in or quantifier-raising are unable to derive the split reading, as shown by Jacobs (1991) and Rullmann (1995). Jacobs and Rullmann, as well as Zeijlstra (2011), suggest an analysis in terms of lexical decomposition, based on the observation that the scope-bearing operator (the modal verb or the universal quantifier) intervenes between the negation part ¬ and the existential quantifier part ∃ of the determiner.

Penka (2010) takes the existence of split reading as evidence that negative indefinites in double negation languages are semantically non- negative. In terms of minimalist syntax, they carry the uninterpretable feature [uNEG], just like *n*-words (see Section 16.8 below). The assumption that *kein Buch* and *geen genie* in (19) and (20) are licensed by a covert operator carrying the interpretable feature [iNEG] in a position higher than the verb accounts for the split reading. Against this idea, Abels and Martí (2010) point out that split scope does not arise only with negative quantifiers, but also with comparative quantifiers (like *fewer than three*) (21a), and even non-monotonic quantifiers like bare numerals (21b), or numerals modified with *exactly* (21c):

(21) a. Während der Untersuchung brauchen weniger als drei
during the examination need less than three
chirurgen im Raum zu sein.
surgeons in.the room to be
'During the examination, there have to be at least *n* surgeons in the room, and *n* is less than three.'
[German]
b. You may attend six courses.
c. [A rule of a research funding body:]
One can be the PI in exactly three projects.

The verb *brauchen* in (21a) is a negative polarity item (see Section 16.7), which requires it to take narrow scope with respect to negation, leading most naturally to the split reading. The wide and the narrow scope readings of (21b) and (21c) are pragmatically odd or very weak. The most prominent interpretation of (21b) is that you may attend up to six courses (not more), which corresponds to the split reading. Similarly, (21c) implies that there is no world in which one is the principal investigator in more than three projects.

Abels and Martí (2010) assume that quantificational determiners in natural language are quantifiers over choice functions (functions from sets to individuals), instead of quantifiers over individuals. As a result, the quantificational determiner by itself scopes high, while the NP restriction of the determiner is interpreted low.

Similarly, Geurts (1996) and de Swart (2000) propose a higher-order translation of negative quantifiers in terms of quantification over properties. Under this analysis, the three readings of (20) are spelled out as in (22):

(22) Iedereen is *geen* genie.
everyone is no genius
[Dutch]
a. Everyone(be no genius) (narrow scope *geen*)
$= \lambda Q(\forall x\, {}^{\vee}Q(x))({}^{\wedge}\lambda y \neg \mathrm{Genius}(y))$
$= \forall x \neg \mathrm{Genius}(x)$

b. $\neg\exists y(\text{Genius}(y) \wedge \forall x(x = y))$ (wide scope *geen*, individuals)

c. be no genius(everyone)

$= \lambda\mathcal{P}\neg\exists P(P = {}^\wedge\lambda y\text{Genius}(y) \wedge {}^\vee\mathcal{P}(P))({}^\wedge\lambda Q\forall x\, {}^\vee Q(x))$

(wide scope *geen*, properties)

$= \neg\exists P(P = {}^\wedge\lambda y\text{Genius}(y) \wedge \forall x\, {}^\vee P(x))$

$= \neg\forall x\text{Genius}(x)$

The higher-order split reading in (22c) is truth-conditionally distinct from the narrow scope interpretation of *geen genie* in (22a), but if we replace *geen genie* ('no genius') by the upward-entailing *een genie* ('a genius'), the derivation in terms of quantification over properties collapses into the narrow scope interpretation. This explains why the split reading arises with certain quantifiers, but not others.

16.6 Negation in generalized quantifier theory

Quantificational noun phrases are generalized quantifiers of type $\langle\langle e, t\rangle, t\rangle$, which denote sets of properties. The denotation of *no* N is spelled out in (23a) as the set of properties such that no N has them. Instead of the functional perspective in (23a), we can also adopt the relational analysis in (23b). In a relational perspective, the determiner *no* relates the denotation of the common noun (**P**) to that of the verb (**Q**) and requires the two sets to have an empty intersection.

(23) a. $[\![\text{No N}]\!] = \lambda P\neg\exists x(N(x) \wedge P(x))$

b. $[\![\text{No}]\!] = \lambda Q\lambda P(\mathbf{P} \cap \mathbf{Q} = \varnothing)$,
where **P** and **Q** correspond with the sets denoted by the predicates P and Q.

The functional and relational, set-theoretic perspectives are equivalent and interchangeable. One of the advantages of the relational view is that it makes it easy to study the logical properties of determiners, such as monotonicity. Monotonicity properties involve the possibility of inference to supersets or subsets of the set under consideration. Downward monotonicity, as defined in (24), relates to the study of negation, because quantifiers that are intuitively felt to be "negative" have this property, as illustrated in (24a)–(24c), but non-negative quantifiers fail to have this property (24d)–(24e).

(24) A quantifier Q relating two sets A and B is monotone decreasing ($mon\downarrow$) iff: $Q(A, B)$ and $B' \subseteq B$ implies $Q(A, B')$.

a. No children ate vegetables → No children ate spinach

b. Not all boys came home → Not all boys came home late

c. At most three students bought a book $\rightarrow$
At most three students bought a book by Chomsky
d. All children ate vegetables $\not\rightarrow$ All children ate spinach
e. Several boys came home $\not\rightarrow$ Several boys came home late

Left (25) and right (24) monotonicity are defined as the entailment properties of the first and the second argument of the generalized quantifier respectively.

(25) A quantifier Q relating two sets A and B is monotone decreasing ($\downarrow$ *mon*) iff: $Q(A, B)$ and $A' \subseteq A$ implies $Q(A', B)$.
a. No student left for spring break $\rightarrow$ No linguistics student left for spring break
b. All students were accepted in the MA program $\rightarrow$
All students with low grades were accepted in the MA program
c. Some students left for spring break $\not\rightarrow$ Some linguistics students left for spring break
d. Not all students were accepted in the MA program $\not\rightarrow$
Not all students with high grades were accepted in the MA program

The comparison of (24) and (25) reveals that quantifiers may have different left and right monotonicity properties. Although *no* is downward entailing in both arguments (24a), (25a), *all* is left (25b), but not right downward entailing (24d).

We can define several linguistically interesting subsets of monotone-decreasing quantifiers in relation to conjunction reduction. The fact that *at most two* is downward entailing explains the inference pattern in (26a), for both A and B are subsets of $A \cup B$. However, *no* licenses in addition the inference in the other direction, giving rise to the biconditional in (26b):

(26) a. At most two students sang or danced $\rightarrow$
At most two students sang and at most two students danced
b. No students sang or danced $\leftrightarrow$
No students sang and no students danced
c. Anti-additivity: $X \in Q$ and $Y \in Q$ iff $X \cup Y \in Q$

These patterns go beyond the De Morgan Laws in (1). The inference in (26b) means that *no* is not just monotone decreasing but is in fact anti-additive, satisfying the stronger entailment in (26c). The monotonicity properties of quantifiers have not only been used to explain patterns of conjunction and disjunction reduction, but are also operative in the analysis of negative polarity items, as we will see in Section 16.7.

16.7 Negative polarity items

Many languages use a special form of the indefinite if it occurs in the scope of negation. English is a prime example of a language using so-called negative polarity items. Compare the sentences in (27) and (28).

(27) a. I did *not* buy *something*. [$\exists\neg$, $*\neg\exists$]
b. I did *not* buy *anything*. [$\neg\exists$, $*\exists\neg$]
c. **Anyone* did *not* come.
d. A doctor who knew *anything* about acupuncture was *not* available.

(28) a. *Nobody* saw *something*. [$\exists\neg\exists$, $*\neg\exists\exists$]
b. *Nobody* saw *anything*. [$\neg\exists\exists$, $*\exists\neg\exists$]
c. *Nobody* said *anything* to *anyone*. [$\neg\exists\exists\exists$]
d. **Anybody* said *nothing*.

Positive polarity items like *something* in (27a) and (28a) are allergic to negation, and take wide scope with respect to this operator. (27b) and (28b) mirror (27a) and (28a) in that the negative polarity item *anything* takes obligatory narrow scope with respect to negation (27b) or the negative quantifier (28b) (see Szabolcsi, 2004).

Negative polarity items (NPIs) need to be licensed, that is, there needs to be an operator with the right semantic properties that the NPI is in the scope of. The licensor typically occurs in a syntactically higher position to the left of the NPI (c-command), so we observe a correlation between syntactic and semantic scope just like in (8). A violation of the c-command constraint leads to ungrammaticalities in the English examples (27c) and (28d). Embedding of the NPI in a larger indefinite nominal constituent which takes narrow semantic scope with respect to negation even if it does not occur in the c-command domain of negation rescues the NPI by inverse scope in configurations like (27d) (Uribe-Etxebarria, 1994; de Swart, 1998b).

NPIs occur in a wider range of contexts than just negation, as emphasized by Ladusaw (1979, 1996):

(29) a. If you saw *anything*, please tell the police.
b. At most three of the children had eaten *anything*.
c. Few commuters *ever* take the train to work.
d. Did *anyone* notice *anything* unusual?
e. This is the best soup I *ever* had.
f. It was a song that became famous long before *anyone* had *ever* heard of the internet, social networking, or iPhones.

The examples in (29) illustrate that NPIs such as *anything* do not inherently carry a negative meaning. Rather they denote existential quantifiers with some additional meaning component characterized as "widening" of a set of alternatives by Kadmon and Landman (1993) and Lahiri (1998); as indicating the bottom of a scale by Fauconnier (1975, 1979), Linebarger (1980, 1987) and Israel (1996); as sensitive to scalar implicatures by Krifka (1995b) and Chierchia (2006), or to a non-deictic interpretation of the variable (Giannakidou, 1998, 2011). This special meaning is particularly strong in so-called minimizers, i.e., indications of a small quantity that function as the bottom of the scale. The sentences in (30) have a strong idiomatic flavor. Their affirmative/upward-entailing counterparts in (31) are not ungrammatical but have a literal meaning only.

(30) a. He didn't *lift a finger* to help me.
b. Nobody had *a red cent*.
c. Every restaurant that charges so much as *a dime* for iceberg lettuce ought to be closed down.

(31) a. #He lifted a finger to help me.
b. #Everybody had a red cent.
c. #Some restaurant that charges so much as a dime for iceberg lettuce ought to be closed down.

NPIs are found in many typologically different languages. Zwarts (1986, 1995) studied negative polarity early on for Dutch (see also van der Wouden, 1997, from whom the examples in (32) are taken). Haspelmath (1997, pp. 193, 215) provides examples of NPIs from Basque and Swedish (33).

(32) a. Geen monnik zal *ook maar* iets bereiken.
no monk will NPI something achieve
'No monk will achieve anything.'
[Dutch]
b. Weinig monniken *kunnen* vader abt *uitstaan*.
few monks can father abbot stand
'Few monks can stand father abbot.'

(33) a. Ez dut *inor* ikusi.
SN I:have:him anybody seen
'I haven't seen anybody.'
[Basque]
b. Ja har inte sett *någon*.
I have SN seen anybody
'I have not seen anybody.'
[Swedish]

NPIs are not restricted to the class of indefinite pronouns or determiners, as the examples in (34) show.

(34) a. She doesn't have a car *yet*.
b. This is the cleverest idea I have seen *in years*.

c. I could *stand* it no more.
d. Hij *hoeft* zijn huis niet te verkopen.
he needs his house not to sell
'He doesn't need to sell his house.'
[Dutch]
e. Daniel n'a pas *du tout* aimé le concert.
Daniel SN has SN of all liked the concert
'Daniel didn't like the concert at all.'
[French]

NPIs in the adverbial and the verbal domain often do not exhibit c-command restrictions (Hoeksema, 1997, 2000, 2002; Tovena et al., 2004).

An important question in the research on NPIs concerns their distribution, that is, what expressions license NPIs? Ladusaw (1979) was the first to advance the hypothesis that NPIs are licensed in downward-entailing contexts. Indeed, NPIs are licensed not only in the context of negation (27) or a negative quantifier (28) but also in the context of downward-entailing quantifiers like *at most three* (29b) or *few* (29c), and the Dutch (32b). The relevance of monotonicity is further illustrated by the contrast in (35):

(35) a. Every student who has *ever* studied logic likes semantics.
b. *Every student who likes semantics has *ever* studied logic.

Universal quantifiers are downward entailing in their left argument (25b), so the NPI *ever* is licensed in the restrictive clause attached to the common noun in (35a). However, universal quantifiers are upward entailing in their right argument, so the NPI is not licensed as part of the VP in (35b).

Notice that not all NPIs have the same licensing conditions. Although *any* is licensed in all downward-entailing environments, a minimizer like *lift a finger* or the Dutch NPI *ook maar* imposes the stronger requirement of anti-additivity (36a), (32a), and does not accept a licensor that is just downward entailing (36b), (36c):

(36) a. No one *lifted a finger* to help.
b. *At most two of the guests *lifted a finger* to help.
c. *Weinig monniken zullen *ook maar* iets bereiken. [Dutch]
'Few monks will achieve anything at all.'

NPIs are also licensed in the antecedent of conditionals (29a), in questions (29d), comparative/superlative constructions (29e), and temporal clauses (29f). The semantics of these constructions goes beyond monotonicity (see von Fintel, 1999; Guerzoni and Sharvit, 2007; Condoravdi, 2010; Hoeksema, 2010a). Corpus research provides a fine-grained picture of the empirical distribution of NPIs (see Hoeksema, 2010b; Soehn et al., 2010).

16.8 Negative concord

Negative concord and negative polarity are two versions of the phenomenon of special indefinites interpreted in the scope of negation. The Italian example (37a) (from Haegeman and Zanuttini, 1996) is a direct counterpart of the English (37b).[4]

(37) a. *Non* ho visto *nessuno*.
SN has seen *n*-body
'I haven't seen anybody.'
[Italian]
b. I have*n't* seen *anybody*. [English]
c. $\neg\exists x\mathrm{See}(I, x)$

In the context of (37a), it is tempting to analyze *nessuno* as an NPI on a par with English *anybody* (37b). The identification with *anybody* would suggest that we assign *nessuno* an interpretation in terms of existential quantification (∃). Function application would provide the desired truth conditions of both (37a) and (37b), spelled out in terms of the first-order logical formula (37c). However, other examples raise problems for this view. Haegeman and Zanuttini (1996) show that *nessuno* can be the sole expression of negation in the sentence (38a). However, Example (38b) is ungrammatical, because the licensor of *anybody* is missing. It does not help to add a negation marker, for *anybody* must be in the c-command domain of its licensor (38c). We need to use *nobody* in (38d) to translate (38a).

(38) a. *Nessuno* ha telefonato.
n-body has called
'Nobody has called.' [Italian]
$\neg\exists x\mathrm{Call}(x)$
b. *Anybody has called. [English]
c. *Anybody has not called.
d. Nobody has called.

The contrast between (37) and (38) indicates that *nessuno* seems to mean 'anybody' in some contexts, and 'nobody' in others. If we combine *nessuno* with *niente* 'nothing' in one sentence, the higher item seems to behave like 'nobody', and the lower one like 'anything' (39).

(39) a. *Nessuno* ha detto *niente*.
n-body has said *n*-thing
'Nobody has said anything.'
$\neg\exists x\exists y\mathrm{Say}(x, y)$ [Italian]

[4] *Nessuno* is not glossed as 'anybody', but as '*n*-body' to reflect its nature as an *n*-word.

b. *Anybody has said anything.
c. Nobody has said anything.
d. #Nobody has said nothing.
$\neg\exists x \neg\exists y \text{Say}(x, y)$

Example (39a) expresses a single negation, even though the combination of *nessuno* and *niente* involves two formally negative expressions, which can have negative interpretations in contexts like (38a). The English translation (39c) involves the combination of a negative quantifier and a negative polarity item. The combination of two NPIs in (39b) is ungrammatical in the absence of a licensor (see Section 16.7 above). The combination of two negative indefinites in (39d) is not ungrammatical, but the sentence does not have the same meaning as (39a): it conveys double, rather than single negation.

The pattern exemplified for Italian in (37)–(39) has been well described in the literature. Jespersen (1917) dubs the phenomenon "double negation", Klima (1964) calls it neg-incorporation, and Labov (1972a) proposes a negative attraction rule. Most current linguistic literature uses the term negative concord for cases where multiple occurrences of negation and indefinite pronouns that appear to be negative express a single negation, and we will follow this use. The indefinite pronouns participating in negative concord are termed *n*-words, following Laka Mugarza (1990). Negative concord is a widespread phenomenon in natural language, as Haspelmath (1997) observes. We find it in Romance, Slavic, Greek, Hungarian, non-standard English, (West) Flemish, Afrikaans, and elsewhere.

Negative concord is a complex phenomenon, which involves two different characteristics, namely negative doubling (i.e., doubling of an *n*-word by a negation marker) and negative spread (i.e., spreading of negation over multiple *n*-words). Cross-linguistic variation arises in the combination of these features. We find languages in which the combination of the negation marker and/or negative quantifiers leads to a double negation reading (like standard English (40)), negative doubling languages (doubling, but no spread, as in standard Afrikaans (41)), strict negative concord (both spread and doubling, as in Russian, Greek, Hungarian (42)), and non-strict negative concord (spread, but doubling with postverbal *n*-words only, as in continental Spanish and standard Italian (37)–(39)).

(40) a. They did*n't* die for *nothing*.
= They died for a reason
b. *Nobody* has *nothing* to hide.
= Everybody has something to hide

(41) a. Ons het *niemand* daar gesien *nie*.
we have *n*-body there seen SN
'We didn't see anybody there.'

[standard Afrikaans]

b. Ons het *niemand ooit* daar gesien *nie*.
we have *n*-body ever there seen SN
'We never saw anybody there.'

c. *Niemand* sien *niks* *nie*.
n-body see *n*-thing SN
'Nobody sees nothing', i.e., 'everybody sees something.'

(Huddlestone, 2010)

(42) a. KANENAS *dhen* ipe TIPOTA.
n-body SN said.3SG *n*-thing
'Nobody said anything.'

[Greek]

b. O Petros *dhen* idhe TIPOTA.
the Peter SN saw.3sg *n*-thing
'Peter didn't see anything.'

c. **kanenas dhen* ipe *tipota*.
anybody SN said.3SG anything

(Giannakidou, 1998)

The truth conditions of sentences involving multiple negation markers and/or *n*-words are uncontroversial, but there are two (or more) expressions in the sentence that seem to contribute to the expression of negation, so it is not easy to determine what each of them means, and how they work together to convey a single negation.

If we treat both *n*-words in (39a) as contributing semantic negation, we would expect the sentence to convey logical double negation, rather than single negation, in a classical logic with function application as the mode of composition. If neither *n*-word in (39a) contributes semantic negation, we would end up with an existential meaning, and we do not know where the negative force of the sentence comes from. If the *n*-words are ambiguous between a negative ($\neg\exists$ or $\forall\neg$) and a non-negative ($\exists$) interpretation, we need to constrain the ambiguity in such a way that the higher *n*-word is necessarily negative, and the lower one is non-negative, for (39a) can only mean $\neg\exists\exists$, not $\exists\neg\exists$. Van der Wouden and Zwarts (1993), Corblin (1996), and Herburger (2001) offer versions of an account under which *n*-words are underspecified or ambiguous, and denote $\exists$ if embedded under negation or a negative quantifier and $\neg\exists$ if unembedded. But most theories try to provide an unambiguous lexical semantics of *n*-words, and treat negative concord as a compositionality problem at the syntax–semantics interface.

Laka Mugarza (1990) takes *n*-words to denote existential quantifiers ($\exists$) taking narrow scope with respect to negation. This would work well for configurations like (37a) and (42b), and it would explain the (infrequent, possibly archaic, but existing) existential uses of *nessuno* and *niente* in NPI licensing contexts like (43) (from Zanuttini, 1991).

(43) Ha telefonato *nessuno*?
has called *n*-body
'Did anybody call?'

[Italian]

The drawback of the proposal is that special syntactic assumptions are required to extend the analysis to sentences like (38a) and (39a), and even (42a).

Giannakidou (2000, 2006) analyzes Greek *n*-words as NPIs that denote universal quantifiers taking wide scope with respect to negation. Under this analysis, the truth conditions of (44a) are spelled out as in (44b).

(44) a. *Dhen* ipe o Pavlos TIPOTA.
SN said.3SG the Paul *n*-thing
'Paul said nothing.'

[Greek]

b. $\forall x(\text{thing}(x) \rightarrow \neg\text{Said}(\text{Paul}, x))$

The Greek *n*-words escape the usual direct scope requirements, because they are emphatic, which allows them to undergo topicalization. As a result, they are licensed in preverbal position by inverse scope (42a), but their unemphatic NPI counterparts are not (42c). This analysis is difficult to extend to strict negative concord languages in which *n*-words are not clearly emphatic, such as Russian, Polish, and Romanian, but appear in subject position nevertheless.

Ladusaw (1992) emphasizes that the main difference between NPIs and *n*-words resides in their different licensing properties. NPIs always need to be licensed, that is appear in the context of a licensor with the appropriate semantic properties. *n*-words, on the other hand, can appear in the context of another *n*-word or the marker of sentential negation, but they do not have to, they are "self-licensing". We see that the *n*-word *nessuno* occurs in the c-command domain of the negation marker in (37a) but is felicitously used in the absence of a licensor in (38a). The infelicity of *anybody* in (38b) shows that an NPI cannot be licensed in this configuration. In (39a), the *n*-word *niente* in object position is licensed by the *n*-word in subject position, but nothing licenses the *n*-word *nessuno*.

The "self-licensing" nature of *n*-words is harder to illustrate in strict negative concord languages in which a marker of sentential negation is present in all sentences containing an *n*-word. Yet, we find an asymmetry between NPIs and *n*-words in their ability to occur in subject position. The Italian *n*-word *nessuno*, and the Greek emphatic *n*-word KANENAS are free to occur in subject position (38a), (39a), (42a), but the English *any* and the Greek non-emphatic polarity item *kanenas* are infelicitous in this position (39b), (42c).

In strict negative concord languages, we also see the self-licensing nature of *n*-words at work in fragment answers such as (45), where the *n*-word is licensed, but the NPI is not:

(45) Q: Pjon ihes? A: KANENAN
Who did you see? *n*-body

[Greek]

A: *kanenan
Anybody

(Giannakidou, 1998)

Zeijlstra (2004), Haegeman and Lohndal (2010), and Penka (2010) work out Ladusaw's intuitions in the minimalist framework, in which a difference exists between interpretable and uninterpretable features. They assign all *n*-words an uninterpretable negation feature [uNEG], which needs to be checked against a negation operator carrying an interpretable negation feature [iNEG]. In non-strict negative concord languages, the [iNEG] operator is overt with postverbal *n*-words (37a), repeated in (46a), but remains covert when the *n*-word is preverbal (39a), repeated in (46b).

(46) a. $\text{non}_{\text{[iNEG]}}$ ho visto $\text{nessuno}_{\text{[uNEG]}}$
checking (Agree)

b. $\text{Op}_{\text{[iNEG]}}$ $\text{nessuno}_{\text{[uNEG]}}$ ha detto $\text{niente}_{\text{[uNEG]}}$

Multiple agreement relations with the same [iNEG] operator account for negative spread (46b). In strict negative concord languages, the negation marker itself also carries a [uNEG] feature, so it is semantically empty. The [iNEG] operator is always covertly present at the clausal level, which licenses *n*-words in subject position, as in (42a). A covert [iNEG] operator is taken to be licensed by an *n*-word, but not an NPI in fragment answers such as (45), because negative concord is viewed as syntactic agreement, whereas negative polarity is taken to be a pragma-semantic phenomenon.

The treatment of negative concord in terms of syntactic agreement yields good empirical results; however, it faces the conceptual problem of invisible but semantically potent operators, versus morpho-syntactically overt but semantically empty negations. The claim that the meaning of the sentence is driven by an implicit negation operator runs against the basic observations this chapter started out with, namely that negation is morpho-syntactically marked in all languages, whereas affirmation usually has zero expression. We have to make sure the covert [iNEG] operator is not licensed in sentences like (4a), which are semantically affirmative, and guarantee that (15c) is interpreted as negative, even though it contains a supposedly semantically empty negation operator, on a par with (4b) and (15a), which contain a semantically potent negation operator. In sum, covert and empty negations are delicate tools to handle in a compositional semantic theory of negation.

In contrast, Zanuttini (1991), de Swart and Sag (2002), Watanabe (2004), Bošković (2009), and de Swart (2010) take the self-licensing nature of *n*-words to support a view of *n*-words as inherently negative. This leads to a unified treatment of *n*-words like *nessuno* and negative quantifiers like *nobody* as negative indefinites denoting $\forall\neg$ or $\neg\exists$. This approach brings back the compositionality problem: How does a sequence of *n*-words convey a single negation, whereas a sequence of negative quantifiers yields a double negation reading? De Swart and Sag (2002) resolve the compositionality problem in polyadic quantifier theory.

De Swart and Sag adopt a standard iterative semantics for double negation, and a second-order resumptive analysis of negative concord. Keenan and Westerståhl (1997) define the resumption of a standard quantifier as the polyadic quantifier which results from application of the original quantifier to *k*-tuples (e.g., pairs, triples), instead of individuals. Application of this idea to the sequence of *n*-words in (39a), repeated here as (47a), leads to the structure in (47b).

(47) a. *Nessuno* ha detto *niente*.
nobody has said nothing
'Nobody has said anything.'
[Italian]

b. $\mathrm{NO}^{\mathrm{hum}\times\mathrm{thing}}_{\mathrm{E2}}(\mathrm{SAY})$

c. $\neg\exists x\exists y\mathrm{Say}(x, y)$

The resumptive quantifier in (47b) ranges over sets of pairs of humans and things that are subsets of the universe E. The empty intersection with the set of pairs in the denotation of *say* requires there to be no pair of a person and a thing such that that pair is member of the denotation of *say*. Quantification over pairs reduces to the first-order representation in (47c). Negative concord is thus the resumptive interpretation of two or more anti-additive quantifiers.

The polyadic quantifier approach predicts that sequences of negative indefinites are ambiguous between a single and a double negation reading. This view is in line with Corblin's (1996) observation that examples like (48) are ambiguous:

(48) *Personne n*'est l'enfant de *personne*.
n-body SN is the child of *n*-body
= No one is the child of anyone. [negative concord]
= Everyone is the child of someone. [double negation]
[French]

French is a negative concord language, but the single negation reading of (48) is pragmatically odd, and the double negation interpretation is preferred here. The ambiguity is accounted for in the polyadic quantifier analysis as the outcome of two different ways of resolving the combination of two negative quantifiers: by iteration or by resumption.

The polyadic quantifier analysis overgenerates, because it predicts more ambiguities than we actually find in natural language. Therefore, de Swart (2010) develops an optimality-theoretic grammar which constrains the various readings and links them to the subclasses of double negation, negative doubling, and strict/non-strict negative concord languages in (37)–(48). Under this analysis, most of the syntactic complexities reside in the tension between NegFirst and FocusLast, and multiplication of morpho-syntactic markings resolves these tensions. The core of the semantics remains the interpretation of the sequence of negation markers and negative indefinites in terms of iteration or resumption.

16.9 Conclusions

The starting point of this chapter was the truth-functional, classical logic interpretation of negation in terms of the propositional connective $\neg$. Negation interacts with presupposition and focus, so it is also relevant to pragmatics. Negation in natural language is always morpho-syntactically marked, but the negation particle occurs in different positions in the sentence across languages. Negation in the domain of nominal constituents can be analyzed in terms of generalized quantifier theory. The scopal interaction of negative quantifiers with other quantifiers and intensional verbs gives rise to a third reading, labeled the "split scope" reading. Generalized quantifier theory allows a broader definition of negation in terms of downward entailment, which plays an important role in the licensing of negative polarity items. *n*-words in negative concord languages share certain features with NPIs, but they are self-licensing. Whether expressions like *nobody*, *nessuno*, KANENAS are inherently negative or not is still a topic of debate in the literature. Cross-linguistic variation in the expression and interpretation of negation thus remains subject to empirical and theoretical research.

17

Conditionals

Paul Egré and Mikaël Cozic

17.1 Introduction

Conditional sentences are sentences of the form "if *A*, (then) *C*", as in the following examples:

(1) If this figure is a square, then it is a rectangle.

(2) If John comes to the party, Mary will be pleased.

(3) If John had come to the party, Mary would have been pleased.

In such sentences, the *if*-clause *A* is called the *antecedent* (sometimes *protasis*) of the conditional, and the *then*-clause *C* is called the *consequent* (or *apodosis*, see Carroll, 1894). Traditionally, conditional sentences have been taken to express hypothetical judgments, as opposed to categorical judgments (see the table of judgments in Kant, 1781), in that the speaker who expresses a sentence of the form "if *A*, *C*" does not assert *C*, but makes a weaker commitment, namely that *C* holds under the hypothesis expressed by *A*. For instance, in saying (1), the speaker expresses something weaker than if she had asserted *this figure is a rectangle*, and similarly with (2) and (3).

The expression of conditionality in language does not necessarily involve explicit *if–then* constructions, as the following examples show:

(4) a. Kiss my dog and you'll get fleas. (Bhatt and Pancheva, 2007)
b. If you kiss my dog, then you'll get fleas.

(5) a. No Hitler, no A-bomb. (Lewis, 1973)
b. If there had been no Hitler, there would have been no A-bomb.

(6) a. Unless you talk to Vito, you'll be in trouble.
b. If you don't talk to Vito, you'll be in trouble.

However, all such sentences can be rephrased by means of an *if*-clause, as shown by the paraphrase given below them, and in this chapter we will focus on the semantic analysis of conditional sentences expressed with *if*.

From a typological point of view, at least three different kinds of conditional sentences are usually distinguished on semantic grounds, namely *indicative* conditionals, *counterfactual* conditionals (sometimes called *subjunctive* conditionals, although, as we will see below, the two notions are not exactly coextensional), and *relevance* conditionals (also known as biscuit conditionals, based on Austin's example reproduced below). An illustration of the indicative–counterfactual distinction is given by (2) vs. (3) above. In (2), the speaker entertains as an open possibility that John comes to the party. In (3), a typical context for utterance is one in which the speaker takes it for granted that John did not come to the party. Thus, indicative and counterfactual conditionals differ primarily with regard to what is assumed about the *antecedent*.

In the case of relevance conditionals, somewhat symmetrically, the difference with indicative conditionals concerns primarily the attitude of the speaker toward the *consequent*. Some classic examples of relevance conditionals are the following:

(7) There are biscuits on the sideboard if you want them. (Austin, 1961)

(8) If you're looking for the captain, he isn't here.
(cited in Geis and Lycan, 1993)

Unlike with ordinary indicative conditionals, consequents are asserted in such sentences. In Austin's example, it is asserted that there are biscuits on the sideboard. Similarly, in Lycan and Geis's example, it is asserted that the captain is not here. Thus, the role of the antecedent appears to be to make the information asserted in the consequent relevant for the purpose of the assertion itself. Relevance conditionals differ from indicative conditionals also in syntactic ways, in particular in that they typically block the insertion of *then* in front of the consequent (see Section 17.9 below):

(9) If you're looking for the captain, *then he isn't here.

This feature, to which we will return, can be seen as an indication that such conditionals do not express that the truth of the consequent depends in an essential way on the truth of the antecedent.

The semantic analysis of conditional sentences has been a hot topic since at least the Stoics (see Sanford, 1989, chapter 1), and one will hardly find any other central construction in natural language for which so many semantic analyses still compete with each other. The goal of this chapter will be to present the most influential semantic frameworks to date, and the ways in which they can be used to cast light on the typology of conditionals into indicative, counterfactuals, and relevance conditionals. One important emphasis throughout the chapter will be the attention given to inferences involving the conditional in natural language, with a view to offering a systematic comparison between alternative frameworks. Another will concern the pragmatic–semantic distinction, and whether all inferences that appear to be valid with the conditional can be captured by means of a uniform semantic mechanism.

The way this chapter is organized is as follows. Section 17.2 starts out with a review of the two-valued material analysis of conditionals, which we use as a baseline for the presentation of competing analyses: as we will see, the material conditional captures several intuitive patterns of inference, but it both under- and overgenerates with regard to very typical inferences we make in natural language. Sections 17.3 and 17.4 then focus on the main alternative to the material conditional analysis, namely the Stalnaker–Lewis analysis of conditionals as variably strict conditionals. Our presentation involves two steps: Section 17.3 compares Stalnaker's and Lewis's respective theories, while Section 17.4 highlights some problematic predictions they make regarding the relation between conditionals, conjunctions, and disjunctions. Sections 17.5 and 17.6 are devoted to refinements of the Lewis–Stalnaker analysis with an eye to the syntax–semantics interface. In Section 17.5, in particular, we compare a referential elaboration on the Lewis–Stalnaker semantics in terms of plural definite descriptions with a quantificational analysis in which conditionals are treated as strict conditionals with a mechanism of variable domain restriction. Section 17.6 considers another such refinement, namely the view of *if*-clauses as restrictors of generalized quantifiers due to Lewis and Kratzer. From a semantic point of view, this view too essentially implements the truth conditions proposed by Stalnaker–Lewis, but again it makes specific predictions about the syntax–semantics interface, in particular regarding the embedding of conditionals under the scope of various operators.

What distinguishes the Stalnaker–Lewis analysis and its variants from the material conditional analysis is that the former are not truth-functional, unlike the latter. In Section 17.7, we turn to another family of alternatives to the Boolean analysis, one that maintains truth-functionality but introduces defective truth conditions for conditionals in a three-valued setting. For indicative conditionals at least, this approach appears quite natural, though arguably less so for counterfactuals. More generally, indicative conditionals are our main focus throughout most of Sections 17.3 to 17.7, in particular because each of the various semantics we consider can be motivated in relation to specific inferences licensed or not by the indicative conditional (Lewis's semantics is an exception, but can actually be applied to indicative conditionals proper). In Sections 17.8 and 17.9, we move away from the examination of semantic frameworks to focus on the specificity of counterfactual conditionals on the one hand (Section 17.8) and relevance conditionals on the other (Section 17.9). The Appendix, finally, gives a quick comparison between the main frameworks.

17.2 The material conditional

The most venerable analysis of conditional sentences dates back to Philo of Megara (fl. 300 BCE) and was later taken up by Frege and by Russell at the inception of modern logic (Frege, 1879; Russell, 1903). On this approach, conditional sentences of the form "if A, C" are handled truth-functionally, which means that the truth value of a conditional sentence is a Boolean function of the truth values of the antecedent and consequent. According to Philo, "the conditional is true when it does not begin with a true proposition and finish with a false one, so that a conditional, according to him, is true in three ways and false in one way" (Sextus Empiricus, 2005, Book 2, 113). In modern terms, a sentence with a material conditional will be represented as $A \supset C$, and what is assumed is that $[\![A \supset C]\!] = 0$ provided $[\![A]\!] = 1$ and $[\![C]\!] = 0$. Because the logic is assumed to be bivalent, this means that $[\![A \supset C]\!] = 1$ *if* $[\![A]\!] = 0$ or $[\![C]\!] = 1$, or equivalently, provided $[\![A]\!] \leq [\![C]\!]$. That is, a material conditional is true if and only if either its antecedent is false or its consequent is true. As can be checked, the material conditional can be integrally defined in terms of negation and conjunction, as $\neg(A \wedge \neg C)$, which captures exactly the constraint that the conditional is true unless the antecedent is true and the consequent false.

In order to see whether the material conditional analysis adequately captures our truth-conditional intuitions about conditional sentences, let us first consider some patterns of inference that are supported by this analysis. As is standard, we will say that a set of sentences Γ entails a sentence ψ (noted $\Gamma \models \psi$) iff every model that makes all sentences of Γ true makes ψ true. Some valid schemata of inference supported by the material conditional are the following:

(10) a. $A \supset C, A \models C$ (Modus Ponens)
b. $A \supset C, \neg C \models \neg A$ (Modus Tollens)
c. $(A \vee C) \models (\neg A \supset C)$ (Or-to-If)[1]
d. $(A \wedge B) \supset C \equiv (A \supset (B \supset C))$ (Import–Export)
e. $(A \vee B) \supset C \equiv (A \supset C) \wedge (B \supset C)$ (Simplification of Disjunctive Antecedents)

[1] This inference is also called the Direct Argument in Stalnaker (1975).

Those schemata are worth singling out, because they are generally considered to be intuitively acceptable for both indicative conditionals and counterfactual conditionals. Other valid schemata according to the material conditional analysis are considered to be more problematic, in particular:

(11) a. $\neg A \models A \supset C$ (Falsity of the Antecedent)
b. $C \models (A \supset C)$ (Truth of the Consequent)
c. $A \supset C \models \neg C \supset \neg A$ (Contraposition)
d. $A \supset C \models (A \wedge B) \supset C$ (Strengthening of the Antecedent)
e. $A \supset B, B \supset C \models A \supset C$ (Transitivity)

Doubts about the first two patterns of inference were raised early on by C. I. Lewis (1912), one of the founders of modal logic, on the grounds that under the material conditional analysis, any true sentence is thus entailed by any other, and conversely any false sentence entails any other. Because of that, schemata (11a) and (11b) are known as the "paradoxes of material implication". Some putative examples of the oddity of those schemata might be the following:

(12) Paris is the capital of France. ?? Therefore if Paris is not the capital of France, Obama is a Republican.

(13) John was in London this morning. ?? So if John was in Paris this morning, John was in London this morning.

Doubts about the other patterns of inference were raised a bit later by Goodman (1947) in particular,[2] and largely motivated the analysis of conditionals later proposed by Stalnaker and Lewis. Some examples of infelicitous inferences based on those schemata are given below:

(14) If Goethe had lived past 1832, he would not be alive today. ?? So, if Goethe were alive today, he would not have lived past 1832. (Kratzer, 1979)

(15) If this match is struck, it will light. ?? So if this match is soaked overnight and it is struck, it will light. (after Goodman, 1947)

(16) If I quit my job, I won't be able to afford my apartment. But if I win a million, I will quit my job. ?? So if I win a million, I won't be able to afford my apartment. (Kaufmann, 2005; based on Adams, 1965)

Another often noted inadequacy of the material conditional analysis with regard to natural language concerns the interplay of the conditional with negation. In classical two-valued logic, we have the following equivalence:

(17) $\neg(A \supset C) \equiv A \wedge \neg C$ (Conditional Negation)

[2] The case of Transitivity appears to be first discussed by Adams (1965).

With indicative conditionals, one often understands "if A, not C" to imply "not (if A, C)" and conversely (see Carroll, 1894, for a symptom of this problem). However, classically, although $\neg(A \supset C) \models A \supset \neg C$, it is not the case that $A \supset \neg C \models \neg(A \supset C)$. Moreover, the inference from $\neg(A \supset C)$ to $A \wedge \neg C$ appears too strong. Under the material conditional analysis, one would predict the following:

(18) It is not the case that if God exists, criminals will go to heaven.
?? So, God exists, and criminals will not go to heaven. (attributed to Anderson and Stevenson, cited in Lycan, 2001)

Whether these inferences are inadequate on semantic or on pragmatic grounds has been and remains an issue. (For instance, consider the conditional (1) above. Clearly, Contraposition (C) seems to be a sound rule in that case, so why is it sound here, and unsound there?) The answer to this question also depends on the prospects for having a unified analysis of indicative and counterfactual conditionals. Quine (1950), for instance, essentially considered the paradoxes of material implication and the other problematic inferences as pragmatic anomalies. The same attitude is taken by Grice (1989a) and Lewis (1973) on indicative conditionals. Grice (1989a), in particular, entertains the idea that an application of the maxim of Quantity ("*make your contribution as informative as required (for the current purposes of the exchange)*") might handle some of the difficulties of the material conditional. This strategy, arguably, might explain why it would be awkward to infer $A \supset C$ from C (since $A \supset C$ is less informative than C). However, it does not straightforwardly account, for example, for why the negation of a conditional is so often understood as a Conditional Negation (CN) (a problem Grice regards as "a serious difficulty" for his account). As pointed out, under the material analysis of the conditional, $\neg(A \supset C)$ entails $A \supset \neg C$, but the converse is not true. Hence, this would be a case in which what is inferred is logically weaker (and so less informative) than what is literally asserted.

Irrespective of whether the material conditional can give a good analysis of indicative conditionals, Quine considered the material conditional analysis to be semantically inadequate for counterfactuals:

> Whatever the proper analysis of the contrafactual conditional may be, we may be sure in advance that it cannot be truth-functional; for, obviously ordinary usage demands that some contrafactual conditionals with false antecedents and false consequents be true and that other contrafactual conditionals with false antecedents and false consequents be false. (Quine, 1950)

An example of such a pair for Quine is given in (19).

(19) a. If I weighed more than 150 kg, I would weigh more than 100 kg.
b. If I weighed more than 150 kg, I would weigh less than 25 kg.

Suppose the speaker weighs exactly 70 kg. Then, both antecedents and consequents can be taken to be false (putting all component sentences in the indicative present tense), yet the first counterfactual is intuitively true, and the second false. Interestingly, putting the two constituent sentences both in present tense actually suggests that (*pace* Quine) the material conditional is equally inadequate to deal with indicative conditionals, since a sentence like *if I weigh more than 150kg, then I weigh more than 100kg* is intuitively true irrespective of whether one weighs 70 kg or not, whereas *if I weigh more than 150kg, I weigh less than 25kg* is intuitively false irrespective of the speaker's weight again.

In summary, we see that while the material conditional certainly captures some of the conditions under which an indicative conditional sentence is judged false, it supports some inferences whose validity is problematic in relation to both indicative and counterfactual conditionals. Furthermore, a two-valued truth-functional analysis simply fails to account for cases in which a conditional with a false antecedent is not automatically judged true. Yet further arguments hold against the material conditional, in particular the fact that it predicts inadequate truth conditions for *if*-clauses under the scope of specific operators (see Section 17.6).

17.3 Strict and variably strict conditionals

The first attempt to fix the inadequacies of the material conditional was made by C. I. Lewis (1918) with the definition of the strict conditional, intended to block the paradoxes of material implication, and going beyond the truth-functional analysis. A strict conditional is a material conditional under the scope of a necessity operator. On that analysis, "if A, C", means "necessarily, if A, C", which we will represent as $\Box(A \supset C)$.[3] Treating necessity operators as universal quantifiers over possible worlds, this means that the logical form of conditional sentences is as follows:

(20) $\forall w(A(w) \supset C(w))$

It is easy to see that this analysis blocks the paradoxes of material implication. For example, the counterpart of the schema of Truth of the Consequent (TC) $C \models A \supset C$ now is: $C \models \Box(A \supset C)$. The schema would be valid provided the following entailment held in first-order logic:

(21) $C(i) \models \forall w(A(w) \supset C(w))$

However, C may hold at world i without holding at all worlds in which A holds. Similarly, a strict conditional analysis can account for Quine's pair,

[3] See Hughes and Cresswell (1996) for a presentation of modal logic and strict conditionals. Frege (1879) should be given credit for an anticipation of the strict conditional view. Frege distinguishes explicitly the material conditional $A \supset C$ from the quantified conditional $\forall x(A(x) \supset C(x))$ relative to natural language. In Frege (1879, §5), he writes about the material conditional: "the causal connection inherent in the word 'if', however, is not expressed by our signs"; in §11, he then writes about the quantified form: "*this is the way in which causal connections are expressed*" (his emphasis).

namely for why we judge (19a) true and (19b) false, even assuming the antecedent to be false at the actual world. Despite this, it is easy to see that the schemata of Contraposition (C), Strengthening of the Antecedent (S) and Transitivity (T) all remain valid under the strict conditional analysis. This is because, seen as a universal quantifier, the strict conditional is downward monotone on its antecedent, and upward monotone on its consequent.

A direct relative of the strict conditional that fixes that problem is the conditional of Stalnaker–Lewis (Stalnaker, 1968; Lewis, 1973), which Lewis has dubbed a "variably strict conditional", essentially because, where a strict conditional says: "if A, C" is true provided C is true in all the worlds where A is true, the variably strict conditional says: "if A, C" is true provided C is true in all the *closest* worlds to the actual world where A is true, where closeness depends on the world of evaluation.

The initial motivation for Stalnaker's analysis of "if A, C", based on an insight originally due to Ramsey (1929), is presented by him as follows:

> first, add the antecedent hypothetically to your stock of beliefs; second, make whatever adjustments are required to maintain consistency (without modifying the hypothetical belief in the antecedent); finally, consider whether or not the consequent is then true. (Stalnaker, 1968)

In Stalnaker's possible world framework, the notion of minimal adjustment is described in terms of selection functions. Given a pair consisting of a world w and antecedent A, $f(A, w)$ is taken to denote the closest world w' to w that makes the antecedent A true. Given this apparatus, a conditional "if A, C" is true at world w if and only if C is true at the closest A-world to w.

More formally, let "$>$" stand for the conditional operator, and define a selection model to be a structure $\langle W, R, V, \lambda, f\rangle$, where W is a set of worlds, R is a reflexive accessibility relation on W, V a valuation of the atomic sentences on worlds in W, λ is the so-called absurd world (satisfying every sentence), and f is a selection function (from pairs of propositions and worlds to worlds). Given such a model M, the truth conditions for conditional sentences of the form $A > C$ are as follows:

(22) $M, w \models A > C$ iff $M, f(A, w) \models C$ (Stalnaker's semantics)

Selection functions satisfy five conditions, namely:

(23) a. $f(A, w) \models A$
b. $f(A, w) = \lambda$ only if there is no w' such that wRw' and $w' \models A$
c. if $w \models A$, then $f(A, w) = w$
d. if $f(A, w) \models C$ and $f(C, w) \models A$, then $f(A, w) = f(C, w)$
e. if $f(A, w) \neq \lambda$, then $wRf(A, w)$

Clauses (23b) and (23e) ensure that the selected world is the absurd world exactly when no possible world satisfies the antecedent.[4] Clause (23a) means

[4] (23e) is not originally included in Stalnaker (1968) but is needed to ensure the converse of (23b), see Nute (1980).

that the closest A-world is an A-world, and (23c) that the closest A-world is the actual world if the actual world satisfies A (a proviso also called Centering). Clause (23d), finally, is needed to ensure consistency in the ordering of possible worlds induced by the selection function (whereby if $f(A, w) = w'$, then w' is prior to all other worlds in which A is true).

Like the strict conditional analysis, Stalnaker's semantics invalidates the paradoxes of material implication, but this time it also invalidates Contraposition, Strengthening of the Antecedent and Transitivity. For instance, consider the problematic instance of strengthening of the antecedent in (15). Assume that the closest world in which the match is struck is a world in which it lights ($f(struck, w) \models light$). This is compatible with the closest world in which the match is soaked and struck being a world where it does not light ($f(soaked \wedge struck, w) \models \neg light$). This implies that the closest world in which the match is struck is not a world in which it is first soaked.

Unlike Stalnaker, Lewis does not use selection functions; however, his semantics for counterfactuals involves the notion of similarity or closeness between worlds. The main difference with an approach in terms of selection functions is that Lewis drops two requirements underlying Stalnaker's approach, the so-called *Uniqueness assumption*, and the *Limit assumption*. The Uniqueness assumption is the assumption that for every antecedent A and world w, there is at most one closest A-world to w. The Limit assumption is the assumption that for every antecedent A and world w, there is at least one closest A-world to w. In order to capture those differences, Lewis's models set an explicit similarity relation between worlds, where $x \leq_w y$ means that x is closer to w than y.[5] Lewis's truth conditions for conditionals are the following: "if A, C" is true in w iff either A holds in no possible world, or every world where A and C are true together is more similar to w than any worlds where A and $\neg C$ hold together, that is:[6]

(24) $M, w \models A > C$ iff either there is no w' such that wRw' and $w' \models A$, or there is an x such that $M, x \models A \wedge C$ such that there is no y such that $y \leq_w x$ and $M, y \models A \wedge \neg C$ (Lewis's semantics)

Like Stalnaker's semantics, Lewis's semantics invalidates Contraposition, Strengthening of the Antecedent, and Transitivity. It makes three predictions regarding natural language that depart from Stalnaker's system, however.

The first relates to the Uniqueness assumption and concerns the schema of Conditional Excluded Middle (CEM), that is:

(25) $(A > C) \vee (A > \neg C)$ (CEM)

[5] The relation $\leq_w$ is a weak ordering, namely it is transitive, and complete. Further assumptions are made by Lewis concerning the actual world and the relation between accessible and inaccessible worlds from a given world.

[6] Note that Lewis's symbol for the conditional is $\Box\!\!\rightarrow$. We deliberately use the same symbol $>$ for both Lewis's and Stalnaker's conditional connective.

CEM is valid on Stalnaker's semantics, because the closest *A*-world is necessarily a *C*-world or a non-*C*-world. Lewis's semantics, however, permits ties between worlds. In particular, there can be two *A*-worlds that are equally close to the actual world, such that one is a *C*-world, and the other is a non-*C*-world. An example in support of this prediction is Quine's Bizet–Verdi example, where neither counterfactual seems to be true:

(26) a. If Bizet and Verdi had been compatriots, they would have been French.
b. If Bizet and Verdi had been compatriots, they would have been Italian.

A second and related difference concerns the treatment of negation. In Stalnaker's semantics, provided A is a possible antecedent, the negation of a conditional $\neg(A > C)$ is equivalent to the Conditional Negation $(A > \neg C)$. This is an important difference with the material conditional analysis. As the Bizet–Verdi example shows, however, in Lewis's approach, $\neg(Compatriots > Italians)$ does not imply $(Compatriots > \neg Italians)$.

The third difference finally pertains to the Limit assumption. Lewis points out that if we say things like *if this line were longer than it is, . . .* , about a line one inch long, there is no closest world where the line is more than one inch long, at least if we order worlds with regard to how little the line differs in size from its actual size. Lewis's argument is cogent. However, it also creates problems. An objection made by Stalnaker (1980) against giving up the Limit assumption concerns a similar case. Suppose Mary is 5 cm shorter than Albert. Clearly, according to Lewis's metric of similarity, there will be closer and closer worlds where Mary is taller than she actually is. In that case, Lewis's semantics predicts the truth of the following:

(27) If Mary were taller than she is, she would be shorter than Albert.

The reason is that a world where Mary is 1 cm taller than she is is a world where she is taller than she actually is, and closer to the actual world than any world in which she is taller than she is and taller than Albert. However, it seems one would like to say:

(28) If Mary were taller than she is, she might be taller than Albert.

In Lewis's semantics, *might* counterfactuals are defined as duals of *would* counterfactuals, so as of the form $\neg(A > \neg C)$. If (27) is true, then (28) must be false, which is inadequate. There is a way out for Lewis, however, namely to assume a different metric of similarity and, for instance, to postulate that all worlds in which Mary is up to 5 cm taller than she is are equally close to the actual world. As emphasized by Schlenker (2004), however, this move amounts to restoring the Limit assumption.

With regard to the set of valid formulae, Conditional Excluded Middle is the distinguishing principle between Lewis's and Stalnaker's system. As it turns out, failure of Uniqueness or of the Limit assumption suffice to invalidate CEM. However, both the Limit assuption and the Uniqueness assumption are required to make CEM a valid principle. Interestingly, it can be seen that CEM is not a valid principle either under the analysis of conditionals as strict conditionals. In both Lewis's and Stalnaker's semantics, however, the conditional is intermediate between a strict and a material conditional, that is we have (assuming a reflexive relation of accessibility for the necessity operator) the following validity:

(29) $\Box(A \supset C) \models (A > C) \models (A \supset C)$

Thus, the Stalnaker–Lewis conditional is weaker than a strict conditional (in that it is non-monotonic), but like the latter it remains stronger than the material conditional.

17.4 *If*, *and*, and *or*

We saw that the conditional of Stalnaker–Lewis invalidates some problematic laws of the material conditional. At the same time, it fails to validate three laws that we initially listed as plausible for indicative and counterfactual conditionals, namely the law of Import–Export (IE), the law of Or-to-If (OI), and the law of Simplification of Disjunctive Antecedents (SDA):

(30) a. $(A > (B > C)) \models ((A \wedge B) > C)$ (IE)
b. $(A \vee C) \models (\neg A > C)$ (OI)
c. $(A \vee B) > C \models (A > C) \wedge (B > C)$ (SDA)

IE fails since the closest B-world(s) to the closest A-world(s) need not be the closest $A \wedge B$-worlds. Similarly, SDA fails because the closest $A \vee B$-world(s) may satisfy only B and not A, and so the closest A-world(s) may fail to make C true. Finally, OI fails because $A \vee C$ may be true only because A is true: thus, the closest $\neg A$ world(s) may very well fail to satisfy C.

Each of these inferences is generally considered to be highly plausible, which suggests that some amendment is needed on the semantics proposed by Stalnaker and Lewis: either by the consideration of some additional semantical mechanism, or by some deeper modification of the semantics itself. Let us consider IE first, which has led McGee to propose a revision of the semantics of Stalnaker and Lewis.[7] According to McGee, the validity of IE is "a fact of English usage, confirmed by numerous examples" (1989, p. 489). McGee's semantics accommodates IE essentially by the following modification of Stalnaker's semantics: instead of defining truth relative to a world

[7] McGee's motivations are actually deeper, as McGee's proposal is to establish a link between Stalnaker's possible-world semantics and Adams's probabilistic semantics for conditionals (Adams, 1975), on which an argument is probabilistically valid iff the premises cannot be highly probable without the conclusion being highly probable. See Adams (1998) for a comprehensive account of the notion of probabilistic validity, and our remarks below in Section 17.7.

only, it defines truth relative to a world and a factual (Boolean) hypothesis. Assuming $f(A, w) \neq \lambda$, the semantics goes as follows, for A and B being factual sentences:

(31) a. $M, w \models_A p$ iff $M, f(A, w) \models p$
b. $M, w \models_A \neg\phi$ iff $M, w \not\models_A \phi$
c. $M, w \models_A (\phi \wedge \psi)$ iff $M, w \models_A \phi$ and $M, w \models_A \psi$
d. $M, w \models_A (\phi \vee \psi)$ iff $M, w \models_A \phi$ or $M, w \models_A \psi$
e. $M, w \models_A (B > \phi)$ iff $M, w \models_{(A \wedge B)} \phi$

By definition, $M, w \models \phi$ iff $M, w \models_{\top} \phi$. Clause (31e) is what ensures the validity of IE. The validity of IE, on the other hand, forces some other prima facie plausible features of the Stalnaker–Lewis conditional to drop.[8] The most spectacular case concerns the schema of *Modus Ponens*. In McGee's framework, Modus Ponens (MP) remains valid for unembedded conditionals but can fail for compound conditionals.[9] An example given by McGee (1985) for this failure is the following:

(32) a. If a Republican wins the election, then if it's not Reagan who wins the election, it will be Anderson.
b. A Republican will win the election.
c. If it's not Reagan who wins the election, it will be Anderson.

The context of McGee's example is that of the 1980 US presidential elections, in which Reagan was ahead in the polls, with Carter as the main Democrat contender, and Anderson as a "distant third". In this context, McGee points out that one can accept (32a) and (32b) and refuse to accept (32c), based on the belief that if it's not Reagan who wins the election, it will be Carter. Let M be a model in which: $M, w \models_{(R \vee A) \wedge \neg R} A$, $M, w \models R \vee A$ and $M, w \not\models_{\neg R} A$. The first premise says that the closest world where either Reagan or Anderson is elected, and where Reagan is not elected, is a world where Anderson is elected. The conclusion, however, denies that the closest world where Reagan is not elected is a world where Anderson is elected. Importantly, this can be true only because the closest world where Reagan does not win the election is no longer assumed to be a world where a Republican wins.

It should be noted that in McGee's semantics, the sentential schema $(R \vee A) > (\neg R > A))$ (usable to get a logical paraphrase of (32a)) is valid. In argument form, however, the inference from Or-to-If is not valid, just as in Stalnaker's and Lewis's case.[10] In Stalnaker's or Lewis's semantics, indeed, this can fail to hold if the closest world where Reagan or Anderson wins is a world where only Reagan wins. According to Stalnaker (1975), the failure of OI is not a defect of the semantics, for if it were valid, from the fact that

8 Relatedly, McGee appears to give up the postulate that $f(A, w) = w$ whenever $w \models A$.

9 See also Yalcin (2012a) for a recent attack on *modus tollens* for conditionals. Yalcin's proposed counterexample involves the interaction of conditionals with the modal *probably*.

10 This exemplifies the failure in McGee's framework of the deduction theorem, namely of the equivalence beween $A \models C$ and $\models A > C$.

$A \models A \vee B$, one could infer $A \models \neg A > B$, a form of the paradox of the Falsity of the Antecedent (FA). Stalnaker's suggested treatment for OI is pragmatic because of that. On Stalnaker's view, OI is indeed a *reasonable* inference, though not a valid inference. The way Stalnaker captures the notion of a reasonable inference is by introducing the notion of the context set, that is the set of worlds compatible with what the speaker presupposes. According to him "when a speaker says 'if A', then everything he is presupposing to hold in the actual situation is presupposed to hold in the hypothetical situation in which A is true". This is reflected in Stalnaker's system by a defeasible constraint on selection functions, (33):

(33) **Constraint on selection**: the world selected by the antecedent of a conditional must be a world of the context set.

An additional assumption needed by Stalnaker is that in order to utter "*A* or *B*", the speaker must allow each disjunct to be true without the other in the context set (the context set contains $A \wedge \neg B$-worlds and $\neg A \wedge B$-worlds). Consider the sentence "if $\neg A$ then . . . ": the closest $\neg A$-world must be a world of the context set, and it must satisfy $\neg A$; hence, it has to be a B-world given the constraint on the assertion of disjunctions.

The debate about whether to deal with failures of IE and OI semantically or pragmatically is probably even more prominent with regard to SDA. Failure of the Stalnaker–Lewis semantics to satisfy SDA was pointed out early on by several scholars (Creary and Hill, 1975; Nute, 1975; Fine, 1975a; Ellis et al., 1977). At least three strategies have been explored to deal with SDA: one has been to question the Boolean status of *or* (see Loewer, 1976; van Rooij, 2006; Alonso-Ovalle, 2009), but to maintain a non-monotonic semantics. The leading principle behind that approach is that *or* selects a set of alternatives and that universal quantification over those is what effects the simplification (see Alonso-Ovalle for details). A distinct strategy, more along the lines of Stalnaker's treatment of OI, maintains a non-monotonic semantics and maintains that *or* is Boolean; it argues that conversational maxims require that the antecedent "if A or B" cannot select just the closest A-worlds, or just the closest B-worlds, but has to select both the closest A-worlds and the closest B-worlds, and any worlds in between (Klinedinst, 2009). Roughly, by saying *if Mary or Susan come to the party*, the speaker has to mean something different from just *if Mary comes to the party* or *if Susan comes to the party*. A third and more radical strategy is to forsake the Lewis–Stalnaker semantics entirely. Such a proposal has been made recently by Fine (2012) and involves adding more structure to the possible-worlds framework than just similarity relation. Fine uses a version of situation semantics in which formulae are made true or false by states, with relations of exact and inexact verification and falsification. Essentially, his proposal is that $A > C$ is true at w iff whenever state t exactly verifies A, and u is a possible outcome of t relative to w, u inexactly verifies C. A disjunction is exactly verified by a state in his account iff the state exactly verifies one of the disjuncts or their conjunction. Finally, it should be noted that SDA is a valid inference rule under a plain strict conditional analysis of the conditional. Several authors see an additional argument in favor of the strict conditional analysis here (Warmbrōd, 1981a; Lycan, 2001).

All of these strategies, finally, also have to accommodate the fact that SDA does have some exceptions. A canonical example is that of McKay and van Inwagen (1977):

(34) If Spain had fought with the Axis or the Allies, she would have fought with the Axis.

In that case, the inference *if Spain had fought with the Allies, she would have fought with the Axis* seems just wrong. Because of examples like this, all of the aforementioned strategies do rely on some pragmatic principles to explain away this inference. What the example suggests, here, is that one of the two alternatives mentioned in the antecedent is not on a par with the other. Fine (2012), for instance, considers SDA to be valid, but a sentence like (34) to be pragmatically odd because of this lack of symmetry between the disjuncts. Lycan sees the strict conditional analysis as capable of accounting for both valid and invalid cases of SDA (though, as pointed out above, the default is for it to validate SDA). Klinedinst's approach, on the other hand, could explain that this is a case in which "if A or B" selects only one class of closest worlds.

In summary, IE, OI, and SDA all are prima facie cases for the idea that the Stalnaker–Lewis analysis of conditionals fails to capture some valid inferences based on conditionals. In the case of OI and SDA, we see that the inference can be accommodated based on pragmatic principles concerning the use of disjunction. In the case of IE, the problem appears to be syntactic, more than pragmatic, namely it concerns the fact that right-nested *if*-clauses add up to the set of hypotheses relevant to evaluate the consequent.

17.5 Referential vs. quantificational analyses

In this section we discuss two refinements of the framework proposed by Stalnaker and by Lewis. Both approaches provide a compromise between Stalnaker's semantics and Lewis's semantics by discarding the Uniqueness assumption, but retaining the Limit assumption. On the first approach, which we can call the *referential treatment* of *if*-clauses, the truth conditions for conditionals remain essentially those given in Stalnaker (1968), except that selection functions now are plural choice functions, that is, relative to an antecedent and world they select a set of worlds instead of a unique world. Empirical arguments in favor of this approach are put forward by Schlenker (2004) in particular, based on a comparison between the semantic behavior of *if*-clauses and the semantic behavior of plural definite descriptions. The second variant we have in mind, which we can call the *quantificational treatment* of *if*-clauses, consists in treating conditionals literally as strict conditionals, but coming with a mechanism of variable domain restriction. This approach has been advocated in particular by Warmbrōd (1981b), von Fintel (2001), and Lycan (2001).

Before examining the main differences between the two approaches, we should highlight what they have in common. The common part is the idea that "if A, C" is true iff C holds in all the closest A-worlds to the actual world. That is, the two approaches will end up predicting identical truth conditions. The two approaches essentially differ concerning the syntax–semantics interface. On the plural choice function analysis defended by Schlenker (2004), the logical form of a conditional "if A, C" is implicitly as follows:

(35) $[\iota W : A(W)](\forall w : W(w))(C(w))$: the (closest) A-worlds, they are such that every one of them is a C-world.

On the strict conditional analysis with changing domain restriction, the logical form rather is as follows:

(36) $(\forall w : R(w))[A(w) \supset C(w)]$: for every world of the restricted domain, either A is not true there or C is.

In (36), R is a parameter that acts as a domain restrictor. Lycan, for that matter, calls this kind of analysis a "parametrically strict conditional"; it may equally be called a contextualized strict conditional. Importantly, this approach need not presuppose that relative to any given world there is a unique A-world. Because of that, the approach also invalidates CEM, like the standard strict conditional analysis.

Both approaches can account for the non-monotonic behavior of conditionals. However, this non-monotonic behavior results from different mechanisms. On Schlenker's approach, non-monotonicity is a property typical of the behavior of definite descriptions, as first observed by Lewis (1973) himself. Indeed, definite descriptions can be seen to fail analogues of Contraposition, Transitivity, and Strengthening of the Antecedent, since in particular the following are invalidated:

(37) a. [*The A*][*C*] $\nvDash$ [*The not C*][*not A*]
b. [*The A*][*B*], [*The B*][*C*] $\nvDash$ [*The A*][*C*]
c. [*The A*][*C*] $\nvDash$ [*The AB*][*C*]

For example, Lewis's original example for the counterpart of failure of strengthening is (38):

(38) The pig is grunting, but the pig with floppy ears is not grunting.

The first occurrence of *the pig* is taken to denote the most salient pig, while the second occurrence, modified with *with floppy ears*, denotes a distinct pig. On the referential analysis of definite descriptions proposed by Schlenker, non-monotonicity directly results from the fact that definite descriptions rely on a salience ordering that varies with the property at issue.[11]

On the parametric strict conditional analysis, the non-monotonic behavior of conditionals is essentially the effect of the changing domain restriction of the universally quantified variable. One of the advantages of handling conditionals as parametrized strict conditionals in this way is also that it gives more flexibility than either Lewis's or Stalnaker's semantics to deal with non-monotonicity. Consider the following example:

(39) If John is with Mary, then he is not with Susan. So if John is with Susan, he is not with Mary.

This arguably is a case in which Contraposition holds. The way it can be predicted is by letting the domain restriction remain constant from one conditional to the next. Contrast this with Example (14). The latter arguably corresponds to a case in which each antecedent sets a different domain restriction:

(40) a. If Goethe had lived past 1832, he would be dead now. But if Goethe were not dead today, he would have lived past 1832.

b. $(\forall w : R(w))[A(w) \supset C(w)]$. $(\forall w : R'(w)[\neg C(w) \supset A(w)]$

In the first conditional, $R(w)$ can be taken to select worlds in which every individual lives less than 120 years after his or her birth. In the second conditional, $R'(w)$ now selects worlds in which no limitation is set on the life span of individuals. This strategy, which underlies Warmbrōd and Lycan's approach to conditionals, is at the bottom of the dynamic approach of counterfactuals presented by von Fintel (2001). Part of the motivation for von Fintel's approach precisely concerns monotonicity issues, since von Fintel observes that NPI, which are typically assumed to be licensed in downward-entailing environments (Ladusaw–Fauconnier generalization), can appear in the antecedents of conditionals, as in (41):

(41) If you had left any later, you would have missed the plane.

As pointed out by von Fintel, if conditionals are assumed to be non-monotonic, we lose a connection between NPI-licensing and downward entailingness. One way of recovering it is to maintain that conditionals are monotone within limits specified by contextual domain restrictions (see von Fintel, 1999). It is less clear whether the referential analysis can accommodate the same limited form of downward entailingness for conditionals.

An additional argument in favor of the analysis of *if*-clauses either as contextually restricted universal quantifiers, or as definite descriptions, is that

[11] It should be stressed, however, that Schlenker does not argue so much for non-monotonicity in his paper as much as for the idea that *if* is the counterpart of *the* in the modal domain. He writes: "even if the monotonic analysis of conditionals is correct, if-clauses should be analyzed as (monotonic) plural descriptions rather than as structures of universal quantification".

either of them can accommodate the combination of *if* with particles such as *only* and *even*. *Even* and *only* are words that can combine with definite descriptions, as in *even the pig*, or *only the pig*. On the account of *if*-clauses as plural definite descriptions, the analysis of *only if* and *even if* can follow the same path as the analysis of *even* and *only* prefixing determiner phrases. In the case of the parametric strict conditional analysis, Lycan (2001, p. 17) puts forward as an advantage of the theory the fact that assuming "if *A*, *C*" means "*C* in any event in which *A*", then "even if *A*, *C*" means "*C* in any event including any in which *A*" and "only if *A*, *C*" means "*C* in no event other than one in which *A*".

One of the issues regarding the choice between the analysis of *if*-clauses as referential definite descriptions vs. contextually restricted universal quantifiers, however, concerns compositionality. Lycan, for example, does not provide a compositional derivation of constructions such as *even if* and *only if*, but such an analysis would appear quite natural under the view of *if*-clauses as descriptions.[12] Secondly, the mechanism by which the restriction is set in a conditional appears to differ depending on the case: in (40a), for instance, $R(w)$ is a default interpretation; in (40b), by contrast, $R'(w)$ appears to be forced by the antecedent itself. Thirdly, failures of compositionality may generalize. Schlenker points out that the analysis of iterated conditional sentences, such as (42) below, "involves a drastic rearrangement of various parts of the sentence" if *if* is analyzed as a universal quantifier, though follows a natural order under the referential analysis:

(42) If John comes, if Mary comes as well, the party will probably be a disaster.

Additional arguments finally are given by Schlenker for the referential account, in relation to the analysis of *then* in *if*-clauses (see below Section 17.9).

In summary, both the contextualized strict conditional analysis and the referential analysis of *if*-clauses as plural definite descriptions offer different ways of amending and restructuring the Stalnaker–Lewis semantics for conditionals. The main difference between them concerns mostly compositionality, and the articulation between monotonicity and contextual domain restrictions.

17.6 *If*-clauses as restrictors

Whether as a material conditional, a strict conditional, or a variably strict conditional, logical theories of the conditional treat the conditional construction *if* ... *then* by means of a binary sentential connective. In that regard, they make no syntactic difference between *or*, *and*, and *if*. This does

[12] See Guerzoni and Lim (2007) for a compositional analysis of *even if* and a discussion of Lycan's view.

not mean that such theories are necessarily inadequate semantically, but they do not care about the syntax–semantics interface.[13] Several arguments can be given to show that coordination by means of *and* or *or* and subordination by means of *if* do not have the same syntax (see Geis, 1970, 1985; Lycan, 2001; Bhatt and Pancheva, 2007). For instance, *if*-clauses can appear both sentence-initially and sentence-finally, but not so for *and* or *or*:

(43) a. Joe left if Mary left.
b. If Mary left Joe left.

(44) a. Joe left and/or Mary left.
b. *and/or Mary left Joe left.

We saw that *if* can follow *even* or *only*, but not so for *and* and *or*:

(45) a. Lee will give you five dollars even if you bother him.
b. *Lee will give you five dollars even and/or you bother him.

More generally, there is a substantial body of evidence that *if*-clauses behave as adverbials, and that *then* is a pronominal adverb (see Iatridou, 1993; Lycan, 2001; Bhatt and Pancheva, 2007; we return to *then* in Section 17.9 below). The details of how such a view should be articulated vary between theories. Lycan, for instance, presents his version of the strict conditional analysis as an adequate way of dealing with subordination. In this section, we focus on the so-called Lewis–Kratzer analysis, which is based on separate evidence for the view that *if* behaves differently from *or* or *and*. Lewis (1975a) considered a range of constructions with *if*-clauses, in which *if*-clauses restrict adverbs of quantification, as in (16):

(46) a. Always, if it rains, it gets cold.
b. Sometimes, it it rains, it gets cold.
c. Most of the time, if it rains, it gets cold.

Whereas (46a) and (46b) can be paraphrased in first-order logic as $\forall t(R(t) \supset C(t))$ and $\exists t(R(t) \wedge C(t))$ respectively, (46c) cannot be paraphrased by means of a unary operator *Most* taking scope either over or under a material conditional or a conjunction (see Kratzer, 1991a; von Fintel, 1998b). For instance, suppose $\mathit{Most}\ t\ A(t)$ is true exactly if the cardinality of the set of individuals that are A is greater than the cardinality of the set of individuals that are not A. And assume that restricted or binary *most*, which we will write down as $[\mathit{Most}\ t : A(t)][C(t)]$, is true exactly if there are more AC individuals than $A\neg C$ individuals. It is easy to see, then, that $\mathit{Most}\ t(R(t) \wedge C(t))$, which says that most times are times at which it rains and it is cold, is stronger than what is intended by $[\mathit{Most}\ t : A(t)][C(t)]$. Conversely, $\mathit{Most}\ t(R(t) \supset C(t))$ is weaker, since it says that most times are either times where it does not rain, or times when it

[13] This does not include the referential and quantificational theories discussed in the last section, which, as linguistic theories, do care about this articulation.

is cold. Quite generally, it was proved by Kaplan and by Barwise and Cooper (1981) that the binary operator *most* cannot be expressed by unary *most* taking scope over a Boolean formula, unlike what happens for the restriction of *every*, which is expressible by the material conditional, or the restriction of *some* which is expressible by means of conjunction. As a matter of fact, even when we consider only the restriction of quantifiers such as *some* and *every*, no uniform Boolean operator can be used to express their restriction.

Taken together, these elements indicate that the operation of quantifier restriction is not adequately handled by means of a binary sentential connective in classical logic. Based on these considerations, Lewis pointed out that for adverbs of quantification more generally, "the *if* of our restrictive if-clauses should not be regarded as a sentential connective. It has no meaning apart from the adverb it restricts" (1975a). Kratzer (1986, 1991a) has offered to generalize Lewis's arguments. Her account consists in three related theses, which are (i) "There is no two-place if . . . then connective in the logical forms of natural languages", (ii) "If-clauses are devices for restricting the domains of various operators", and (iii) "Whenever there is no explicit operator, we have to posit one." On Kratzer's account, a bare conditional such as *if John leaves, Mary will leave* is equivalent to *if John leaves, then it must be the case that Mary will leave*, or *It must be the case that Mary leaves if John leaves*. Whether the modal *must* is overt or covert, the function of the *if*-clause is to restrict its modal base (the set of worlds quantified over by *must*).

One of the strengths of the Lewis–Kratzer account is that it derives the equivalence felt between sentences in which the operator appears above or below *if*:

(47) a. There is one chance in three that if you throw an even number, it will be a six.
b. If you throw an even number, there is one in three that it will be a six.

(47b), in that case, can be assumed to result from the logical form [there is one chance in three: even][six] by movement (with *even* as restrictor, and *six* as the nuclear scope of the operator [there is one chance in three]).[14] Similarly, it can be used to provide a direct justification of the law of import–export, namely the fact that right-nested *if*-clauses can be expressed by conjoining their antecedents into one antecedent. Specifically, the Lewis–Kratzer analysis of *if*-clauses is also particularly appropriate regarding the interaction of *if*-clauses with probability operators (see Kratzer, 1991a; Egré and Cozic, 2011). Grice (1989a), for instance, considers a scenario in which Yog played 100 games of chess, played white on 90 of those 100 games, won exactly 80 of those when he had white, and lost all of 10 games in which he had black. Grice considers the case in which a speaker talks about the last

[14] Huitink (2007) presents two different compositional implementations of the Lewis–Kratzer analysis, one by von Stechow, the other by von Fintel.

game, not knowing whether Yog had white or black. This is a case in which the speaker can truthfully say:

(48) a. There is a probability of 8/9 that if Yog had white, he won.
b. There is a probability of 1/2 that if Yog lost, he had black.
c. There is a probability of 9/10 that either Yog didn't have white or he won.

Clearly, we would not be able to explain the joint consistency of all three claims if each of the operators "there is a probability of x" was taking scope over a sentence analyzed as a material conditional, for all three are equivalent under the material conditional analysis. On the other hand, we get the right truth conditions if the *if*-clause, in the first two examples, is assumed to restrict a probability operator (or identically, a proportional quantifier):

(49) a. $[8/9 : white][win]$
b. $[1/2 : \neg win][black]$
c. $[9/10][\neg white \vee \ won]$

As another example, assume a domain with exactly three worlds, a, b and c, with equal probability, and assume that a and b are all and only worlds in which it rains, and a is the only world in which it gets cold. This is a case in which one can say:

(50) There is a probability of 1/2 that if it rains, it gets cold.

This is a case in which, relative to the probability distribution under consideration, no Boolean proposition over the domain can receive a probability equal to half (there are eight propositions expressible on the algebra, taking either probability 0, 1/3, 2/3, or 1). This indicates that the embedded sentence *if it rains, it gets cold* does not express any Boolean proposition in that case (see Hájek and Hall, 1994; Adams, 1998; Egré and Cozic, 2011).

Under the analysis of *if*-clauses as restrictors, however, adequate truth conditions for (50) are directly predicted. Importantly, this argument shows that the conditional probability that it rains, given that it is cold, cannot be equated to the probability of any two-valued proposition taken to represent the conditional sentence as a whole. This, in a nutshell, is the gist of Lewis's so-called triviality result for conditionals (1976), showing that one cannot in general equate the probability of a conditional sentence to the conditional probability of the consequent given the antecedent (an equation often called Adams's thesis in the more recent literature).[15]

Several aspects of Kratzer's analysis have been recently criticized, however, in particular regarding the interaction of theses (i) and (iii). One argument

[15] The literature on Adams's thesis and Lewis's triviality results is very large. See in particular Hájek and Hall (1994) for a technical survey, Bradley (2002) for a generalization of Lewis's result, Kaufmann (2009) for a recent comprehensive treatment of the probability of conditionals, and Douven and Verbrugge (2010) for an investigation of the empirical validity of Adams's thesis.

discussed by von Fintel (2007, 2011), and more recently by Huitink (2007) and Rothschild (2014), concerns cases of anaphor, such as in (51):

(51) a. If John leaves, Mary will leave.
b. I do not think so.

The argument given is that the anaphor introduced by *so* in (51b) should refer back to the conditional sentence in (51a), with its silent necessity operator. However, this would appear to say that the person who denies (51a) denies the whole modalized sentence expressed in (51a), which is too strong if the modality is an epistemic modality relative to the utterer of (51a). The way Kratzer's account can explain the example is either by assuming that the covert modal expresses necessity relative to both speakers, or that the anaphor picks up only the structural contribution of the antecedent and consequent to the proposition expressed in (51a) (see von Fintel, 2006). Based on this and on further arguments, von Fintel, Huitink, and Rothschild propose an alternative approach, namely to maintain the expression of *if ... then* by means of an unmodalized binary sentential connective, but to give up on using a two-valued underlying semantics.[16] We discuss the prospects of such an account in the next section.

17.7 Trivalent analyses

An important reason to entertain a trivalent analysis for conditional sentences concerns the proviso that a material conditional sentence is classically true whenever its antecedent is false. A common consideration is that an indicative conditional whose antecedent is not true cannot be evaluated as true or false and so remains indeterminate in truth value. Probably the first author to have made this proposal explicitly is De Finetti (1936), in a short paper about trivalent logic and conditional probability, where he contrasts two connectives, one called implication ($A \supset C$), and the other called subordination ($C|A$), with the truth tables as in Table 17.1 (columns are for the consequent C, and rows for the antecedent A).[17] In Table 17.1, 1 stands for true, 0 for false, and 1/2 for the third truth value (which De Finetti writes N).[18] Although De Finetti gives few comments on his tables, he motivates the one on the right by the consideration of bets. He gives the example of a bet on a running race supposed to take place the next morning. The target proposition is that if the race takes place, the winner will be so-and-so.

[16] See also Yalcin (2012a) on further elements of criticism of the restrictor view.

[17] We are indebted to Jean Baratgin and Guy Politzer for bringing De Finetti's paper to our notice. Milne (2012) points out that the idea of a defective truth table for the conditional was proposed independently by J. Schächter as early as 1935 (the same year as De Finetti's communication in Paris) and, in the area of psychology, by Wason in 1966.

[18] N stands for neither true nor false. We use $1/2$ instead of N, following Łukasiewicz (1970), since it is handy to use it for the other connectives, to preserve that conjunction is the minimum, disjunction the maximum, and negation the distance from 1, over the set $\{1, 1/2, 0\}$.

Table 17.1 *Three-valued material conditional (left) vs. De Finetti's (right)*

$A \supset C$	1	1/2	0
1	1	1/2	0
1/2	1	1/2	1/2
0	1	1	1

$C\|A$	1	1/2	0
1	1	1/2	0
1/2	1/2	1/2	1/2
0	1/2	1/2	1/2

De Finetti points out that if the race does not take place, the bet is called off.[19] The left table, for so-called implication, on the other hand, coincides with the table for the material conditional in Kleene's strong logic (or similarly, in Łukasiewicz logic). Unlike what De Finetti calls supposition, this conditional is exactly true when the antecedent is false, and when the consequent is true, thereby preserving the defining property of the bivalent material conditional.

De Finetti's table for so-called supposition has been put forward independently by Belnap (1970), and some of its recent advocates are McDermott (1996), Huitink (2008), and Rothschild (2014).[20] Its main interest in relation to the considerations of the previous section is that it appears to be suitable to deal with restricted quantification by means of *if*-clauses.[21]

In order to deal with quantifier restriction, Belnap proposes the following truth conditions (the case of *most* is a generalization not directly in Belnap, but see Huitink (2008)):

(52) a. $[\![\forall x(Cx|Ax)]\!] \neq 1/2$ provided $[\![\exists x Ax]\!] = 1$.
If so, $[\![\forall x(Cx|Ax)]\!]$ is the minimum of the set of $[\![Cd]\!]$ for every d such that $[\![Ad]\!] = 1$.

b. $[\![\exists x(Cx|Ax)]\!] \neq 1/2$ provided $[\![\exists x Ax]\!] = 1$.
If so, $[\![\exists x(Cx|Ax)]\!]$ is the maximum of the set of $[\![Cd]\!]$ for every d such that $[\![Ad]\!] = 1$.

c. $[\![Most\ x(Cx|Ax)]\!] \neq 1/2$ provided $[\![\exists x Ax]\!] = 1$. If so, $[\![Most\ x(Cx|Ax)]\!] = 1$ if among individuals d for which $[\![Ad]\!] = 1$, most of them are such that $[\![Cd]\!] = 1$; it is 0 otherwise.

[19] De Finetti (1937) identifies conditional probabilities as the betting quotients for such conditional bets and shows on the basis of a Dutch Book argument that these conditional probabilities should obey the so-called ratio formula $P(A|B) = P(A \wedge B)/P(B)$. On that occasion, De Finetti elaborates an algebra, later called "conditional event algebra", which is analogous to the trivalent logic described above. Milne (1997) provides an extensive philosophical and historical study of De Finetti's approach to conditionals.

[20] Belnap's original semantics for the conditional was soon thereafter modified in Belnap (1973), where Belnap no longer assumes that a conditional has to be defective whenever its antecedent is false. To prevent confusion, we will refer to this conditional primarily as the De Finetti–Belnap conditional, or simply as De Finetti's conditional (see Table 17.2, p. 523).

[21] This feature, explored by Belnap, was mentioned in a footnote by Lewis (1975a) as an alternative to the treatment of *if*-clauses as restrictors. Von Fintel (2006) should be credited for bringing attention to Lewis's remark in the last few years, and for opening again the debate about the validity of the Lewis–Kratzer analysis. Interest for the defective truth table also looms quite large in the literature on the psychology of conditionals. See in particular Evans et al. (1993), Politzer et al. (2010), and further references in Milne (2012).

By this mechanism, restriction can be handled uniformly for all three quantifiers considered in the previous section. In particular, (52a) is true provided all of the As are Cs. It is false if some A is not C. The sentence is indeterminate if no individual is A. (52b), similarly is true exactly when the sentence would be true in the bivalent case, is indeterminate if there is no A or no C, and is false if there is an A and every such A is not C. (52c), it should be noted, now provides a way of restricting unary *most* by means of the suppositional connective.

Another application of the De Finetti–Belnap table concerns the treatment of conditional sentences in the scope of probability operators (see McDermott, 1996; Rothschild, 2014). We saw in the previous section that in some cases, given a probability distribution, a sentence like *there is a probability of 1/2 that if it rains, it gets cold*, cannot be expressed by the assignment of a probability to any possible-world proposition. We explained in what sense this can be considered as evidence for the Lewis–Kratzer analysis of *if*-clauses. However, several philosophers, based on Lewis's triviality result, have defended the view that conditionals should not be seen as having truth conditions for that matter (in particular Adams, 1965; Gibbard, 1981; Edgington, 1995b, all representatives of the so-called "No Truth Value" view of conditionals). The trivalent analysis offers an alternative to both views. De Finetti (1936) introduced three-valued logic precisely to account for the logic of conditional probability, and McDermott (1996) and Rothschild (2014) consider the following notion of probability assignment for a conditional expressed by $(C|A)$. Let $[\![\phi]\!]_1$ be the set of worlds in which ϕ takes value 1, and $[\![\phi]\!]_0$ be the set of worlds in which ϕ takes the value 0. Given a probability distribution p over the sentences of a propositional language with the De Finetti–Belnap suppositional connective, define an extended probability assignment to be the function p' such that the following equation holds:

$$p'(A) = \frac{p([\![A]\!]_1)}{p([\![A]\!]_1 \cup [\![A]\!]_0)}.$$

This is the probability that A is true, given that it is defined. As shown by McDermott and Rothschild, this can be used to capture conditional probabilities in terms of the probability of the suppositional conditional. For instance, consider again the domain W with three worlds a, b, c with equal probability, and such that $[\![A]\!]_1 = \{a, c\}$ and $[\![C]\!]_1 = \{a\}$. One can check that $p'(C|A) = p([\![C \wedge A]\!]_1/p([\![A]\!]_1) = 1/2$, that is, the probability of the conditional is equal to the conditional probability.

Some further benefits of this trivalent analysis are worth pointing out. In particular, the law of Import–Export is a valid law for the De Finetti conditional, assuming the Strong Kleene analysis of conjunction, and defining validity as preservation of the value 1 from premises to conclusion. Likewise, the paradoxes of material implication are not valid schemata, and neither is Strengthening of the Antecedent, nor Contraposition. Transitivity holds, however, indicating that the latter three schemata need not hold or fall together. Likewise, $\neg(C|A)$ and $(\neg C|A)$ are equivalent under that definition of validity.

Not all of the desirable features of the indicative conditional are retained, however, under that definition of validity. First of all, defining validity in terms of preservation of the value 1 overgenerates: it implies that from "if A then C", one can validly infer "if C then A", a fallacy known as the Affirmation of the Consequent. There are several ways around this problem. One way is to maintain the standard definition of validity, but to constrain the trivalent truth table of the conditional so as to avoid the problem (namely Farrell, 1979, whose truth table coincides with De Finetti's, except that $v(C|A) = 0$ when $v(A) = 1/2$ and $v(C) = 0$). Another approach is to modify the usual definition of logical consequence. Three-valued logic offers more options than two-valued logic for that: besides validity as preservation of the value 1, one can define validity as preservation of the value > 0. As applied to the Strong Kleene valuation scheme for disjunction, conjunction, and negation, the latter definition gives the logic LP (Priest's "Logic of Paradox", 1979), which is dual to Kleene's Strong logic (standardly called K3; see Priest, 2008 for an overview of both logics).

The definition of validity as preservation of values > 0 from premises to conclusion blocks the Fallacy of Affirming the Consequent for De Finetti's scheme. It preserves the equivalence between wide scope negation and narrow scope negation and the law of Import–Export, and it invalidates Transitivity. But this time it also validates some problematic schemata, in particular the paradoxes of material implication, as well as Contraposition and antecedent strengthening. Because of that, one influential choice in relation to De Finetti's schema (for instance McDermott, 1996, section 4), has been to define validity by requiring both the preservation of value 1 from premises to conclusion, *and* as the preservation of value 0 from conclusion to premises. As applied to the Strong Kleene connectives, this corresponds to taking the intersection of K3 and LP, a logic sometimes called S3 (for instance in Field, 2008, for "symmetric Kleene logic"), since preserving value 0 from conclusions to premises is equivalent to preserving value $>$ 0 from premises to conclusion. Under this combined definition of validity, only the schema of Conditional Negation and Import–Export remain valid among the main schemata we have discussed (see the Appendix, Table 17.2).

For McDermott, an additional motivation for the choice of this definition of logical consequence is that it makes a bridge between a probabilistic notion of validity (along the lines of Adams's, (1998), definition of p-validity), intended to mirror the degree to which a proposition is accepted or assertable, and the trivalent notion of validity, in the form of the following sufficiency condition: if A logically implies C, then $p'(A) \leq p'(C)$, where $p'(\phi)$ is defined as above as the extended probability of ϕ.[22]

[22] Let $[\![A]\!]_1 \subseteq [\![C]\!]_1$, and $[\![C]\!]_0 \subseteq [\![A]\!]_0$, and let $p([\![A]\!]_i) = a_i$, for $i = 1, 1/2, 0$, and likewise $p([\![C]\!]_i) = c_i$. Then, $a_1 \leq c_1$, and $c_0 \leq a_0$, which implies that $\frac{a_1}{a_1+a_0} \leq \frac{c_1}{c_1+c_0}$, that is $p'(A) \leq p'(C)$.

The choice of the S3-schema does not avoid an undergeneration problem, however, depending on how some inferences are viewed. In particular, Modus Ponens and Modus Tollens are not valid for De Finetti's conditional, and other standard schemata are lost for the other connectives (in particular Disjunctive Syllogism, the inference from $A \vee C$ and $\neg A$ to C). The Or-to-If inference from $A \vee C$ to $(C|\neg A)$ is not valid either in case A is true, and the reader can check that Simplification of Disjunctive Antecedents is not valid in case exactly one of the disjuncts is undefined.[23] A proposal made by Huitink (assuming validity to be value 1-preservation) is that OI can be pragmatically regained in terms of Strawson-entailment (see Strawson, 1952; Belnap, 1973; von Fintel, 1999) namely for the case where one assumes that $(C|\neg A)$ is either true or false, which forces $\neg A$ to be true. This suggests that, even in the domain of trivalent analyses, some pragmatic machinery may need to be brought in to deal with specific inferences. On the other hand, appeal to Strawson-entailment may be too powerful a mechanism in the case of conditionals (as opposed to presupposition, see Belnap, 1973), since it might actually rescue all the patterns listed as invalid under the original scheme for consequence (see Table 17.2).[24]

To conclude this section, we should point out that several other partial and trivalent analyses have been suggested for the conditional (see Bradley, 2002; Cantwell, 2008, among others), as well as many-valued semantics more generally (see Stalnaker and Jeffrey, 1994; Kaufmann, 2009). Giving an overview of those would be beyond the scope of this chapter: even for the case of three-valued conditionals, we can see that the definition of what counts as a good conditional depends not only on the choice of a particular valuation scheme for the connectives, but again on what counts as an adequate definition of validity for a given scheme. Another pressing issue for trivalent approaches, moreover, concerns the treatment of counterfactual conditionals. For three-valued approaches as well as for two-valued approaches, the issue of non-truth-functionality raised by Quine (1950) appears to hold equally (all the more since, obviously, not all counterfactual conditionals should be considered undefined in truth value on the grounds that their antecedent is contrary to fact). This, however, is not necessarily an argument against a three-valued approach, but the indication that more machinery needs to be adduced to deal with tense and mood proper.[25]

[23] Both problems are averted if validity is defined only as preservation of the value > 0, but not the Modus Ponens and Modus Tollens cases.

[24] According to Huitink (p.c.): "Strawson-entailment doesn't apply across the board, but only when the premises and conclusion can *consistently* be assumed to have a truth-value given that the premises are true." An example Huitink gives to illustrate this point is: "Or-to-if is also Strawson-valid, but Strawson-entailment places a cut between ordinary cases, (where 'A or C' is true and both A and C are still open) and those where 'A or C' is grounded in A. In the latter case, 'if not-A then C' cannot be defined."

[25] See Farrell (1979) for a discussion of three-valued logic in connection to counterfactual conditionals. Farrell basically argues that modal operators need to be added in to handle counterfactuals in that framework.

17.8 Indicative vs. counterfactual conditionals

A central division within conditional sentences is the division between so-called *indicative* and *subjunctive* conditionals. A classic example of the division is Adams's pair (1970):

(53) a. If Oswald did not kill Kennedy, then someone else did.
b. If Oswald had not killed Kennedy, then someone else would have.

As pointed out by Adams, the two sentences do not have the same truth conditions. (53a) is true given what we know about Kennedy's death, namely that Kennedy was killed by someone. (53b) is not obviously true, however, since even under the additional assumption that Kennedy was actually killed by Oswald, the sentence will only be true to someone who believes there was a conspiracy to kill Kennedy. (53a) is called an indicative conditional sentence: in particular, it uses past indicative in both the antecedent and the consequent. (53b) is called a subjunctive conditional: in that case it uses the past in the antecedent, and subjunctive *would* in the consequent. A clearer illustration of the difference is given by cases in which the English subjunctive appears both in the antecedent and consequent, as in:

(54) If Mary were rich, she would be happy.

Iatridou (2000) defines the subjunctive mood as "the morphological paradigm that appears in the complement of verbs of volition and/or command". In English, *were* and *would* both correspond to such paradigms, as evidenced by such sentences as: *I wish I were rich*, or *I wish it would rain*. So-called subjunctive conditionals are often associated to the expression of counterfactuality in language. However, it is widely agreed that this is a misnomer (Iatridou, 2000; Kaufmann, 2005). Iatridou points out that some languages use the subjunctive to express counterfactuality (namely, German, Icelandic, Spanish, Italian), whereas other languages simply do not have a separate subjunctive mood (Danish, Dutch), or some languages that have a subjunctive mood do not use it to express counterfactuals (namely French). An illustration of the fact that in English a conditional can be in the subjunctive without expressing a counterfactual conditional is given by Anderson's (1951) example:

(55) If the patient had taken arsenic, he would show exactly the same symptoms that he does in fact show.

In uttering (55), the speaker indicates that he considers it an open possibility that the patient took arsenic. From a semantic point of view, therefore, it is more adequate to talk of a division between counterfactual and non-counterfactual conditionals, to distinguish between two kinds of cases: those in which the antecedent is assumed to be false in the context, and those in which it is not assumed to be false. The indicative–subjunctive distinction is morphological rather than semantic. In English, however, the relation between morphology and counterfactuality seems to be the following: *the subjunctive is necessary to express counterfactuality*, or equivalently, *the expression of counterfactuality bans the indicative*, that is, indicative implies non-counterfactuality. However, *the use of the subjunctive is not sufficient to express counterfactuality*.

Ever since the work of Goodman (1947), the question has been asked whether a unified semantics can be given for indicative and counterfactual conditionals. Lewis (1973) famously considered indicative conditionals and counterfactual conditionals to have distinct truth conditions (for him, in particular, indicative conditionals had the truth conditions of the material conditional). An opposing view is expressed in the work of Stalnaker, who basically considers that indicative and counterfactual conditionals have identical truth conditions, but that they come with different pragmatic presuppositions. In this section we first briefly explain the main ingredients of Stalnaker's account and then give an overview of its relation with more recent work about the interaction between tense and mood in conditionals.

The way Stalnaker (1975) accounts for the division between indicative and counterfactual conditionals is by the same mechanism used to account for SDAs, namely by means of the constraint on selection functions exposed in (33), that "if the conditional is evaluated at a world in the context set, then the world selected must, if possible, be within the context set as well". Let S denote the context set, namely the set of propositions mutually believed by the participants in the conversation, and let $f(S, \phi)$ denote the set of worlds $f(w, \phi)$ such that $w \in S$, that is the set of closest ϕ-worlds to the worlds in the context set. More formally, Stalnaker's selection constraint is expressible as follows (see von Fintel, 1998a):

(56) if $S \cap A \neq \varnothing$, then $f(S, A) \subseteq S$

If we consider A to be some antecedent *if*-clause, then the constraint says that if the antecedent is compatible with the context set, the closest world to the antecedent will also be in the context set. An illustration of Stalnaker's constraint can be given on the indicative Oswald case (53b). Here the shared presupposition between speakers is that Kennedy was killed by someone (K), that is: $S \subseteq K$. Clearly, the proposition that Kennedy was killed can be decomposed into worlds where Oswald was the killer (O) and worlds where someone else was the killer (E). By the selection constraint, $f(\neg O, S) \subseteq S$, hence $f(\neg O, S) \subseteq K$. Moreover, by clause 1 of Stalnaker's semantics, $f(\neg O, S) \subseteq \neg O$, hence $f(\neg O, S) \subseteq E$, which means that the closest world where Oswald did not kill Kennedy is a world where someone else did.

In contrast to the case of indicative conditionals, Stalnaker makes the hypothesis that "the subjunctive mood in English and some other languages is a conventional device for indicating that presuppositions are being suspended, which means in the case of subjunctive conditional statements that the selection function is one that may reach outside the context set". This corresponds to the following feature of the context:

(57) When the subjunctive is used, possibly $f(A, S) \nsubseteq S$

To illustrate it, assume that it is now presupposed that Oswald actually killed Kennedy, that is $S \subseteq O$. Necessarily $f(\neg O, S) \subseteq \neg O$, hence $f(\neg O, S) \subseteq \neg S$. In that case, the closest world where Oswald did not kill Kennedy must be outside of the context set, but this can be a world where Kennedy is not killed.

An important aspect of Stalnaker's theory is that the use of the subjunctive does not always force an interpretation that goes outside of the context set. An example given by Stalnaker concerns the following piece of reasoning:

(58) The murderer used an ice pick. But if the butler had done it, he wouldn't have used an ice pick. So the butler did not do it.

At the moment the conditional is uttered, it cannot be presupposed that the butler did not do it, for otherwise the conclusion of the argument would be redundant, and hence the conditional is not counterfactual. Thus this is a case in which the context set is compatible with both options regarding the butler. As pointed out by Stalnaker and as emphasized by von Fintel, the same reasoning in the indicative sounds odd, however:

(59) The murderer used an ice pick. (?) But if the butler did it, he didn't use an ice pick. So the butler didn't do it.

The problem here is that by the selection constraint, the closest world where the butler did it should be a world where he used an ice pick, an assumption contradicted by the consequent. Hence, the use of the subjunctive is more appropriate here, but we see that it is not mandated to always go outside the context set.

Stalnaker's hypothesis gives a pragmatic answer to the question of how the choice is made between indicative and subjunctive conditionals. Another difficult question concerns the interaction of tense and mood in the expression of indicative and subjunctive conditionals. An observation common to all accounts of counterfactuals, in particular, is that they use past morphology. Consider the following pair (adapted from Schulz, 2007):

(60) a. If Peter took the plane, he would be in Frankfurt this evening.
b. If Peter took the plane, he must be in Frankfurt by now.

In the indicative conditional (60b), the antecedent refers to a past event relative to the utterance time of the sentence. This is not so in (60a), where the speaker means that if Peter were to take the plane *now* or even possibly at some moment between now and the evening, he would be in Frankfurt in the evening. In that case, the past tense does not appear to play its temporal function, namely to refer to a past moment relative to the utterance situation. This feature has been given considerable attention in a number of recent works (see Iatridou, 2000; Ippolito, 2003; Asher and McCready, 2007; Schulz, 2007). We cannot hope to discuss all of those accounts here (see Schulz, 2007, chapter 6, for an extended survey).

To make the connection with Stalnaker's account of the indicative/subjunctive division, however, we find it worthwhile to give a brief overview of Iatridou's account. On Iatridou's account the use of the past in counterfactuals is essentially modal, and not temporal. However, the mechanism behind the temporal and the modal understanding of the past is essentially the same. In the temporal case, Iatridou points out that the past signals precedence, namely that the topic time $T(t)$ (temporal interval for the event talked about in t) of the event reported is located before the utterance time $S(t)$ (relevant interval of the utterance). In the modal case, by analogy, Iatridou distinguishes between the set of topic worlds $T(w)$, the worlds talked about, and the context set $S(w)$, namely the worlds of the speaker. In that case, the past signals exclusion of topic worlds from the context set. Whether as temporal or modal, however, Iatridou does not see the exclusion triggered by the past as semantically mandated, but rather she views it as cancellable and optional in some contexts (in agreement with Anderson's example in the modal case).

A further generalization proposed by Iatridou is that "when the temporal coordinates of an event are not set with respect to the utterance time, morphology is always Imperfect". For instance, the pair (60a) vs. (60b) would translate in French as:

(61) a. Si Pierre prenait l'avion, il serait à Francfort ce soir.
b. Si Pierre a pris l'avion, il doit être à Francfort à présent.

In (61a), *prenait* is the imperfect past (*imparfait de l'indicatif*), whereas *a pris* in (61b) is the perfect past (*passé composé*). The same analysis of the past as exclusion works for modals like *would* and *might* in English, seen as past forms of the modal roots *woll* and *moll*, and Iatridou shows that it can be extended to other paradigms. In the case of the French conditional mood, for instance, the latter can be seen as being formed of past imperfect morphology appended to a future morpheme, as evidenced by the contrast:

(62) Si tu viens, tu aime-r-as la ville.
if you come-IND-PRES, you like-FUT-2-SG-PRES the city
'If you come, you will like the city.'

(63) Si tu venais, tu aime-r-ais la ville.
if you come-IMP-PAST, you like-FUT-2-SG-IMP-PAST the city
'If you came, you would like the city.'

The interaction of tense and mood becomes more involved with the so-called *past irrealis*, namely for sentences such as the following:

(64) Si tu étais venu, tu aurais aimé la ville.
if you were come, you have-would liked the city
'If you had come, you would have liked the city.'

Typically, a sentence in this form refers to a counterfactual possibility relative to a past topic time. So the past tense in the antecedent can refer to a past event. Moreover, the use of the pluperfect is needed to express that this counterfactual possibility is relative to the past. However, the sentence can occasionally be used in the same sense as: 'if you could have come (tomorrow), you would have liked the city', but with the implicature that the addressee has settled not to come.

17.9 Relevance conditionals

To conclude this chapter, we turn to the problem of the semantic analysis of relevance conditionals such as (7), a variant of which is repeated here as (65):

(65) There are biscuits on the sideboard if you're hungry.

These conditionals, also called *biscuit conditionals*, *Austin conditionals*, and *nonconditional conditionals* (Geis and Lycan, 1993; Siegel, 2006) pose a problem too for the prospect of having a unified analysis of conditional sentences, since, unlike standard indicative conditionals, uttering a relevance conditional appears to be essentially asserting the consequent, without letting the truth of the consequent depend on the truth of the antecedent. Like the literature on counterfactual conditionals, the literature on biscuit conditionals is too large for us to do justice to the topic. However, we wish to highlight at least two aspects of the research on these conditionals.

The first aspect, mentioned above in the introduction, is that relevance conditionals differ from standard indicative conditionals by the exclusion of the adverb *then* in the consequent. An important contribution on the distribution of *then* in conditional sentences more generally is Iatridou (1993). Iatridou uses as background theory the Lewis–Kratzer analysis of *if*-clauses, that is she supposes that bare conditionals come with a silent operator *Must*. Her proposal is that use of *then* in the consequent of a conditional sentence "if A, C" introduces an assertion and a presupposition, as follows:

(66) a. Assertion: $[Must : A][C]$
b. Presupposition: $\neg[Must : \neg A][C]$

For example, under a strict conditional analysis, an indicative conditional such as: *if John visits, then Mary will be happy* would assert that in all the worlds in which John visits, Mary is happy, and would presuppose that in some of the worlds in which John does not visit, Mary is not happy. Iatridou's hypothesis is highly predictive, in particular it can explain oddities of the use of *then* for many cases where the presupposition is violated, as in the following:

(67) If Bill is dead or alive, (*then) John will find him.

In a relevance conditional like (65), similarly, Iatridou points out that the insertion of "then" should imply that in some of the worlds in which you are not hungry, there are no biscuits on the sideboard. However, such a meaning is precisely ruled out in this case, since the presence or absence of biscuits on the sideboard is not meant to depend on the addressee's hunger condition.

Further arguments have been adduced in favor of Iatridou's analysis of *then*, in fact in support of the referential analysis of *if*-clauses, rather than on the restrictor analysis originally used by Iatridou. Bittner (2001), Schlenker (2004), and Bhatt and Pancheva (2007) treat conditionals as correlative constructions, with *if*-clauses analyzed as free relatives in the position of sentence topics, and with *then* as a world pronoun acting as a proform. A central element of analogy between *if*-clauses in the modal domain and topicalization in the individual domain concerns left-dislocated constructions in German. Iatridou gives the following example from German:

(68) Hans, der hat es verstanden.
Hans, he has it understood

In this case, the sentence asserts that Hans has understood and either presupposes or implicates that other people have failed to understand. Thus, the *der* in this construction appears to behave exactly like "then" in the modal domain. The connection between conditionals and left-dislocated constructions in German has recently been used by Ebert et al. (2008) to propose a unified analysis of indicative conditionals and biscuit conditionals. Ebert et al. point out that German distinguishes between two kinds of topic constructions, German left dislocation (GLD) and hanging topic left dislocation (HTLD):

(69) Den Pfarrer, den kann keiner leiden. (GLD)
the pastor, him can no one bear

(70) Der/den Pfarrer, keiner kann ihn leiden. (HTLD)
the pastor, no one can him bear

In agreement with the referential analysis of Schlenker, they see some analogies between GLD and indicative conditionals. According to them, HTLD constructions present corresponding analogies with biscuit conditionals. GLD and HTLD set up two different kinds of topicality on their analysis, *aboutness* topicality for GLD, and *frame setting* topicality for HTLD. In the latter case, their analysis for (70) does not treat the pronoun *ihn* as directly bound to the topic, *den Pfarrer*, contrary to what happens in (69), but rather, as a free variable, whose reference is linked to that of the topic only because the latter is made salient in the context. In contrast to that, they see the coreference as obligatory for GLD, in particular because the latter permits binding, unlike HTLD. This analogy enables Ebert et al. to give a parallel analysis of indicative conditionals vs. biscuit conditionals. They propose the following logical forms for an indicative conditional and for its relevance counterpart:

(71) a. If you are looking for the captain, then he is here.
b. $\mathrm{REF}_X(\iota_{w_0} w(looking(w)(listener))) \wedge \mathrm{ASSERT}(here(X)(captain))$

(72) a. If you are looking for the captain, he is here.
b. $\mathrm{REF}_X(\iota_{w_0} w(looking(w)(listener))) \wedge \mathrm{ASSERT}(here(w_0)(captain))$

On their analysis, $\mathrm{REF}_X(y)$ indicates the establishment of an act of topical reference of y as the topic X, $\iota_{w_0} wP(w)$ denotes "the closest world w satisfying P relative to w_0", and $\mathrm{ASSERT}(\phi)$ indicates the act of assertion of the sentence ϕ. The main difference between the two constructions is that in the biscuit case the proposition asserted is anchored to the actual world, whereas in the indicative conditional case the proposition asserted picks up the referent introduced as the topic. In the second case, only the consequent of the conditional is asserted, and the antecedent only sets a topic relevant for the assertion proper. As shown by Ebert et al., this kind of frame setting happens in other sentences, such as the following:

(73) As for the pastor, the marriage sermon was wonderful.

Whether the referential analysis of *if*-clauses is really needed to capture the distinction proposed by Ebert et al. can be subjected to discussion. For instance, the way (71) is intelligible would typically be in some bound sense, as in: *whenever you are looking for the captain, he is here*. The latter is readily analyzed as a case of universal quantification over time situations, and the temporal reference of the consequent is bound by the antecedent. Compare with: *Are you now looking for the captain? he is here*. In that case, the temporal reference of the consequent has to be the present moment, and the question is only asked to make the assertion relevant.

Several other proposals have been made to deal with biscuit conditionals recently. Franke (2007) in particular outlines an explanation of why the antecedent of a biscuit conditional is believed based on purely pragmatic considerations about the epistemic status of the antecedent relative to the consequent. DeRose and Grandy (1999) suggest that Belnap's trivalent account of indicative conditionals can actually be accommodated to deal with biscuit conditionals. Siegel (2006) denies that the consequent of a biscuit conditional is always asserted as true by the speaker and proposes a metalinguistic analysis of biscuit conditionals of the form "if *A*, then there is a relevant assertion of 'C' ". Although it is not the place to adjudicate the debate between these various proposals, it may be pointed out that Ebert et al.'s is probably the main one driven by the observation of the exclusion of *then* in conditional sentences.

17.10 Perspectives

We have been deliberately partial and selective in building this chapter on conditionals, mostly with the aim of being self-contained, but omitting some important references and some aspects of the semantics of conditionals. We refer to von Fintel (2011) for another recent survey on conditionals with a partly different angle on the topic, providing further bibliographical indications, in particular concerning the link between conditionals and dynamic semantics, conditionals and epistemic modals, and further aspects of the interaction of tense and mood in conditionals.

We should mention two lines of research which lie at the frontiers of linguistic inquiry proper. The first bears on the relation between belief dynamics and conditionals and is deeply influenced by the famous Ramsey Test (1929) according to which the belief attitude toward "If A, then C" is determined by the belief attitude toward C after a rational belief change based on the supposition that A.[26] After several decades of intense scrutiny in different frameworks, the Ramsey Test is still an object of study (Bradley, 2007; Dietz and Douven, 2010; Hill, 2012). A second line of research on conditionals concerns the interface between the psychology of reasoning and the semantics and pragmatics of conditionals. Interest for the connection with conditional reasoning was sparked by Wason's famous selection task (1960), the origin of a very large literature on the verification biases for conditional sentences. Some more recent works on the psychology of hypothetical reasoning include Johnson-Laird and Byrne (2002), Over and Evans (2003), Over et al. (2007), Politzer and Bourmaud (2002), Politzer (2007); Douven and Verbrugge (2010).

Appendix

The following table summarizes the main frameworks and schemata examined in Sections 17.2 to 17.7, comparing which schemata are valid (+) or not (−) among Falsity of the Antecedent (FA), Truth of the Consequent (TC), Strengthening of the antecedent (S), Contraposition (C), Transitivity (T), Conditional Excluded Middle (CEM), Simplification of Disjunctive Antecedents (SDA), Or-to-If (OI), Import–Export (IE), Conditional Negation (CN) (the latter being the equivalence between $\neg(A \to C)$ and $A \to \neg C$), Modus Ponens (MP) and Modus Tollens (MT). "Plural" refers to the plural version of Stalnaker's analysis (no Uniqueness Assumption), and "Strict" to the basic strict

[26] Adams's thesis can be seen and has often been viewed as a probabilistic version of the Ramsey Test, where conditionalization is assumed to be a rule of rational belief change.

Table 17.2 *Overview of the frameworks/inference schemata discussed*

	Material	Strict	Stalnaker	Plural	Lewis	McGee	De Finetti
FA	+	−	−	−	−	−	−
TC	+	−	−	−	−	−	−
S	+	+	−	−	−	−	−
C	+	+	−	−	−	−	−
T	+	+	−	−	−	−	−
CEM	+	−	+	−	−	−	−
SDA	+	+	−	−	−	−	−
OI	+	−	−	−	−	−	−
IE	+	−	−	−	−	+	+
CN	−	−	+	−	−	+	+
MP	+	+	+	+	+	−	−
MT	+	+	+	+	+	−	−

conditional analysis. For the three-valued analysis, the rightmost column assumes De Finetti's scheme for the conditional under the S3 or symmetric version of Kleene consequence (preservation of value 1 from premises to conclusion, and of value 0 from conclusion to premises). For the Strict analysis, Stalnaker and Lewis's analyses, and the Plural analysis, the table assumes that the actual world is always among the accessible worlds (reflexivity) and also the assumption of Centering (if the actual world is an A-world, then it is one of the closest A-worlds or the closest). For McGee's analysis, we refer to his modification of Stalnaker's semantics and assume schemata to obey the syntactic proviso of the semantics (conditionals can only have factual antecedents). The parallel between the predictions of McGee's semantics and De Finetti's scheme (under S3) may suggest that the two semantics are equivalent throughout on their common language. This is not the case, however. For example, as pointed out in Section 17.4, the embedded conditional $(A \vee C) > (\neg A > C)$ is McGee-valid (assuming, again, factual antecedents), but it is not valid for De Finetti's conditional under the S3 scheme (for instance when A is true).

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18

Modality

Lisa Matthewson

18.1 Introduction

There are an infinite number of ways the world could have been. For example, my first name happens to be *Lisa*, but my parents *could* have named me *Super Princess Lisa Superhero Easter Bunny*.[1] Another way to say this is there are some possible worlds (Lewis, 1973) where my name is Super Princess Lisa Superhero Easter Bunny. Natural language allows us to say all kinds of things about these possible worlds – such as *My parents should have named me Super Princess Lisa Superhero Easter Bunny*, or *If my parents had named me Super Princess Lisa Superhero Easter Bunny, I would have been angry at them*. The ability to talk about possible worlds is known as modal displacement (von Fintel and Gillies, 2011, who follow Hockett's (1960) discussion of temporal and spatial displacement).

Modal displacement is, as far as we know, unique to human language, universal to all languages, and acquired early. English-acquiring two-year-olds freely talk about what is permitted, obligated, or compatible with someone's abilities; they say things like *you can't get it till it's Mother's Day*,[2] *he just can borrow him*,[3] or *you have to be quiet so she can sleep*,[4] and we expect that

[1] Thanks to Madeleine Davis (p.c.) for the name idea.

[2] www.youtube.com/watch?v=YQ9vv4CPzcY&feature=related.

[3] www.youtube.com/watch?v=NDLK6dopfuc.

[4] www.youtube.com/watch?v=4Y5nbStIjeI.

speakers of all languages (even those under-represented on YouTube) can similarly talk about permission, obligation, and ability.

Interestingly, however, languages also vary in how they express and categorize modal meanings. Unlike in English, in the Salish language St'át'imcets (Lillooet) the same morpheme (the enclitic *=ka*) can express either *permission* or *obligation*, as in (1). A different morpheme (the circumfix *ka-. . . -a*) is used to express *ability*, as in (2).[5]

(1) wá7=**ka** s-lep' i=k'ún7=a ku=pála7 máqa7
ipfv=deon stat-bury det.pl=fish.egg=exis det=one snow
i. 'The eggs *can* stay in the ground for a year.'
ii. 'The eggs *have to* stay in the ground for a year.'
(Rullmann et al., 2008, p. 329)

(2) *Context: They also wrestled the young bulls.*
wa7 xíl-em=wit ets7á kw=s=zwat-en-ítas swát=as
ipfv do-mid=3pl deic det=nmlz=know-dir-3pl.erg who=3sbjv
ku=wá7 **ka**-xilh-ts-tal'í-**ha** áti7 ku=xwém
det=ipfv circ-do-caus-top-circ deic det=fast
'They did that to find out who could do it the fastest.'
(Matthewson, 2005, p. 89)

The goal of this chapter is to provide an introduction to three topics which are central to understanding the semantics of modal elements: modal flavour (Section 18.2), modal force (Section 18.3), and modal–temporal interactions (Section 18.4). For each of these phenomena, I will outline its treatment in a standard Kratzerian semantics (Kratzer, 1981, 1991b, 2012), present some data on its expression cross-linguistically, and point the reader to some ongoing debates and interesting unanswered questions. In the remainder of this section, I give a basic introduction to the possible-worlds approach to modality and to the three major topics we will be discussing.

Several introductions to modality are already available: see, for example, von Fintel and Gillies (2011), Hacquard (2011), or Swanson (2008) for a more philosophical perspective. Other relevant recent works include Portner's (2009) comprehensive monograph and Kratzer's (2012) collection of updated versions of her seminal papers. In this chapter I will be unashamedly Kratzerian, because Kratzer is where every student of modality needs to begin. There are other approaches (see, e.g., Groenendijk et al., 1996; Ninan, 2005; Yalcin, 2007; Lassiter, 2011b), and there is also of course no single Kratzerian analysis, but rather a family of related analyses, which are constantly being developed and updated in ongoing research.

[5] Abbreviations in this chapter not covered by the Leipzig Glossing Rules: ii : series ii pronoun, circ : circumstantial, cn : common noun connective, cust : customary aspect, deic : deictic, deon : deontic, dir : directive transitivizer, emph : emphatic, epis : epistemic modal, exis : assertion of existence, infer : inferential evidential, lex : lexical particle, mid : middle, mod : modal, necess : necessity modal, nonaff : non-affirmative, pn : proper name, possib : possibility modal, prosp : prospective aspect, sens.non.vis : sensory non-visual evidential, s.pl : plural subject, stat : stative, vai : intransitive animate verb, val : valency adjuster, vti : transitive inanimate verb.

18.1.1 Possible worlds and modality

Propositions containing modal elements make contingent claims about the actual world, by asserting something about a set of worlds in which certain propositions are true. A simple example is given in (3).

(3) *Context: The Youth Orchestra is holding auditions. At one point the conductor says:*
Madeleine **can** put her violin away now.

Can is a possibility modal, which introduces existential quantification over worlds. So as a first pass, (3) asserts that there is at least one possible world in which Madeleine puts her violin away. However, that first pass is far too weak. There are an infinite number of worlds in which Madeleine puts her violin away, and there are an infinite number of worlds in which she keeps playing. (There are also other, less 'normal' worlds, in which she keeps her violin out but starts using it as a coffee cup, or in which her violin spontaneously crumbles to dust.) As a second pass, (3) asserts that there is at least one world in which Madeleine obeys the conductor's actual-world rules for the audition, and in which she puts her violin away.

Why did we say 'the conductor's *actual-world* rules'? This is what ensures that (3) makes a contingent claim. In the actual world, the conductor's rules happen not to exclude Madeleine from putting her violin away. (Maybe the rules include the proposition that each auditioner plays one piece and two scales, and Madeleine has already played those things.) But it could easily have been the case that the conductor demanded that she keep playing (if, for example, the rules contained the proposition that auditioners play two pieces and four scales). It is a general feature of modal elements that they use some facts about the evaluation world to narrow down the set of worlds being quantified over.

How did we know that (3) was a statement about rules (rather than about abilities, or wishes, or what is possible given the available evidence)? And given that it is about rules, how did we know that it expressed permission, rather than obligation? The former question concerns *modal flavour*, and the latter concerns *modal force*. With English modal auxiliaries, modal flavour questions are primarily (but not exclusively) settled pragmatically, while modal force questions are primarily settled lexically.

The modal flavour of *can* in (3) is deontic. We know this because of the discourse context, as the conductor is in a position of power and is likely to make pronouncements about rules. In the alternative context in (4), *can* has a different modal flavour: it imparts information about ability.

(4) *Context: Madeleine is three and has recently started violin lessons. At first, she wasn't able to put her violin away in its case because she wasn't strong enough to loosen the bow. But she has grown stronger.*
Madeleine **can** put her violin away now.

The modal flavour of *can* is not completely determined by context; it is also lexically restricted. *Can* cannot have an epistemic flavour: it cannot assert something about the worlds compatible with a body of evidence.[6] *Might*, on the other hand, can easily have this interpretation, as shown in (5b).

(5) *Context: A homicide detective is summarizing the content of a report which presents the findings of the investigative team.*
  a. #According to the report, Gerry **can** be the murderer.
  b. According to the report, Gerry **might** be the murderer.

Non-auxiliary modal elements frequently lexically encode modal flavour. For example, the attitude verb *want* encodes bouletic modality (to do with desires), and the adverb *maybe* is unambiguously epistemic.

Turning to modal force, our example modal *can* is lexically specified to existentially quantify over worlds. It contrasts with universally quantifying modals like *must* or *have to*, as shown in (6).

(6) *Context: A violin audition. The conductor says:*
  a. Madeleine **can** put her violin away now.
  b. Madeleine **must**/**has to** put her violin away now.

Example (6b) expresses obligation, rather than permission; it says (roughly) that in *all* worlds in which Madeleine obeys the conductor's actual-world rules, she puts her violin away.[7] In other words, there is no way to obey the actual rules without putting the violin away. But there is a pragmatic element to modal force, too: notice that even (6a) probably leads, in the audition context, to Madeleine putting her violin away. Thus, in certain contexts *can*-sentences can pragmatically function almost like obligations. However, the obligation is cancellable in (6a), but not in (6b), as shown in (7). This shows that *must*/*have to* semantically conveys obligation, but *can* does not.

(7) a. Madeleine **can** put her violin away now (but she can also keep playing if she wants).
  b. Madeleine **must**/**has to** put her violin away now (#but she can also keep playing if she wants).

We have seen so far that the truth values of modal assertions depend on the world in which they are uttered, because the set of worlds quantified over is narrowed down by a set of propositions which are true in the evaluation world. In a similar fashion, their truth values depend on the *time* at which they are uttered. Suppose, for example, that the conductor's actual-world rules require that each auditioner play at least one piece and two scales. At time t, Madeleine has played one piece and no scales, and five minutes later at t', she has played two scales as well. Sentence (3) would be false at t, and true at t', because at t Madeleine's putting her violin away is not compatible with the conductor's actual rules, but at t', it is. Moreover, the propositions

[6] Except when it appears under negation; see Palmer (2001, p. 103) and McCormack and Smith (2002, p. 135), among others.
[7] This is a simplification; see Section 18.2.1.

we use to narrow the worlds quantified over can change over time: the conductor could change her rules from one minute to the next, or a person's abilities could change.

Just like modal flavour and modal force, modal–temporal interactions can be lexically restricted. More often, however, they are influenced by tense or aspect functional heads; this is especially easy to see in languages where modals overtly inflect for these categories. The Dutch data in (8) show that past marking on the modal auxiliary causes the modal to be evaluated at some past time.

(8) a. we **moeten** winnen
we **must**.PRS.1PL win.INF
'We have to win.'
(In all worlds compatible with our obligations or goals at the *utterance time*, we win.)

b. we **moesten** winnen
we **must**.PST.1PL win.INF
'We had to win.'
(In all worlds compatible with our obligations or goals at some *past time*, we win.)

c. we **kunnen** winnen
we **can**.PRS.1PL win.INF
'We are able to win.'
(In some world compatible with our abilities at the *utterance time*, we win.)

d. we **konden** winnen
we **can**.PST.1PL win.INF
'We were able to win.'
(In some world compatible with our abilities at some *past time*, we win.)

(Hotze Rullmann, p.c.)

In the next section we turn to a more in-depth discussion of modal flavour.

18.2 Modal flavour

Our discussion so far has been completely informal and has also been simplified. The first way in which it has been simplified is that we have bluntly talked about *modal flavour*. However, one of Kratzer's important proposals is that modal flavour comprises two separate parameters – called 'conversational backgrounds' – a *modal base* and at least one *ordering source*. In Section 18.2.1 we briefly review the motivation for this double relativity of modals, and in Section 18.2.2 we discuss where the conversational backgrounds come from. Section 18.2.3 presents some cross-linguistic data, and Section 18.2.4 discusses ongoing debate about the status of the epistemic–circumstantial division in conversational backgrounds.

18.2.1 Modal base and ordering source

What we have so far can be formalized as in (9).[8] Modals are interpreted relative to one conversational background, a function from worlds to sets of propositions. By intersecting that set of propositions, we obtain a set of worlds accessible from w, the worlds in which all the propositions are true.[9] Necessity modals like *must* assert that the prejacent (the core proposition embedded under the modal) is true in all the accessible worlds. Possibility modals existentially quantify over the accessible worlds.

(9) a. $[\![must]\!]^{w,g} = \lambda f_{\langle s,\langle st,t\rangle\rangle}.\lambda p_{\langle s,t\rangle}.\forall w'[w' \in \cap f(w) \rightarrow p(w') = 1]$
b. $[\![can]\!]^{w,g} = \lambda f_{\langle s,\langle st,t\rangle\rangle}.\lambda p_{\langle s,t\rangle}.\exists w'[w' \in \cap f(w) \;\&\; p(w') = 1]$

Kratzer shows conclusively that such an analysis is inadequate. The first problem is that sometimes the propositions given by the conversational background are inconsistent, in which case all necessity claims come out trivially true and all possibility claims come out trivially false. Take example (10):

(10) *Context: The conductor's rules state that auditioners play at least one piece and two scales, they play no more than five scales, and they play everything from memory. When Jane auditions, she uses sheet music rather than playing from memory. Now it's Madeleine's turn and she has played one piece and two scales.*
a. Madeleine **must** stop playing now.
b. Madeleine **can** stop playing now.

We want to predict that (10a) is false and (10b) is true. The simple system so far predicts the reverse. The problem is that the conversational background lumps together propositions describing the rules with propositions describing Jane's actions, and the resulting set of propositions is inconsistent (there are no worlds in which all the rules are obeyed and in which Jane disobeyed the rules). Since there are no worlds to quantify over, the universal quantification in (10a) is trivially true, and the existential quantification in (10b) is false.

A second problem with the simple system is that it has no way to deal with graded modality, as in (11).

(11) a. Michl is **probably** the murderer.
b. There is a **good possibility** that Michl is the murderer.
c. There is a **slight possibility** that Michl is the murderer.
d. Michl is **more likely** to be the murderer than Jakl.
(Kratzer, 1991b, p. 643)

[8] I assume a basic familiarity with semantic formalism, approximately to the level of Heim and Kratzer (1998).

[9] Propositions are sets of worlds (the worlds in which the proposition is true), so a set of propositions is a set of sets of worlds. The intersection of those sets of worlds gives the set of worlds in which all the propositions are true.

An analysis of these examples requires more than just checking whether Michl is the murderer in at least one accessible world. We need to be able to rank possibilities using a notion of normalcy or stereotypicality: given the facts, some things are more expected than others.

A third problem is that the simple system predicts that (12a) asymmetrically entails (12b). If someone climbed Mount Toby in all worlds compatible with the actual-world evidence, then they climbed it in the actual world (since the actual world has to be compatible with the actual-world evidence).[10]

(12) a. She must have climbed Mount Toby.
b. She climbed Mount Toby.

(Kratzer, 1991b, p. 645)

The solution to all these problems is that modals are interpreted relative to two conversational backgrounds: a modal base and at least one ordering source. The modal base assigns to each world a set of propositions which are true in that world, and the ordering source assigns to each world a (possibly inconsistent) set of propositions representing, for example, norms, ideals, laws, desires. The set of worlds in which all the modal base propositions are true is then ordered according to how many of the ordering source propositions are true in each world, and the modal quantifies over only the most ideal worlds as identified by the ordering source.

The ordering determined by a set of propositions A is defined in (13): w is at least as close as z to the ideal determined by A if and only if all propositions in A that are true in z are also true in w.

(13) For all worlds w and $z \in W : w \leq_A z$ iff $\{p : p \in A \text{ and } z \in p\} \subseteq \{p : p \in A \text{ and } w \in p\}$

(Kratzer, 2012, p. 39)

If we assume for the purposes of simplicity that there is always a world (or set of worlds) which comes closer to the ideal than any other worlds (i.e., we adopt the Limit Assumption), we can define an operator which selects the 'best' worlds, and then have the modals quantify only over these. Examples (14) and (15) draw on von Fintel and Gillies (2011, p. 61) and Portner (2009, p. 67); f is the modal base and h is the ordering source. (See Lewis, 1973 and Stalnaker, 1984 on the Limit Assumption, and for modal definitions which do not adopt it, see Kratzer, 1981, p. 48 and Kratzer, 1991b, p. 644.)

(14) For a given order $\leq_A$ on worlds:
$\forall X \subseteq W[\text{BEST}_A(X) = \{w \in X : \neg\exists w' \in X[w' \leq_A w]\}]$

(15) a. $[\![must]\!]^{w,g} = \lambda f_{\langle s,\langle st,t\rangle\rangle}.\lambda h_{\langle s,\langle st,t\rangle\rangle}.\lambda p_{\langle s,t\rangle}.\forall w' \in \text{BEST}_{h(w)}(\cap f(w)) : p(w) = 1$
b. $[\![can]\!]^{w,g} = \lambda f_{\langle s,\langle}st, t\rangle\rangle.\lambda h_{\langle s,\langle st,t\rangle\rangle}.\lambda p_{\langle s,t\rangle}.\exists w' \in \text{BEST}_{h(w)}(\cap f(w))) : p(w) = 1$

[10] Von Fintel and Gillies (2010) argue that (12a) *does* entail (12b); see Section 18.3.1 below.

Here is an example of how the modal base and the ordering source interact to give the right results.

(16) *Context: As in (10), except that Madeleine has played one piece and five scales.*
Madeleine **must** stop playing now.

Example (16) asserts that in all worlds which are compatible with the facts about the audition and which are best according to the conductor's actual-world rules, Madeleine stops playing. This is the right result. The set of worlds compatible with the facts includes only worlds where one of the conductor's rules has already been broken. But that's okay – we just find the best we can. Out of the worlds where Jane has already broken the rules, the best ones are those where Madeleine obeys the rules. And in all of those, she stops playing now.

As hinted already, all modal bases are *realistic*: they assign to any world a set of propositions which are true in that world. In other words, for any world w and modal base f, w is a member of $\cap f(w)$ (see, e.g., Kratzer, 2012, p. 55). It is often assumed that there are two types of realistic conversational background: epistemic, and circumstantial/root. The former produces sets of propositions representing the available evidence; the latter produces sets of propositions representing relevant facts about the circumstances. (In Section 18.2.4, I discuss this dichotomy further, and the difficulties with formally distinguishing the two types.) If a conversational background is non-realistic, it must be an ordering source.[11] Common examples of flavours of ordering source are deontic (dealing with rules), bouletic (dealing with desires), teleological (dealing with goals), and stereotypical (dealing with normalcy). The first three of these operate on circumstantial modal bases; Portner (2009) groups them under the term *priority modals*. See Palmer (2001) on the different categories of modal flavour which are made use of cross-linguistically.

18.2.2 Where do conversational backgrounds come from?

One of Kratzer's important insights is that conversational backgrounds can be restricted by things external to the semantics of the modal itself. For a start, they can be restricted via overt adverbial phrases, as shown in (17).

(17) a. **According to the audition rules**, Madeleine can put her violin away now.
b. **Physically**, Madeleine can put her violin away now.
c. **Given the information in the report**, Gerry might be the murderer.

[11] This is because a non-realistic conversational background may contain an inconsistent set of propositions, and using this as a modal base would lead to the triviality problems discussed above.

If there is no overt restriction on conversational background, it can be provided by the context of use.[12] When uttered by a conductor during a violin audition, *can* is likely to be interpreted deontically, while in a different context, *can* can impart information about abilities. This context-dependency can be modelled in various ways. In the system I adopted for concreteness in (15), the modal base and ordering source are given by variables present in the syntax, which receive their value from the contextually given assignment function.

Given that modals can receive their conversational backgrounds from the context of use, Kratzer argues that it is not necessary to postulate lexical ambiguity for modals which allow varying flavours of conversational background. For example, we do not need can_1 and can_2 in the lexicon, where can_1 is deontic and can_2 is an ability modal.

Importantly, Kratzer does not claim that conversational backgrounds are restricted exclusively by context or by overt adverbial phrases. There is no reason why conversational backgrounds should not also be linguistically restricted by the modal itself, and Kratzer (1981, 1991b, 2012) gives examples of German modals which are compatible only with certain types of conversational background. We already saw that affirmative *can* may not be interpreted epistemically (see Portner, 2009, p. 55, for further details) and that non-auxiliary modal elements routinely place lexical restrictions on conversational background.

Interestingly, the fact that modals may have lexically restricted conversational backgrounds weakens the argument against an ambiguity analysis. It is still conceptually preferable to avoid having can_1 and can_2, if possible. But if there are languages which have distinct lexical items for these two meanings, there might in fact be some hidden ambiguities in languages which use just one lexical item.

Recent work on the evidential properties of epistemic modals also suggests that we may need to contemplate ambiguity for English modal auxiliaries. Von Fintel and Gillies (2010) and Kratzer (2009, 2012), among others, argue that at least some epistemic modals, including *must*, are lexically restricted to relying on indirect evidence for the embedded proposition. One simple way to implement such a restriction only for epistemic uses would involve ambiguity or polysemy between epistemic and non-epistemic *must*.[13,14]

[12] Even in the presence of an overt adverbial phrase, the conversational background can be given by the context, as pointed out by Nauze (2008, p. 157). The modal in (i) has an epistemic interpretation, in spite of the deontic adverbial.

> *Context: We are discussing the upcoming trial of the suspected criminal, Jockl. The trial has not yet beg[u]n and we wonder what the outcome will be.*
>
> (i) In view of what the law provides, Jockl **may** be executed.
>
> (Nauze, 2008, p. 157)

[13] Nauze (2008, p. 153), for example, argues for a polysemy account.

[14] An argument which is sometimes advanced against an ambiguity analysis is that there are as many different particular conversational backgrounds as there are contexts and that this multiplicity of meanings

A final option for conversational backgrounds is that modals might acquire some of their meaning restrictions through their position in the syntactic structure. A recent proponent of this approach is Hacquard (2006, 2009, 2010), who spells out an analysis in which the structural height of a modal indirectly restricts its conversational background. Hacquard proposes that modals are relativized to events rather than worlds, and their interpretation depends on features of the relevant event, such as its runtime or participants. High-scoping modals in matrix clauses depend on the speech event, and thus on the time of utterance and the speaker. Usually, high modals receive epistemic interpretations, because epistemic modal bases require an information state, which is usually provided by the speaker of the speech event.[15] Circumstantial modal bases, on the other hand, depend on the circumstances of an event (e.g., its location, time, participants). As such they are VP-event-relative and will tend to scope low. This provides a principled explanation for the pervasive finding that epistemic modals scope above non-epistemic ones (see, e.g., Jackendoff, 1972; McDowell, 1987; Picallo, 1990; Brennan, 1993; Cinque, 1999; Butler, 2003; Barbiers, 2006).

The goals of Hacquard's proposal are a unified analysis which avoids lexical ambiguity, and an explanation for the correlation between syntactic height and interpretation. Her analysis insightfully addresses one of the most puzzling issues in the study of modals, the tension between the desire for a unified analysis, and an explanation for distinct readings. One interesting question is whether the unified analysis is tenable cross-linguistically. Hacquard states that a major motivation for rejecting an ambiguity analysis of modals is the generalization that, cross-linguistically, modal elements express a range of flavours. She writes that 'this multiplicity of modal meanings is common enough cross-linguistically, and in languages from different families, so as to make a lexical ambiguity account unlikely: it is highly improbable that the same lexical accident should be found in language after language' (Hacquard, 2011, p. 1489). She also argues that a problem with proposals which assign separate lexical entries for roots and epistemics is 'the fact that, cross-linguistically, they are expressed by the same lexical items' (Hacquard, 2006, p. 114).

However, it is not obviously true that the pervasive cross-linguistic pattern is for single modal elements to express a range of modal flavours. According to van der Auwera and Ammann (2011), slightly more than half of their sample of 207 languages have no modals which allow both

would be impossible to deal with lexically (see, e.g., Hacquard, 2011, p. 11). However, this argument is weakened by the fact that modals in many languages do lexically encode overarching modal flavours like 'deontic' or 'epistemic'. An ambiguity account combined with contextual dependence is therefore tenable, and would be parallel to Partee's (1988a) analysis of the quantifiers *many* and *few*. Partee claims that *many* and *few* are each ambiguous between cardinal and proportional readings, but the specific cardinalities or proportions they require are dependent on context.

[15] Or by the holder of the attitude event, in the case of a modal embedded under an attitude verb.

epistemic and non-epistemic interpretations (i.e., no instances of what they call 'overlap' between modal flavours). Moreover, the percentage of languages which lexically encode conversational background may actually be higher than this. As outlined by Davis et al. (2014) and Matthewson (2013b), there are cases which van der Auwera and Ammann analyse as involving overlap, but which really involve lexical distinctness. For example, van der Auwera and Ammann argue that Kiowa has overlap between modal flavours in half of its system (i.e., in either the possibility domain or the necessity one). However, there is no evidence for overlap in the source cited (Watkins and McKenzie, 1984, pp. 220–222), and Kiowa is actually a language where epistemic and non-epistemic modality are expressed via distinct morpho-syntactic strategies (Andrew McKenzie, p.c.). Epistemic modals are typically adverbs, deontic possibility is expressed using the irrealis, and ability or the lack of it is expressed by incorporating auxiliaries, inflection, or out-of-control marking.[16] Similarly, Mandarin is classified by van der Auwera and Ammann as a language which standardly allows overlap, but this appears to be incorrect: the overwhelming pattern in Mandarin is for modals to lexically restrict modal flavour (Liu, 2013).

In short, our current cross-linguistic understanding allows us to conclude only that some modals in some languages allow variable modal flavour, while some or all modals in other languages lexically specify modal flavour. This is just what the Kratzerian analysis leads us to expect. Languages can view the common meaning components (quantification over possible worlds) as criterial for lexical division, or they can focus on the distinction between different modal flavours. As a final comment, a requirement for extending Hacquard's analysis to a universal proposal would be evidence that the syntactic differences between different modal interpretations show up in languages from different families. As shown by Hacquard and others, the tests required to establish syntactic differences are often quite subtle, and they have not been done for the majority of the world's languages. This is an area where further research is needed.

In the next section, we will get a taste of a language which lexically encodes conversational background throughout its modal system.

18.2.3 Modal flavour in Gitksan

Gitksan is an endangered and understudied Tsimshianic language spoken in northern British Columbia, Canada.[17] Its core modal system is summarized in Table 18.1 (Matthewson, 2013a; see also Peterson, 2010).

We see that there is no overlap between epistemic and circumstantial interpretations. The former are strictly expressed by means of the

[16] These different morpho-syntactic strategies may turn out to support the syntax–meaning correlations argued for by Hacquard, but they would not support the claim that different modal flavours are produced by the syntax in combination with a maximally general modal lexical entry.

[17] ISO 639-3 code 'git'. The term *Gitksan* is conventionally used to cover that part of the Nass-Gitksan dialect continuum which stretches from Git-anyaaw (Kitwancool) to Ansbayaxw (Kispiox).

Table 18.1 *Gitksan modal system*

		POSSIBILITY	(WEAK) NECESSITY
CIRCUMSTANTIAL	PLAIN	*da'ak̲hlxw*	*sgi*
	DEONTIC	*anook̲*	
EPISTEMIC	PLAIN	*ima('a)*[a]	
	REPORTATIVE	*g̲at*	

[a] This element has various pronunciations, partly dependent on dialect: either *ima*, *imaa*, or *ima'*.

second-position clitics *ima('a)* and *g̲at*, the latter strictly by the clause-initial verbs or predicative particles *da'ak̲hlxw*, *anook̲*, and *sgi*. Examples are given in (18)–(19). The reportative *g̲at* in (18b) is not necessarily translated into English using a modal; however, Peterson (2010) argues that it has epistemic modal semantics. A more revealing translation of (18b) would be 'Given what I heard, the berries might/must be ripe.'

(18) a. *Context: There was a bad can of fish; everyone at the dinner got sick.*
yugw=**ima'**=hl nee=dii am=hl hon=hl gup-diit
IPFV=EPIS=CN NEG=CNTR good=CN fish=CN eat-3PL.II
'The fish they ate must've been bad.'
(Matthewson, 2013a, p. 360, adapted from Peterson, 2010, p. 162)

b. *Context: Your brother told you the berries are ripe now. Later, you tell me the berries are ripe, based on what your brother told you.*
hlaa mukw-t=**g̲at**=hl maa'y
INCEPT ripe-3SG.II=REPORT=CN berries
'The berries are ripe (I heard).'
(Matthewson, 2013a, p. 362)

(19) a. **da'ak̲hlxw**-i-s Henry dim jam-t
CIRC.POSSIB-TR-PN Henry PROSP cook-3SG.II
'Henry is able to cook.' / 'Henry was able to cook.'
(Matthewson, 2013a, p. 371)

b. **anook̲**-xw(=hl) dim ha'w-s Savanna (k'yoots)
DEON.POSSIB-VAL(=CN) PROSP go.home-PN Savanna (yesterday)
'Savanna was allowed to go home (yesterday).'
(Matthewson, 2013a, p. 377)

c. **sgi** dim (ap) ha'w-s Lisa
CIRC.NECESS PROSP (VERUM) go.home-PN Lisa
'Lisa should/must go home.' / 'Lisa should (have) gone home.'
(Matthewson, 2013a, p. 380)

The split between epistemic and circumstantial readings is absolute in Gitksan: the modals can be used with the flavours illustrated here, but they cannot be used with the opposite ones. For example, in (20) the context is (pure) circumstantial: the issue is not whether it is compatible with the evidence that berries are growing here, but whether it is compatible with the circumstances that berries could grow here (this is adapted from Kratzer's hydrangea example, 1991b, p. 646). We see that epistemic *ima('a)* is infelicitous.

(20) *Context: You're up in the Suskwa and notice a burnt patch of forest. You know that huckleberries typically take seed in burnt alpine areas.*

a. **da'ak̲hlxw**=hl dim limx̲s=hl maa'y go'osun
CIRC=CN PROSP grow.PL=CN berries LOC.here
'Berries might/can/are able to grow here.'

b. #limx̲s=**ima**=hl maa'y go'osun
grow.PL=EPIS=CN berries LOC.here
'Berries might be growing here.'

(Peterson, 2010, p. 158)

Lexical distinctions between modal flavours are pervasive in many languages, as mentioned in Section 18.2.2, and as shown recently in formal work on St'át'imcets (Lillooet Salish: Matthewson et al., 2007; Rullmann et al., 2008; Davis et al., 2009), Javanese (Austronesian: Vander Klok, 2008, 2012), Blackfoot (Algonquian: Reis Silva, 2009), Kwak'wala (Wakashan: Menzies, 2010), Nez Perce (Penutian: Deal, 2011), and Nsyilxcen (Okanagan Salish: Menzies, 2013).

Even though many languages lexically distinguish epistemic from circumstantial modal bases, it turns out to be not so easy to distinguish the two types theoretically. I turn to this issue in the next section.

18.2.4 Epistemic vs. circumstantial: the issues

Epistemic and circumstantial interpretations should be easy to tell apart. Kratzer (2012, p. 52) gives the German pair in (21) to illustrate (English translations added). Example (21a) is circumstantial and asserts that Kathl has the ability to make a pound of Quark out of this can of milk. Example (21b) is epistemic and asserts that it is compatible with the evidence that Kathl might actually do that. If Kathl can, but surely will not, make a pound of Quark out of this milk, (a) is true and (b) is false.

(21) a. aus dieser Kanne Milch **kann** die Kathl ein Pfund
from this can of milk **can** the Kathl one pound of
Quark machen
cottage cheese make
'Kathl can make a pound of Quark out of this can of milk.'

b. es **kann** sein, dass die Kathl aus dieser Kanne Milch ein Pfund
it **may** be that the Kathl from this can of milk one pound
Quark macht
cottage cheese makes
'Kathl might make a pound of Quark out of this can of milk.'

The theoretical problem is that both types of modal base depend on facts about the world of evaluation, and as such, there is no formal way to distinguish the two. As Nauze (2008, p. 155) points out, in many contexts the very same set of propositions can serve as either an epistemic modal base or a circumstantial one. Kratzer (2012, p. 24) concurs and writes that '[i]t now seems to me a hopeless enterprise to try to characterize formal objects like conversational backgrounds as "circumstantial" versus "epistemic"'.

To see the problem, imagine that the relevant circumstances for a particular modal assertion are identical to the relevant evidence we have (that is, we know everything that is relevant). In this case, a circumstantial and an epistemic modal base will contain the exact same set of propositions. Nauze gives the example in (22), which involves similar modal flavours to (21) but has a context in which the two modal bases (which we want to classify as circumstantial and epistemic respectively) contain identical propositions.[18]

(22) *Context: It is 2.50 pm on Saturday and we all know that France is playing England at 3.00 pm in the Six Nations rugby tournament. Furthermore we know that Fabrice is home (and has a television receiving the game).*

a. Fabrice **can** watch the game.

b. Fabrice **might** watch the game.

(Nauze, 2008, pp. 154–155)

In recent work, Kratzer (2012, 2013) (building on work by Arregui, 2005, 2007, 2009; Hacquard, 2006, 2010) develops an alternative approach to restricting the domains over which modals quantify. The new approach includes a substantive rethinking of the epistemic–circumstantial divide.[19] The major division Kratzer proposes is between *factual* and *content* modes of projecting conversational backgrounds. Factual mode functions return a set of worlds which all contain *counterparts* of some actual-world situation or body of evidence.[20] For example, (23) contains a factual modal. The claim is that in all worlds in which the same rumour exists as in the actual world, and in which the rumour bears the same relation to reality as it does in the actual world, Roger was elected chief. The sentence commits the speaker to the belief that Roger was elected in the actual world (modulo the wiggle room provided by a stereotypical ordering source).

(23) Given the rumour, Roger **must** have been elected chief (#but he actually wasn't).

[18] The problem cannot be solved by using different types of ordering sources. Nauze (2008, p. 155) also shows that deontic and stereotypical ordering sources can contain identical sets of propositions in the same context.

[19] Another facet of the new approach is the idea that a modal's domain is projected from an *anchor*. Anchors may be individuals, events, situations, or bodies of evidence. Implicit domain-fixing functions map the anchors to ordered sets of modal alternatives. Here I set the details of anchors aside, concentrating on the issue of the epistemic–circumstantial divide.

[20] On counterparts, see Lewis (1986).

Table 18.2 *Traditional vs. new classifications of (modes of projection of) conversational backgrounds*

<table>
<tr><td>traditional classification</td><td>circumstantial</td><td colspan="2">epistemic</td></tr>
<tr><td>new classification</td><td colspan="2">factual</td><td>content</td></tr>
</table>

The content mode, on the other hand, provides functions which return sets of worlds compatible with the *propositional content* of some actual-world source of information. This is illustrated in (24). Here, the claim is that in all worlds in which the *content of the rumour* is true, Roger was elected chief. This allows the speaker to believe that the rumour was a lie.

(24) According to the rumour, Roger **must** have been elected chief (but he actually wasn't).

Notice that *must* behaves differently in (23) and (24), even though both these uses would traditionally be classified as epistemic. The new classification therefore splits the old class of epistemic modals. Content-mode epistemics are not based on the speaker's knowledge, or necessarily on *anyone's* knowledge – the content of rumours and other similar sources of information can be false.[21]

The traditional class of circumstantial modals, on the other hand, all use the factual mode, as they all rely on some actual-world facts and quantify over worlds in which counterparts of those facts hold. The relation between the old and new classifications is schematized in Table 18.2.

The split between factual- and content-mode epistemics is lexicalized in many languages. For example, the St'át'imcets reportative modal *ku7* is factual, as shown by the fact that the St'át'imcets sentence on which (23)–(24) are based does not allow the speaker to totally disbelieve the rumour (see Matthewson et al., 2007). In contrast, the German reportative modal *sollen* is a content-based modal and *does* allow the speaker to disbelieve the rumour (Kratzer, 2012, p. 35).[22] Other elements traditionally analysed as evidentials also lexically encode the difference between factual- and content-mode conversational backgrounds. This is shown in (25)–(28) for St'át'imcets. The factual modal *k'a* requires the speaker to have indirect inferential evidence for the prejacent, while the content modal *lákw7a* requires the speaker to have sensory, non-visual evidence for the prejacent. Only *lákw7a* allows the speaker to believe that the prejacent is false (Matthewson, 2011, 2012a).

[21] Kratzer (2012) calls the two types of epistemic modals *evidential* vs. *informational*. This is a different use of the term *evidential* from its traditional use, which picks out elements which encode information source (Aikhenvald, 2004).

[22] The Quechua and Cheyenne reportatives also allow the speaker to disbelieve the report (Faller, 2002; Murray, 2009). Faller (2002) and Murray (2009) do not analyse their respective reportatives as having modal semantics, but Faller (2011) analyses the Quechua one as a content-mode ('informational') modal, similar to German *sollen*.

(25) #wá7=**k'a** ku=mám'teq láku7 áltsq7=a, t'u7 nílh=a
be=INFER DET=walk DEIC outside=EXIS but FOC=a
cwílh=t'u7 ti=sk'éxem=a wa7 qan'ím-ens-an
after.all=just DET=wind=EXIS IPFV hear-DIR-1SG.ERG
'Someone might/must have been walking outside, but it was the wind.'

(26) wa7 **lákw7a** ku=mám'teq láku7 áltsq7=a, t'u7 nílh=a
be SENS.NON.VIS DET=walk DEIC outside=EXIS but FOC=a
cwílh=t'u7 ti=sk'éxem=a wa7 qan'ím-ens-an
after.all=just DET=wind=EXIS IPFV hear-DIR-1SG.ERG
'It sounded like someone was walking outside, but it was the wind.'

(27) #t'ec=**k'a**=t'u7 ku=páoy, t'u7 áoz=t'u7 kw=a=s áma
tasty=INFER=just DET=pie but NEG=just DET=IPFV=3POSS good
#'The pie might/must have been good, but it wasn't good.'

(28) *Context: It smelled as if the pie was good, but there was too much salt so it was actually horrible.*
t'éc=t'u7 **lákw7a** ku=páoy, t'u7 áoz=t'u7 kw=a=s
sweet=just SENS.NON.VIS DET=pie but NEG=just DET=IPFV=3POSS
áma
good
'The pie seemed good, but it wasn't good.'

This analysis requires us to assume, following ideas found in McCready (2010a), that the sensory evidence invoked by *lákw7a* has propositional content.[23] So, the factual mode (27) might assert that the pie was good in all worlds in which there was a counterpart of the actual-world smell, and in which the smell bore the same relation to the taste of the pie as it did in the actual world. (Anyone who asserts that cannot simultaneously assert that the pie was bad.) The content mode (28), on the other hand, might assert that the pie was good in all worlds compatible with the content of the sensory-evidence proposition that the pie smelled good. Since my sensory evidence might have been tricking me, it is possible that the pie was bad.

The fact that the St'át'imcets evidentials *k'a* and *lákw7a* lexicalize the split between factual and content modes of conversational background projection has two consequences. The first is that one diagnostic which is sometimes used to argue for a non-modal analysis of evidentials collapses. The diagnostic in question relies on whether an utterance containing the evidential is compatible with the speaker's knowing or believing that the prejacent proposition is false (Faller, 2002; Murray, 2009). The story is that since a modal asserts that its prejacent proposition is possibly or necessarily true,

[23] Thanks to an anonymous reviewer for raising this issue. McCready uses the example of a bloody knife hidden in a cupboard: the knife itself is just a knife, but the proposition that the knife is there is what serves as evidence.

Table 18.3 *A three-way categorization of conversational backgrounds*

<table>
<tr><th></th><th>factual–circumstantial</th><th>factual–evidential</th><th>content–evidential</th></tr>
<tr><td rowspan="2">English</td><td>can</td><td colspan="2">might</td></tr>
<tr><td colspan="3">must</td></tr>
<tr><td>St’át’imcets</td><td>ka (DEON),
ka-...-a (CIRC)</td><td>k’a (INFER),
ku7 (REPORT)</td><td>lákw7a
(SENS.NON.VIS)</td></tr>
</table>

an evidential which allows statements of the form ‘evidential-φ, but not φ’ cannot have modal semantics. However, we just saw that content-mode modals allow statements of this form, because they quantify over worlds compatible with the content of some body of evidence, and do not place any restriction on whether the prejacent is true in the actual world. So the diagnostic of deniability is not sufficient to rule out a modal analysis of evidential elements (Matthewson, 2012a).

The second consequence of the *k’a/lákw7a* situation is that it supports a recently emerging idea about how to unify the old class of epistemic modals, even under the new classification into factual and content modes. The idea is that epistemics are modals which rely on *indirect evidence* about propositions and therefore that epistemic modals fall into the class of evidential elements. As von Fintel and Gillies (2011, p. 113) put it, epistemic modals have a ‘resistance to plain facts but sensitivity to stores of information’. The ‘stores of information’ can include ships’ logs, interview notes, or computers but always constitute indirect evidence of actual-world events. The idea that epistemic modals *always* rely on indirect evidence is fleshed out in von Fintel and Gillies (2007, 2010) and Kratzer (2012). In general, we are seeing a convergence of research on epistemic modality in languages like English with cross-linguistic research on evidentiality which, since Izvorski (1997), has been exploring and debating the idea that at least some evidentials are epistemic modals (Garrett, 2001; McCready and Asher, 2006; Matthewson et al., 2007; McCready and Ogata, 2007; Speas, 2008; Peterson, 2010; Faller, 2011; Lee, 2011, among many others).

The picture I have been sketching leads to a classification as in Table 18.3, where a three-way split is generated. The factual–content division is a difference in modes of projection (whether the modal quantifies over worlds containing a counterpart of some situation or body of evidence, or over worlds compatible with the propositional content of some body of evidence). The circumstantial–evidential division is a difference in whether information source is encoded.

We see that English lexically encodes the circumstantial–evidential split, as well as having some modals which allow all three modes of projection. St’át’imcets encodes the full three-way split. We also predict that languages may have modals which are lexicalized to cover all kinds of factual interpretations, including traditional circumstantial interpretations as well as factual–evidential ones. Whether this prediction is upheld is a topic for future research.

Before leaving the issue of modal flavour, I will mention one more issue of ongoing debate in the area of epistemic modality. Suppose we could agree that epistemic modals depend on stores of information which constitute indirect evidence for actual-world events. There is then still debate about whether epistemic modals necessarily rely on an *agent* who is the holder of that store of information. If an agent is involved, how is that relativism to an agent capturable? The literature on this topic is large and interesting, and consensus has not yet been reached (for relevant discussion, see Garrett, 2001; Hacquard, 2006, 2010; von Fintel and Gillies, 2007, 2008, 2011; Yalcin, 2007; Stephenson, 2008; Waldie, 2012, among others).

18.3 Modal force

18.3.1 Issues in modal force

So far we have looked mainly at necessity and possibility modals, but a picture of modals as encoding either universal or existential quantification over worlds is too simplistic in several important ways. First, there is the existence of graded modality, as we see in (29) (repeated from (11)).

(29) a. Michl is **probably** the murderer.
b. There is a **good possibility** that Michl is the murderer.
c. There is a **slight possibility** that Michl is the murderer.
d. Michl is **more likely** to be the murderer than Jakl.

(Kratzer, 1991b, p. 643)

Kratzer (1981, 1991b) argues that the ordering source provides a way to account for graded modal force. Kratzer defines various graded modal notions such as 'slight possibility', 'good possibility', and 'better possibility'; examples are given in (30)–(31) (see discussion in Portner, 2009, pp. 69–71).

(30) p is a **good possibility** in w with respect to a modal base f and an ordering source g iff:

$\exists u \in \cap f(w)(\forall v \in \cap f(w)(v \leq_{g(w)} u \rightarrow v \in p))$

(Kratzer, 1991b, p. 644)

(31) p is **at least as good a possibility as** q in w with respect to f and g iff:

$\neg\exists u \in \cap f(w)(u \in q - p \;\&\; \forall v \in \cap f(w)(v \in p - q \rightarrow u \leq_{g(w)} v))$

(Kratzer, 2012, p. 41)

A proposition p is a good possibility if there is some world u, such that all higher-ranked worlds than u are p-worlds. To see whether p is at least as good a possibility as q, we look at the worlds p and q do not have in common (i.e., the worlds in $q - p$ and in $p - q$). p is at least as good a possibility as q if there is no world in $q - p$ that is ranked higher than all worlds in $p - q$.

Recent work on graded modality has debated the extent to which the ordering-source-based analysis is sufficient to capture all the relevant facts. One issue is the existence of overtly quantifiable degrees of probability, as in (32). These are not obviously handlable in a standard Kratzerian analysis (although see Kratzer, 2012, pp. 42f.).

(32) a. It was twice as likely to rain as it was to snow.
(Swanson, 2008, p. 1202)
b. There is a 60% probability that it is raining.
(Portner, 2009, p. 73)
c. It is 95% certain that Jorge will win the race.
(Lassiter, 2011a, p. 198)

Researchers such as Halpern (1997, 2003), Swanson (2006, 2008), Portner (2009), Yalcin (2007, 2010), Lassiter (2011a,b), Kratzer (2012) have been exploring the idea that gradable modal elements like *probable/probably/probability* should be analysed as probability operators, and/or that their analysis should adopt insights from the study of gradable adjectives (e.g., Kennedy and McNally, 2005a). A gradable adjectives analysis would mean that these elements introduce a scale which is an ordered set of degrees of possibility or probability.

A related issue to that of graded modality, which happens to be lexicalized in English modal auxiliaries, is the distinction between strong and weak necessity, illustrated in (33).

(33) a. After using the bathroom, everybody **ought to** wash their hands; employees **have to**.
(von Fintel and Gillies, 2008, p. 116)
b. After using the bathroom, everybody **should** wash their hands; employees **must**.

There are several different approaches to weak necessity modals (see Portner, 2009, pp. 79ff. and Rubinstein, 2012, for recent summary and discussion). One family of approaches adapts the probability semantics just discussed for epistemic elements; it views weak necessity modals as assigning a greater likelihood of success or utility to their prejacent than to other alternatives (see, e.g., Goble, 1996; Finlay, 2009, 2010; Lassiter, 2011b).

Another family of approaches to weak necessity involves domain restriction and is based on the fact that universally quantifying over a smaller set of worlds gives rise to a weaker claim.[24] Following an intuition by

[24] For a third set of approaches which rely on pragmatic differences between strong and weak necessity modals (e.g., a presupposition on *must* that is missing on *should*, or evidential differences between the two), see Ninan (2005), Copley (2006), Swanson (2008).

Sloman (1970), von Fintel and Gillies (2008) argue that *ought* universally quantifies over a domain which is narrowed down by an additional restriction, over and above the restrictions on the domain of *must*. In (34a), for example, the claim is that in all the worlds where the relevant facts are the same as in the actual world and in which you meet your goal of getting to Ashfield, you take Route 2. There are no other options for meeting your goal. In (34b), the claim is weaker: in all worlds in which you satisfy a secondary goal (such as avoiding heavy traffic) you take Route 2.

(34) a. To go to Ashfield, you **have to/must** take Route 2.
b. To go to Ashfield, you **ought to** take Route 2.
(von Fintel and Gillies, 2008, p. 118)

Von Fintel and Iatridou argue that the secondary goal is due to a second ordering source, whose presence can be signalled by counterfactual morphology in a range of languages. This approach uses only tools provided by a standard analysis of modals, but/and it raises interesting questions about ordering sources. One issue discussed by Rubinstein (2012) is how we tell which ordering source is which – which is the 'primary' and which the 'secondary'? Rubinstein proposes that weak necessity modals rely on ordering sources which involve a departure from the collective commitments of participants in the discourse. For example, suppose there are four ways to get to Amherst from Cambridge. A speaker who utters (35) conveys that while taking Route 9 is not a necessity given the collectively agreed-upon goal of getting to Amherst, it is a necessity given some assumption that the speaker presupposes is *not* collectively shared with the hearer (such as seeing nice scenery, or stopping for lunch at a particular place on the way).

(35) To go to Amherst, you **ought** to take Route 9.
(Rubinstein, 2012, p. 9)

Further questions raised by the ordering-source approach include the issue of what prevents even a single ordering source from weakening a strong necessity modal more than we would like. Similarly, what prevents a weak necessity modal from becoming as weak as a possibility modal? And finally, do epistemic strong necessity modals really even have *one* ordering source? Both von Fintel and Iatridou (2008) and von Fintel and Gillies (2010) doubt that they do. These authors disagree with one of the basic supposed empirical motivations for ordering sources, namely that (36a) is weaker than (36b) because it involves a non-realistic, stereotypical ordering source.

(36) a. She **must** have climbed Mount Toby.
b. She climbed Mount Toby.
(Kratzer, 1991b, p. 645)

According to von Fintel and Gillies, epistemic *must* does *not* signal weakening with respect to the assertion of the plain prejacent. Instead, it signals indirect evidentiality (as discussed in the previous section), and this leads to a perceived weakening. One thing to note about this idea is that the evidentiality claim is independent of the no-ordering-source claim. It could conceivably be correct that *must* requires indirect evidence, but false that it makes no use of an ordering source.

A final strand of current research in the area of modal force is modals without duals. These are modals which do not come in necessity–possibility pairs, but can be used in contexts supporting either necessity or possibility claims. These have been most extensively discussed for languages other than English (Rullmann et al., 2008; Davis et al., 2009; Peterson, 2010; Deal, 2011). In the next subsection, I discuss two examples of such languages, Gitksan and Nez Perce.

18.3.2 Modal force in Gitksan and Nez Perce

The Gitksan epistemic modals *ima('a)* and *g̲at*, seen above in Section 18.2.3, differ from English modal auxiliaries in that they do not appear to be specialized for a particular modal force. Instead of forming a paradigmatic universal–existential pair, they contrast with each other only in information source. *Ima('a)* and *g̲at* are compatible with situations which license necessity assertions, and with situations which license possibility assertions. Consequently, acceptable translations into English differ widely, as shown in (37).

(37) *Context: You're wondering where your friend is. You notice his rod and tackle box are not in their usual place.*
yugw=**ima**=hl dim ixw-t
IPFV=**epis**=CN PROSP fish.with.line-3
'He might be going fishing.' / 'He must be going fishing.' / 'He's probably going fishing.' / 'He's likely going fishing.' / 'He could be going fishing.' / 'Maybe/perhaps he's going fishing.'
(Peterson, 2010, p. 161)

Note that in the example above the spelling of *ixw* has been corrected (cf. Rigsby, 1986, p. 170).

The claim that *ima('a)* is not semantically a necessity modal is supported by data such as in (38). In this discourse context, *must* would be infelicitous in English.

(38) *Context: You thought your friend was fishing. But you see his rod and tackle box are still at his house. You really don't know if he's fishing or not.*
yugw=**imaa**=hl da'awhl ixw-t oo ligi nee=**yimaa**=dii ixw-t
IPFV=EPIS=CN then fish-3 or INDEF NEG=EPIS=CNTR fish-3
'Maybe he's fishing, maybe he's not fishing.'
(Matthewson, 2013a, p. 361)

Peterson (2010) analyses *ima('a)* as a possibility modal which can be strengthened via an ordering source. This idea is the inverse of the domain-restriction approach to weak necessity discussed in the previous section, and relies on the idea that while narrowing the domain of a universal quantifier causes weakening, narrowing the domain of an existential quantifier causes strengthening.

Superficially similar data, in the non-epistemic realm, are presented for Nez Perce by Deal (2011). As shown in (39), the circumstantial modal *o'qa* is translatable as, and at first glance apparently interpretable as, either a possibility or a necessity modal.

(39) *Context: I am watching people clean out a cooler and throw away various things.*
hi-wqíi-cix-∅ 'iléx̂ni hipt ke yox̂ hi-pá-ap-**o'qa**
3SUBJ-throw.away-IPFV.PL-PRES a.lot food REL DEM 3SBJ-S.PL-eat-MOD
(i) 'They are throwing away a lot of food that they could eat.'
(ii) 'They are throwing away a lot of food that they should eat.'
(Deal, 2011, p. 574)

Deal shows, however, that in downward-entailing environments, *o'qa* behaves only as a possibility modal would be expected to behave. This is shown in (40), with the modal inside the downward-entailing first argument of the universal quantifier *'óykala* 'all'.

(40) *Context: As in (39).*
hi-wqíi-cix-∅ 'óykala hipt ke yox̂ hi-pá-ap-**o'qa**
3SUBJ-throw.away-IPFV.PL-PRES all food REL DEM 3SBJ-S.PL-eat-MOD
(i) 'They are throwing away all the food that they **could** eat. They are throwing away all their food.'
(ii) #'They are throwing away all the food that they **should** eat (but keeping some junk food).'
(Deal, 2011, p. 574)

Although the English translation in (40-i) entails (the first part of) (40-ii), the Nez Perce sentence is not a viable way to express the specific negated-necessity meaning of (40-ii). That is, the Nez Perce sentence cannot be understood as conveying that they are throwing away all the food they *should* eat, but keeping some food they *could* eat (the junk food).

Deal analyses *o'qa* as a possibility modal, which is acceptable in non-downward-entailing necessity contexts because there is no contrasting necessity modal to induce a scalar implicature. In other words, Nez Perce's circumstantial modal system parallels what English's nominal quantifier system would look like if it possessed the existential quantifier *some*, but no universal quantifier like *all* or *every*. In such a version of English, (41a) would fail to implicate that not all the guests brought presents and therefore would be acceptable in a context where all of the guests brought presents.

This is parallel to the felicitous use of *o'qa* in the necessity context in (39-ii). The downward-entailing (41b) would (just like in real-life English) be unable to express the negated-universal meaning: (41b) would be unable to express the claim that it is false that *all* of the guests brought presents (but true that *some* of them did). This parallels the infelicity of *o'qa* in the downward-entailing necessity context in (40-ii).

(41) a. Some of the guests brought presents.
b. It is false that some of the guests brought presents.

Peterson's analysis of Gitksan epistemic *ima('a)* and Deal's analysis of Nez Perce circumstantial *o'qa* make the same predictions for non-downward-entailing environments (that the modals can be used in both possibility and necessity contexts), but different predictions for downward-entailing contexts (*ima('a)*, but not *o'qa*, is predicted to be acceptable in necessity contexts). Unfortunately, the predictions for downward-entailing environments are difficult or impossible to test for *ima('a)*, owing both to independent features of Gitksan, and to inherent difficulties with placing epistemic modals in downward-entailing environments in the first place. See Matthewson (2013a) for Gitksan, and Deal (2011, p. 566), who writes about Nez Perce that 'Owing to difficulties in embedding certain epistemic expressions in downward-entailing contexts, the intricacies of the epistemic system are not yet fully understood.'

There are other approaches to modals without duals, for example a domain-restricted necessity analysis by Rullmann et al. (2008), and a degree-modal analysis by Kratzer (2012).[25] There are also yet more empirical configurations, which raise further analytical questions. For example, Nsyilxcen (Okanagan Salish) possesses two epistemic modals, *mat* and *cmay*. *Mat* is felicitous in both possibility and necessity contexts, but *cmay* is felicitous only in possibility contexts. This is shown in (42)–(43).

(42) *Context (possibility): You know that Mary loves to go running and often goes on runs randomly. She could also be at the store or at school. I ask you, where is Mary?*
a. Mary **mat** ac-qíc-əlx
Mary MOD CUST-run-LEX
'Mary might be running.'
b. Mary **cmay** ac-qíc-əlx
Mary MOD CUST-run-LEX
'Mary might be running.'

(Menzies, 2013, p. 2)

[25] One of Kratzer's motivations for a degree-modal analysis is that Rullmann et al. (2008), Peterson (2010), and Deal (2011) fail to explain the absence of duals in the respective languages (Kratzer, 2013, pp. 184–185). While a degree-modal analysis may turn out to be preferable, I am not sure that the absence of duals is something which necessarily requires explanation. Some modals have duals, some do not. Attitude verbs do not seem to have duals, for example.

(43) *Context (necessity): Mary runs every day to train for a marathon. She usually runs at 6 pm on Tuesdays. Today is Tuesday and it's 6 pm. I ask you, where is Mary?*

a. Mary **mat** ac-qíc-əlx
Mary MOD CUST-run-LEX
'Mary must be running.'

b. #Mary **cmay** ac-qíc-əlx
Mary MOD CUST-run-LEX
'Mary might be running.'

(Menzies, 2013, p. 2)

We thus see that within a single language's epistemic system, one modal behaves as if it lacked a dual, while one behaves like a strict possibility modal. This raises interesting questions for the idea that possibility modals in languages like English are weak because of scalar implicatures induced by the contrasting necessity modal. See Section 18.5 for discussion of an emerging formal typology of modal force.

18.4 Modal–temporal interactions

The denotations we have so far for English modal auxiliaries, repeated in (44), are dependent on both a modal base and an ordering source, but contain no sensitivity to time.

(44) a. $[\![must]\!]^{w,g} = \lambda f_{\langle s,\langle st,t\rangle\rangle}.\lambda h_{\langle s,\langle st,t\rangle\rangle}.\lambda p_{\langle s,t\rangle}.\forall w' \in \text{BEST}_{h(w)}(\cap f(w)) : p(w) = 1$

b. $[\![can]\!]^{w,g} = \lambda f_{\langle s,\langle st,t\rangle\rangle}.\lambda h_{\langle s,\langle st,t\rangle\rangle}.\lambda p_{\langle s,t\rangle}.\exists w' \in \text{BEST}_{h(w)}(\cap f(w))) : p(w) = 1$

However, as pointed out above and as discussed by many authors including Condoravdi (2002) and Ippolito (2003), the truth conditions of modal statements depend not only on a world of evaluation but also on a time of evaluation. Conversational backgrounds must therefore be functions which take times as one of their arguments. A time-dependent denotation for *must* is given in (45).

(45) $[\![must]\!]^{w,g} = \lambda f_{\langle s,\langle st,t\rangle\rangle}.\lambda h_{\langle s,\langle st,t\rangle\rangle}.\lambda P_{\langle i,\langle s,t\rangle\rangle}.\lambda t.\forall w' \in \text{BEST}_{h(w)}(\cap f(w,t)) : P(t)(w') = 1$

Simply introducing a time of evaluation is of course not the full story. As Portner (2009, p. 223) observes, there are at least three ways in which the temporal interpretation of modal sentences can be restricted: first, by independent tense or aspect operators and their scope properties; second, by temporal restrictions in the lexical entries of the modals themselves, and third, by 'general semantic or pragmatic principles which help determine temporal meaning, but which are not tied to any particular grammatical element'. Portner (2009, Chapter 5) gives a comprehensive overview of the issues in modal–temporal interactions and the major available approaches. In this section I will first outline an approach to modal–temporal interactions which draws on and generalizes Condoravdi's (2002) work, and then discuss the contentious issue of whether epistemic modals can scope under past tense. In Section 18.4.3 I present some cross-linguistic evidence for the proposed approach to modal–temporal interactions.

18.4.1 Sketch of an approach to modal–temporal interactions

The discussion in this subsection is presented with respect to English data unless otherwise noted, but the architecture of the framework is intended to be cross-linguistically applicable. Following much work in the literature, I assume that modals appear syntactically below tense,[26] but above viewpoint aspect. The reference time interval which is provided by tense saturates the time argument in the lexical denotation of the modal (see (45) above). The tense thus provides the evaluation time for the modal base, called the temporal perspective by Condoravdi (2002). Viewpoint aspect restricts the relation between the temporal perspective and the time of the event described by the prejacent clause; this relation is called the temporal orientation of the modal by Condoravdi. Temporal perspective and temporal orientation are illustrated in (46).

(46) a. Merlin might win the game.
temporal perspective: PRESENT (based on available evidence at utterance time)
temporal orientation: FUTURE (event follows temporal perspective)

b. Merlin might have won the game.
temporal perspective: PRESENT (based on available evidence at utterance time)
temporal orientation: PAST (event precedes temporal perspective)

Simple versions of perfective, imperfective, perfect, and prospective viewpoint aspects are given in (47)–(50). Exactly one of perfective or imperfective applies in each clause, and either perfect or prospective may optionally add between the first aspect and the modal.[27]

[26] More generally (to take into account tenseless languages), what is crucial is that the modal is provided with a reference time in whatever way the language independently provides reference times to non-modal clauses.

[27] Some analyses, including that of Condoravdi (2002), do not include a prospective viewpoint aspect but instead place an inherent future semantics in the modal itself. I am using prospective here by analogy to languages which overtly mark future temporal orientation with prospective aspect markers, such as Gitksan (see Section 18.4.3). Kratzer (2011b) argues that English possesses a null prospective aspect marker which co-occurs with modals, and its absence can lead to actuality entailments. (For other work on the important topic of actuality entailments, which unfortunately I do not have space to go into here, see Bhatt, 1999; Hacquard, 2006, 2009; Mari and Martin, 2007, among others.)

(47) $[\![\text{PFV}]\!]^{g,w} = \lambda P_{\langle l,st\rangle}\lambda t \lambda w.\exists e[P(e)(w)\ \&\ \tau(e) \subseteq t]$ (Kratzer, 1998a)

(48) $[\![\text{IPFV}]\!]^{g,w} = \lambda P_{\langle l,st\rangle}\lambda t \lambda w.\exists e[P(e)(w)\ \&\ t \subseteq \tau(e)]$ (Kratzer, 1998a)

(49) $[\![\text{PRF}]\!]^{g,w} = \lambda P_{\langle l,st\rangle}\lambda t \lambda w.\exists t'[t' < t\ \&\ P(t')(w)]$

(50) $[\![\text{PROSP}]\!]^{g,w} = \lambda P_{\langle l,st\rangle}\lambda t \lambda w.\exists t'[t \leq t'\ \&\ P(t')(w)]$

The schemas in (51) show how the various temporal operators apply. In each case the tense provides the temporal perspective (TP), and aspect restricts the temporal orientation (TO). Note that prospective aspect merely induces non-pastness; depending on the Aktionsart of the predicate and the perfective/imperfective distinction, prospective can derive either strict future orientation (with an eventive perfective verb) or ambiguously present/future orientation (with a stative predicate and/or an imperfective).

(51) a. He might dance:
PRES (*might* (PROSP (PFV (λe.he-dance(e)))))
TP: present TO: future
b. He might be dancing:
PRES(*might* (PROSP (IPFV (λe.he-dance(e)))))
TP: present TO: present or future
c. He might have danced:
PRES(*might* (PRF (PFV (λe.he-dance(e)))))
TP: present TO: past
d. He might have been dancing:
PRES(*might* (PRF (IPFV (λe.he-dance(e)))))
TP: present TO: past

The schemas so far all have present tense, therefore present temporal perspective. As is well known, English modal auxiliaries do not synchronically inflect for tense, but in languages in which they do (such as Dutch or German), past tense morphology on the modal gives past temporal perspective. This also happens with English semi-modals such as *have/had to* or *is/was able to*. Otherwise, past TP in English is marked by the perfect auxiliary *have*. In (51c)–(51d), *have* introduces a low-scoping perfect aspect and gives past TO, but *have* can also induce past TP when it combines with a modal which contains historical past tense morphology (such as *might* or *could*). These two different roles for *have* underlie the famous ambiguity of *might have*-constructions, pointed out by many including Condoravdi (2002), Huddleston and Pullum (2002), Ippolito (2003), and illustrated in (52)–(53).[28]

[28] The details of how *have* manages compositionally to contribute past TP have been debated in the literature and go beyond what we can discuss here (see Condoravdi, 2002; Ippolito, 2003; Arregui, 2005; Hacquard, 2006; Laca, 2008; Rullmann and Matthewson, 2012, for discussion).

(52) Q: Why is John looking happy?
A: I'm not sure, but he might have won the game.
PRES(*might*(PRF(PFV(λe.he-win(e)))))
TP: present TO: past

(53) Q: Why is John looking sad?
A: Because he might have won the game,
if he hadn't fumbled that pass.
PAST(*might*(PROSP(PFV(λe.he-win(e)))))
TP: past TO: future

The readings in (52) and (53) differ not only in temporal properties but in conversational background: (52) is epistemic, while (53) is circumstantial (more specifically, metaphysical, according to Condoravdi, 2002, although see Abusch, 2012, for a dissenting view).[29] How the unattested combinations of temporal perspective, temporal orientation, and conversational background are ruled out is a question that immediately arises. One sub-part of the puzzle is the restriction of the circumstantial reading in (53) to future orientation. If (53) does involve metaphysical modality, its future orientation follows from Condoravdi's (2002) Diversity Condition, or from Werner's (2003) Disparity Principle. These are general principles which rely on the fact that metaphysical modals quantify over worlds which only vary for times following the temporal perspective.

A second sub-part of the puzzle posed by (52)–(53) is the restriction of the epistemic interpretation to a present temporal perspective. This can be derived within Condoravdi's system via a stipulation that epistemic modals cannot scope under either past tense or the perfect auxiliary. This issue has been the subject of much debate, and I discuss it in slightly more detail in the next subsection.

18.4.2 Past epistemics

Can epistemic modals have past temporal perspectives? The issue is whether sentences like (54a–c) can make an assertion about what was epistemically possible or necessary at some past time.

(54) a. Jack's wife **couldn't** be rich. (Stowell, 2004, p. 625)
b. There **had to** be a hundred people there. (Stowell, 2004, p. 626)
c. There **might have** been ice cream in the freezer. (von Fintel and Gillies, 2008, p. 87)

Many researchers have denied that epistemic modals can have past temporal perspectives, at least in English. Hacquard (2011, p. 1495), for example, states

[29] A metaphysical modal base is a circumstantial modal base which provides a set of worlds which are all identical to the actual world up to and including the time at which the modal base is calculated (Thomason, 2002).

that 'epistemic modals are evaluated at the speech time' (see also Groenendijk and Stokhof, 1975; Cinque, 1999; Condoravdi, 2002; Stowell, 2004; Hacquard, 2006; Borgonovo and Cummins, 2007; Demirdache and Uribe-Etxebarria, 2008; Laca, 2008). A common belief is that the semantic restriction on the temporal properties of epistemic modals derives from a syntactic restriction, namely that epistemic modals scope over tense, while non-epistemic modals scope under it. Hacquard (2011) (among others) adopts Cinque's (1999) hierarchy of functional heads, relevant portions of which are given in (55):[30]

(55) $\text{Mod}_{\text{epis}} > \text{Tense} > \text{Aspect} > \text{Mod}_{\text{volitional}} > \text{Mod}_{\text{deontic necessity}}$
$> \text{Mod}_{\text{ability/deontic possibility}}$

(Hacquard, 2011, p. 1496)

The view that epistemic modals always scope over tense has not gone unchallenged. Epistemic modals have been shown to allow past temporal perspectives in a number of languages; see Eide (2003, 2005) for Norwegian, Kratzer (2009) for English and German, and Homer (2013), Mari (2010), and Martin (2011) for French. Within English and to a certain extent for other languages, the issue is still controversial. Von Fintel and Gillies (2008) argue that (54c) does have a past-TP epistemic reading; the reading is facilitated by a discourse context as in (56). Von Fintel and Gillies (2008, p. 87) state that here 'It is possible for [the speaker] to have said something true, even though at the time of utterance she knows . . . there is no ice cream in the freezer.'

(56) *Context: Sophie is looking for some ice cream and checks the freezer. There is none in there. Asked why she opened the freezer, she replies:*
There **might have** been ice-cream in the freezer.

(von Fintel and Gillies, 2008, p. 87)

The debate about past epistemics goes beyond simple empirical disagreement: among those who acknowledge that epistemic modals can have a past temporal perspective, some deny that it reflects the ability of the epistemic modal to scope under a clause-mate past tense. It has, for example, been proposed that the relevant readings involve an elided embedding attitude verb or *because*-clause (Hacquard, 2006, 2011), or that they are felicitous due to contexts of (free) indirect discourse (Fagan, 2001; Boogaart, 2007; Hacquard, 2006, 2011). For arguments against some of these escape hatches, see Homer (2013), Rullmann and Matthewson (2012), and see Portner (2009, pp. 222–236) for summary and discussion.[31]

[30] As discussed in Section 18.2.2 above, Hacquard does not derive the effects of syntactic position on interpretation simply from a cartographic syntax. Her proposal is that the different interpretations arise because modals interact locally with different elements which partially determine the modal's interpretation.

[31] Portner (2009, p. 227) himself states that a past temporal perspective is rare but not impossible for epistemic modals, and that the past readings may be limited to stative sentences. See also Iatridou (1990) for relevant discussion, including the claim that some but not all of what we currently classify as epistemics can scope under tense.

In a broader cross-linguistic context, Chen et al. (forthcoming) provide evidence that twelve languages from seven families allow past-TP epistemics: English, Dutch, German, Mandarin, St'át'imcets, Northern Straits Salish, Halkomelen (Salish), Gitksan, Blackfoot (Algonquian), Atayal (Austronesian), Javanese (Austronesian), and Ktunaxa (isolate). They argue that cross-linguistically, modal flavour is independent of temporal perspective and that all possibility modals can have past temporal perspectives, whether they are interpreted epistemically or circumstantially. Some of the evidence for this claim is presented in the next subsection.

18.4.3 Modal–temporal interactions across languages

In this section I present evidence for two proposals: first, that epistemic modals can have a past temporal perspective in a range of languages, and second, that viewpoint aspects within the prejacent clause help determine the temporal orientation. The first claim is supported by the data in (57)–(59), from Blackfoot, Ktunaxa, and St'át'imcets respectively. Each of these languages has lexical items dedicated to epistemic modality, so the modal flavour is unambiguously epistemic. The past temporal perspective is ensured by the discourse context and is not overtly marked because tense is non-overt in all these languages.

(57) *Context: Stacey bought a bone for Pat's pet, thinking it might be a dog. Later, she finds out the pet is a snake. When Pat asks her why she bought a bone, she says:*
matonni ni-maat-ssksini-'p-wa ot-aanist-a'pssi-wa
yesterday 1-NEG-know.VTI-LOC:0-NONAFF 3-manner-be.VAI-3
piiksiksinaa-wa **aahkam**-omitaa-wa
snake-3 EPIS-dog-3
'Yesterday, I didn't know it was a snake, it might have been a dog.'
(Louie, 2012, elicited using the Feeding Fluffy storyboard, TFS Working Group 2012)[32]

(58) *Context: Your neighbour doesn't show up for work and you know there's been a flu going around. You send your son to bring her hot soup. She actually took the day off because her apartment flooded, so she asks why you sent her soup in the middle of the day.*
ɬin hin sa·niɬxuʔ-ni
EPIS 2 sick-IND
'You might have been sick.'
(Laturnus, 2012)

(59) *Context: When you looked out of your window earlier today the ground was wet, so it looked like it might have rained. But you find out later that sprinklers had been watering the ground.*
kwís=**k'a**=tu7
rain=EPIS=then
'It might have rained.'

[32] www.totemfieldstoryboards.org/stories/feeding_fluffy/.

Further evidence for past-TP epistemic modals is given in (60)–(62) from Gitksan; these data also support the second proposal of this section, namely that viewpoint aspects control temporal orientation. Observe that (60)–(62) are a minimal triplet containing the epistemic modal *ima('a)*, a uniformly past temporal perspective (ensured by the context), and all three possible temporal orientations, past, present, and future respectively. While in (60) there is no overt marking of past orientation, in (62) the future orientation is achieved by means of the overt prospective aspect marker *dim*.

(60) *Context: When you looked out your window earlier today, the ground was wet, so it looked like it might have rained. But you found out later that the sprinklers had been watering the ground.*
yugw=**imaa**=hl wis da'awhl
IPFV=EPIS=CN rain then
'It might have rained.' [based on my evidence earlier]
(Matthewson, 2013a, p. 366)

(61) *Context: When you looked out your window earlier today, water was falling, so it looked like it was raining. But you found out later it was the gutters leaking.*
yugw=**imaa**=hl wis da'awhl
IPFV=EPIS=CN rain then
'It might have been raining earlier.'
(Matthewson, 2013a, p. 363)

(62) *Context: This morning you looked out your window and judging by the clouds, it looked like it might have been going to rain, so you took your raincoat. Later you're explaining to me why you did that.*
yugw=**imaa**=hl **dim** wis
IPFV=EPIS=CN PROSP rain
'It might have been going to rain.'
(Matthewson, 2013a, p. 366)

Prospective aspect marking is obligatory whenever a modal is future-oriented in Gitksan (Matthewson, 2013a). This leads to at least three consequences. First, English and Gitksan differ superficially, in that temporally unmarked epistemic modals can be future-oriented in English but not in Gitksan; this is shown in (63).

(63) yugw=**imaa**=hl wis
IPFV=EPIS=CN rain
'It might have rained.' / 'It might be raining.' / ≠ 'It might rain (in the future).'
✓ Context: You see puddles, and the flowers looking fresh and damp. PAST TO
✓ Context: You hear pattering on the roof. PRESENT TO
\# Context: You hear thunder, so you think it might rain soon. FUTURE TO
(Matthewson, 2013a, pp. 364–365)

Second, English and Gitksan are mirror images, since past orientation is obligatorily marked in English (via *have*), but future orientation is obligatorily marked in Gitksan (via *dim*). And third, English and Gitksan can be analysed as abstractly parallel, if we are willing to postulate a null prospective aspect in English and a null perfect in Gitksan (cf. Van de Vate, 2011).

In this section I have sketched a Condoravdi-inspired approach to modal–temporal interactions, which makes the universal hypotheses that temporal perspective is given by tense (or the language-internal functional equivalent) and temporal orientation is restricted by aspect. Obviously, languages vary independently in their temporal systems. An overarching goal is therefore to establish the extent to which variation in modal–temporal interactions reduces to those independent temporal differences. For example, we have already seen that languages without overt past–present distinctions allow past temporal perspectives without any overt marking. This is predicted by the system presented. Whether other predictions are upheld is a matter for future research.

18.5 Typological and other remaining questions

In this chapter we have discussed the basics in three major areas in modality research: modal flavour, modal force, and modal-temporal interactions. Many empirical and analytical questions remain about all of these areas, as well as about the interactions between them. Assuming that our ultimate goal is a theory of universals and variation in human language, one important task for the field is to gather information about modality in unfamiliar and understudied languages. Formal research on such languages will allow us to develop a formal typology of modality, which in turn will facilitate greater theoretical understanding.

There is, of course, already a rich tradition of modality research in the typological literature (see Bybee et al., 1994; de Haan, 1997; van der Auwera and Plungian, 1998; Palmer, 2001; Hengeveld, 2004; van der Auwera and Ammann, 2011, among others). These works provide extensive information about how modal notions are expressed across languages (e.g., as verbs, affixes), what types of categories are encoded, and the grammaticalization paths of modal elements. Added to this is a recent growth of formal research on modality, which is able (through hypothesis-driven investigation and the collection of negative evidence) to isolate precisely and accurately the semantics of modal elements in a range of languages.[33,34]

[33] For critiques of a non-hypothesis-driven typological approach to modality, see Matthewson (2013b) and Davis et al. (2014). Along similar lines, Nauze (2008, p. 19) points out that a good typology of modality must rely not only on general descriptive sources such as grammars but on 'semantically motivated descriptions' of modal systems.

[34] For a recent example of formal cross-linguistic research on modality, see Arregui et al. (2014), who provide a modal analysis of imperfective aspects in several different languages.

One major set of questions which cross-linguistic study of modality needs to address is what the lexicalization patterns are across languages for modal flavour, modal force, temporal properties, and all combinations of these. There is already evidence that flavour, force, and temporal properties are not randomly combined. For example, there is a well-known flavour-orientation correlation which we hinted at above, namely that circumstantial modals usually – sometimes even obligatorily – have future orientation. As Kratzer (2012, p. 54) writes, circumstantial modal bases target facts which are 'external or internal circumstances of people, things or places that determine their possible futures'. In contrast, realistic epistemic modals target 'evidence of things implying or suggesting the presence of other facts in the past, present, or future'.

The circumstantial/future-orientation correlation arises in different language families and has been documented and analysed by, among others, Coates (1995), Enç (1996), Condoravdi (2002), Stowell (2004), Copley (2006), Werner (2003, 2006), Borgonovo and Cummins (2007), Van de Vate (2011), Chen (2012), Kratzer (2012, 2013), Matthewson (2012b, 2013a), Thomas (2013). There are also three-way correlations between force, flavour, and temporal orientation, such as a restriction of epistemic necessity modals to past orientation; see Werner (2006), Portner (2009) on English and Lekakou and Nilsen (2008) on Greek.[35] On the other hand, Tonhauser (2011) argues that the Paraguayan Guaraní future marker *-ta* allows epistemic necessity interpretations, and Giannakidou and Mari (2013) argue that the future morpheme in both Greek and Italian conveys epistemic modality. Further research is obviously required.

There has not yet been as much research into flavour–force correlations, but an interesting question is whether one particular modal flavour might be more likely to lack duals than another. Impressionistically, it seems that epistemic modals (including elements which have traditionally been analysed as evidentials) may be more likely to lack duals. Gitksan is a case in point; we saw above that this language encodes force distinctions in the circumstantial domain, but not the epistemic. Another example is Niuean (Polynesian), which possesses a general-purpose epistemic modal *liga*, usable in contexts of both high and low certainty, but two circumstantial modals, *maeke* and *lata*, which are specialized for force (possibility and necessity respectively). Examples (64)–(66) show *liga* with various translations, which correspond to the different modal forces the modal allows.

(64) **liga** kua fano tei
EPIS PRF go PRF
'He/she/they **might** have left.'
(Matthewson et al., 2012, p. 224)

[35] Abraham (1998, p. 233) argues more radically for modals of all forces that 'reference to the future under no circumstances gives an epistemic reading'.

(65) *Context: Tom wasn't fishing yesterday, and you were wondering about his health. But today you see him fishing.*
Hī ika a Tom he aho nei . . . **liga** malolo a ia
catch.fish fish ABS Tom on day this EPIS strong ABS 3SG
'Tom is fishing today . . . he's **probably** well.'
(Matthewson et al., 2012, p. 228)

(66) ne **liga** kua veli hifo e tama ke he pelapela
PAST EPIS PRF fall down ABS child to mud
'The boy **must** have fallen in the mud.'
(Seiter, 1980, p. 13)

Example (67) shows the possibility modal *maeke* in one of its most frequent uses, an ability reading, and Example (68) shows the necessity modal *lata* with an obligation interpretation.

(67) kua **maeke** he tama ia ke taute pasikala afi
PRF CIRC.POSSIB at child that SBJ fix bicycle fire
'That child is able to fix motorbikes.'
(Seiter, 1980, p. 140)

(68) **lata** ke ō a tautolu he aho nei ki Queen Street
CIRC.NECESS SBJ go.PL ABS we.PL.INCL on day this to Queen Street
'We should go to Queen Street today.'
(Seiter, 1980, p. 133)

One of the most comprehensive contributions in the area of modal typology is Nauze (2008). Nauze investigates a relatively small sample (six languages from six families, as opposed to the 207 languages of van der Auwera and Ammann, 2011). However, Nauze's work has the advantage that it is based not just on traditional descriptions such as grammars (which typically give insufficient information about the semantics of modality) but also on field-work, personal discussion with language experts, and targeted and/or formal literature. Nauze advances the following (tentative) proposal:

> Modal elements can only have more than one meaning along a unique axis of the semantic space: they either vary on the horizontal axis and thus are polyfunctional in the original sense of expressing different types of modality or they vary on the vertical axis and can express possibility and necessity, but they cannot vary on both axes. (Nauze, 2008, p. 222)

This proposed universal rules out a modal element which is polyfunctional in terms of both modal flavour and modal force.

In very recent work, Vander Klok (2013) refines Nauze's proposal. Vander Klok observes that Nauze predicts that a language could possess one modal expression which is polyfunctional along the modal force dimension, and another expression which is polyfunctional along the modal flavour dimension, within the same domain (epistemic or non-epistemic). For example,

Table 18.4 *Hypothetical modal system of the root domain: predicted to exist under Nauze's (2008) typology (Vander Klok, 2013, p. 18)*

		Modal flavour		
		Root domain		
		Deontic	Pure circumstantial	Teleological
Modal force	Necessity	*x*	*y*	*y*
	Possibility	*x*	*w*	*z*

a language should be able to contain one modal which is specified for a particular non-epistemic flavour (e.g., deontic) and lacks a dual, covering both possibility and necessity readings, and simultaneously contain other circumstantial modals which are polyfunctional along the flavour dimension. A hypothetical system of this type is schematized in Table 18.4.

Based on languages like Gitksan and Paciran Javanese, Vander Klok hypothesizes that a more restrictive universal might hold. She proposes that languages allow for referential ambiguity along only one axis within each modal domain (epistemic vs. non-epistemic). The system in Table 18.4 violates this restriction, because it involves referential ambiguity along both the flavour and the force dimensions, within the same (circumstantial) domain. The Gitksan system satisfies the more restricted universal: although it possesses some modals which vary along a force dimension (the epistemic modals *ima('a)* and *g̲at*), and some modals which vary along a flavour dimension (the circumstantial necessity modal *sgi*, which allows deontic, pure circumstantial, and teleological readings), the two types of polyfunctionality are each confined to their own half of the system. More cross-linguistic research is obviously required to test these typological predictions.

18.5.1 Other areas of modal research

Modality is a very large topic, and any one paper on it must unfortunately set aside many important sub-topics. One way in which the field of modality extends beyond what I have discussed here is simply in terms of construction types. In this chapter the English data were drawn mainly from modal auxiliaries (as is the tradition in much of the literature). However, the data from other languages were not restricted to auxiliaries; we have looked at modal verbs, affixes, second-position clitics, and adverbs. Modal semantics also arises in conditionals, viewpoint aspects, tenses, moods, indefinite articles, adverbs, adjectives, infinitivals, and so on.[36] The null hypothesis is that the basic semantic concepts presented here will be equally applicable to

[36] References for any one of these topics would be too numerous to cite.

other items involving modal semantics; any counter-examples to this provide interesting avenues of research.

Sometimes, the failure of a semantic analysis to extend to a new domain is due to independent factors like syntax. For example, I mentioned above that Chen et al. (forthcoming) found that epistemic modals can have past temporal perspectives in eight languages. There are a few counter-examples to the pattern in Chen et al.'s language sample, among them SENĆOŦEN (the Saanich dialect of Northern Straits Salish) and Hul'q'umi'num' (the Island dialect of Halkomelem Salish). According to Turner (2013), epistemic modals in these two languages do not allow past temporal perspectives. However, Turner suggests that this may be due to the fact that the epistemic modals in question are of the wrong syntactic category. She draws a parallel between the epistemic modals in SENĆOŦEN and Hul'q'umi'num' and the English epistemic adverb *maybe*. Unlike the modal auxiliary *might*, *maybe* does not scope under tense and cannot receive a past temporal perspective.

(69) *Context: Sophie is looking for some ice cream and checks the freezer. There is none in there. Asked why she opened the freezer, she replies:*
There **might** have been ice cream in the freezer.
#**Maybe** there was ice cream in the freezer.
(adapted from von Fintel and Gillies, 2008, p. 87)

This is one simple example of how variation in modal semantics is reducible to independent factors like the syntactic category of the modal elements. It also illustrates how phenomena in unfamiliar languages have parallels or counterparts within familiar languages when the latter are re-examined in the light of the former.

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19

Questions

Paul Dekker, Maria Aloni, and Jeroen Groenendijk

19.1 Introduction

In this chapter we give an overview of the research area which studies the meaning of questions. We start with explaining some general notions and insights in this area, and then zoom in on the three most influential semantic theories of questions, which all attempt to characterize question meaning in terms of "answerhood conditions". (They are thus following up on the notion of "truth conditions" as the core notion of a formal semantics for indicative sentences.) Next, we discuss some special topics in the study of questions and answers, where we focus on issues which are concerned with identity and questions which have to do with scope. Finally, we describe some pragmatic features of answering questions and the general role that questions play in the dynamics of discourse, leading up to a concise introduction of the recent framework of inquisitive semantics.[1]

[1] Some of the introductory material in this chapter is based on Dekker et al. (2007). See Groenendijk and Stokhof (1997), Hagstrom (2003), Krifka (2011) and Cross and Roelofsen (2014) for other excellent surveys of question semantics.

19.2 Questions in formal semantics

Questions can be studied from various perspectives. For a syntactician, questions are linguistic entities, sentences of a certain kind with distinctive formal features. In English they typically display a change in word order (*Is Marco smart?* versus *Marco is smart*), they host *wh*-expressions with characteristic syntactic features (*who*, *what*, *where*, *how*, but also *which students*, *which Canadians* and the like), and in spoken language a question normally, but not invariably, comes with specific intonation, while in written language it is accompanied by a question mark.

For a semanticist, questions are abstract objects taken as the denotations of the above-described type of syntactic expressions. A semanticist here may take his cue from the (formal) study of indicative sentences. There the aim is to uncover a domain of denotations (labeled "propositions" mostly), as, for instance, an algebra which hosts logical constructions (like that of conjunction, disjunction, negation) and logical relations (like entailment, synonymy, and (in-)consistency). In the semantic study of interrogatives the aim is to establish a corresponding domain of denotations that underlies suitable notions of question entailment and answerhood.

From a pragmatic perspective, questions are essentially events in a discourse or dialogue. In response to the utterance of an interrogative sentence one may legitimately ask "Was that a question?" Questions, then, are certain acts in a conversation the very performance of which is subject to linguistic and pragmatic rules. According to Fregean speech act theorists, simple sentences just have some propositional content as their semantic value, and a question is the act of bringing it up with a request of determining whether the proposition is true.

Questions are also the objects of wonder and doubt and can be studied from an epistemological or philosophical perspective. Questions are the things which cognitive beings can be concerned with, the questions which a person may have. Judy may ask herself whether or not she will be in Paris next year, and she may also wonder "Who am I?", "Does God exist?", or "How will the stock market develop?", all of this without explicitly asking anybody, or ever putting the questions into words.

One may wonder whether the four sketched perspectives on questions have a common focus, or whether they concern different aspects of eventually one and the same underlying phenomenon. Of course, the semantic study of questions most often takes the syntactic notion of an interrogative as given and as its point of departure, or, conversely, one can take interrogatives to be the syntactic means for expressing them. Furthermore, a semantic question can be taken to be issued in a discourse, and then a suitable pragmatic question is under what circumstances is this appropriate, and what would constitute, under given circumstances, a good reply. Finally, we may at least start from the pragmatic assumption that epistemology and semantics draw from the same domain, that the objects of wonder and doubt are the possible meanings of interrogatives. Whether our concerns in life are semantic is a question we modestly postpone to a later date.

Having made these equivocating assumptions, some ambiguities remain to be settled. Something which gets described under one label (that of a question) may turn out to be different things after all. At least we should realize that when the term *question* is used, it can be ambiguous. A phrase like *Menno's question* can refer to an interrogative sentence which Menno has uttered, or some associated abstract semantic object that he referred to in a questionnaire, or a speech act he performed on television, or just what we think is currently troubling Menno's mind. In this chapter the notion of a question is reserved entirely to that of the semantic denotation of interrogative expressions (the syntactic notion). For the pragmatic and epistemic notions of a question we try to systematically use the terms *question posed* and *question faced*, respectively.

19.2.1 The Semantics of questions

What is the meaning of an interrogative sentence? Maybe it is worthwhile reconsidering a similar question about indicative sentences, the answer to which is probably more widely known. While interrogative sentences are normally used to pose questions, and imperative sentences to issue commands, indicative sentences are normally used to convey information about the world around us. What information? That the actual world or situation is like it is said to be by the indicative, in other words, that the indicative gives a true description of that world/situation. There is more to be said about the meaning of indicatives, but if we focus on this aspect of meaning, then we can say that a hearer understands an indicative sentence if he knows what a world or situation should be like for the sentence to be true. As Wittgenstein (1922, 4.024) has put it:

> Einen Satz verstehen, heißt, wissen was der Fall ist, wenn er wahr ist. (To understand a proposition means to know what is the case, if it is true.)

Insights like this, the roots of which can be traced back to the work of Frege, Russell and later Tarski, have evoked the slogan "Meaning equals truth conditions", and this slogan in turn has prompted the semanticist to try and specify, for every sentence of a given language, under what circumstances it is or would be true.

Interrogative sentences can be approached in a similar spirit, be it not in terms of truth, but in terms of answerhood. Interrogative sentences are normally used to pose questions, and the purpose of posing a question normally is to get a good answer to it. Obviously, *Marco came to the party yesterday*, even if true, cannot count as an answer to the question *Did Muriel visit Prague?* (even though sometimes it can, in pragmatically deranged situations). Proper answers include *Yes, Muriel did*, and *No, Muriel never did.* The question appears to dictate what counts as an answer, a confirmation or denial, a certain proposition, or some typical constituent part of a proposition. In case of polar questions like the one we are facing here (also known as *yes/no*-questions), there are always two possible answers, basically *Yes* and *No.* However, in cases of *wh*-questions, those with a *wh*-phrase inside, there usually are many more possible answers. Consider the question: *Who wants to join us on a trip to the beach?* Again, *Marco came to the party yesterday* does not count as a proper answer, but *Marco, Michelle, and Muriel want to join* does count as an answer, as does *Nobody wants to.* As a matter of fact, taking the sentence frame "... want to join" and filling in the dots with any list of names, one gets a sentence expressing a possible answer.

In the case of questions, the conclusion that suggests itself is that one knows the meaning of an interrogative sentence if one knows, given the circumstances, what counts as an answer to the question it expresses. Since, however, this ought to be perfectly general, that is, since one should be supposed to know what would be an answer in all possible circumstances, this means that the meaning of a question resides in its answerhood *conditions*.

19.3 Three classical theories of questions

The insight that the meaning of a question resides in its answerhood conditions has been developed in three different, but obviously related, ways, which we will consecutively discuss in the next three subsections. We briefly compare the three approaches in the fourth.

19.3.1 Proposition set theory

The earliest formal linguistic treatment of questions is from Hamblin (1973). There, "answerhood conditions" are spelled out as the set of possible propositional answers to a question. Adopting notation introduced in Groenendijk and Stokhof (1997), let us use ? as a question forming (sentential) operator, one that may bind variables $x_1 \dots x_n$ which figure as the variables that are questioned. Intuitively, $?x_1 \dots x_n\varphi$ queries among the valuations of the variables $x_1 \dots x_n$ whether the proposition that φ holds under that valuation. For example, consider the question in (1):

(1) Who called? ($?xCx$)

The question is interpreted as the set of possible answers that Marco called, that Michelle called, that Muriel called, that Don called, and so on. This may be rendered formally as follows (where D is the relevant domain of individuals and $[\![\varphi]\!]_g$ the interpretation of φ relative to some assignment g of values to the free variables in φ).

$$[\![?xCx]\!]_g = \{p \mid p = [\![Cx]\!]_{g[x/d]} \;\&\; d \in D\}.$$

Thus, the meaning of the question is considered to be the set of propositions p so that p is the proposition that d called, for any individual d in the relevant domain of individuals. Analogously, (2) is also interpreted as the set of possible answers that Marco interviewed Prof. Arms, Michelle interviewed Prof. Baker, Muriel interviewed Prof. Charms, and so on where Marco, Michelle and Muriel are students and the professors are professors, of course.

(2) Which student interviewed which professor? ($?xy(Sx \wedge Py \wedge Ixy)$)

This can be expressed formally as follows:

$[\![?xy(Sx \wedge Py \wedge Ixy)]\!]_g = \{p \mid p = [\![Sx \wedge Py \wedge Ixy]\!]_{g[x/d,y/d']} \; \& \; d, d' \in D\}$.

(This may not be the intended interpretation, but at this level of detail it is the most likely one.)

For polar questions, in which case the ?-operator does not bind any variable, Hamblin introduces a separate rule. Consider the following example:

(3) Did anybody call? ($?\exists xCx$)

The question in (9) is interpreted in a way that the two possible answers are that somebody called and that nobody called. This can be expressed formally as follows:[2]

$[\![?\exists xCx]\!]_g = \{p \mid p = [\![\exists xCx]\!]_g \; or \; p = [\![\neg\exists xCx]\!]_g\}$.

Hamblin has provided a nice and elegant formal idea of questions in terms of their possible answers. However, it has been questioned on three scores. Karttunen (1977) has argued that it should not just be the possible answers, but the possible *true* answers that we are interested in. Groenendijk and Stokhof (1984) have argued that it is the *exhaustive (or complete)* answers. Krifka (2001a), among many others, has argued that answers need not be propositional, but can be constituent answers as well.

19.3.2 Structured meanings

An approach to the semantics of interrogatives formally different from the one above, is the so-called categorial or structured meanings approach (e.g., von Stechow, 1991a; Krifka, 2001a). This type of approach also seeks the key to the meaning of interrogatives in terms of their possible answers, but it does not take propositional answers as the fundamental notion, but so-called constituent answers.

[2] Under a general rule that interprets $?x_1 \ldots x_n\varphi$ in a way that it also applies when ? does not bind any variable and delivers the results along the lines exemplified above for cases where it does, the result would be that for a polar question only the "positive" answer is captured. This can be remedied if for (1) we also add the proposition that nobody called as an answer, and for (2) the proposition that no student invited any professor. Then the general scheme would also deliver the negative answer to a polar question.

The main idea is that questions basically are propositional functions, with *wh*-elements indicating arguments of these functions to be filled in in order to get propositional answers.

Consider the following examples, where we use λ-abstraction to represent propositional functions:

(4) Who called? $(\lambda x\, Cx)$
Marco. $((\lambda x\, Cx)(m) \Leftrightarrow Cm)$

(5) Which boys saw which girls? $(\lambda xy\, Sxy)$
Marco Judy. $((\lambda xySxy)(m, j) \Leftrightarrow Smj)$

(6) Is it raining? $(\lambda f\, f(r))$
No. $((\lambda f\, f(r))(\lambda p\, \neg p) \Leftrightarrow (\lambda p\, \neg p)(r) \Leftrightarrow \neg r)$

Question (4) can be naturally understood as a request to fill in a true instantiation of the variable x for the sentential function Cx. If any argument is supplied by means of a constituent answer, like *Marco* (m), it fills the open place (x) and delivers a Hamblin-style answer, that Marco called (Cm). The difference with the propositional approach consists in the fact that question and answer combine by functional application. Questions are functions requiring arguments supplied by, hopefully satisfying, answers. If an interrogative hosts multiple *wh*-elements, as in Example (5), it denotes a function that demands tuples of objects as an argument to produce a proposition. In the case above, the pair consisting of Marco and Judy supplies this argument. Marco and Judy fill in, respectively, the first (x) and the second (y) open space in the relevant propositional function, thus yielding the propositional answer that Marco saw Judy. In the case of a polar question (6), the question is a propositional function demanding a valuation of the proposition that it is raining (r) itself. The type of argument thus is itself a function on the domain of propositions, a confirmation function, *Yes* $(\lambda p\ p)$ or a falsifying function, *No* $(\lambda p\, \neg p)$.

Obviously, the structured meanings approach properly deals with non-sentential ("constituent") answers.

(7) Is it raining?
Is it not raining?

(8) Who wants an ice cream?
Who does not want an ice cream?

The proposition set approach predicts that the two questions in (7) are equivalent. A good answer to the first question of these pairs also fully answers the second, intuitively, as well as formally. However, an affirmative reply (*Yes*) to the first question in (7) implies that it is raining; whereas as a reply to the second question in (7) it implies that it is not raining.[3] This comes out right

[3] Roelofsen and Farkas (2015) have however shown that the phenomena of polarity particle responses are more complicated than is reported here.

on the structured meanings approach. Similarly, a constituent answer like *Judy* to the first of the questions in (8) means that Judy wants an ice cream, while if it answers the second question it means that Judy does not want one. Also this directly follows from the structured meanings approach.

From this elementary exposition, it may already be clear that the structured meanings approach to questions can do anything with them, in a direct or otherwise indirect way, that the propositional approaches can do, including the partition approach discussed in the next section. For, formally, a framework of structured meanings is more fine-grained than an unstructured one, and unstructured propositions can in principle be constructed from the components contributed by the structured meanings approach. This, however, comes at the price of having meanings – questions and their characteristic answers – live in a variety of categories. They can be functions and arguments of all kinds of types. This may, but need not of course, obscure some structural characteristics of questions and answers which may be more immediately visible at the propositional level. For instance, logical relations of answerhood and entailment between questions are most naturally dealt with on such a propositional level. Furthermore, question-embedding verbs such as *wonder* and *know* (as in *wonder whether*, *know who*) cannot directly, intuitively, apply to the meanings of their embedded arguments if they can be any type of functions. The partition theory of questions sets out to address these issues.

19.3.3 Partition theory

In the Groenendijk and Stokhof treatment of interrogatives, questions "partition logical space". (See, e.g., Groenendijk and Stokhof, 1984, 1997; see also, Higginbotham and May, 1981; Higginbotham, 1996; Haida, 2007.) The partitions are derived from "abstracts", which are essentially the kinds of meanings employed in structured meanings semantics, and which are used to group together situations or possibilities in which the same answers are true. *Sameness* of answers, of course, induces an equivalence relation on the set of possibilities, hence the derived objects are indeed partitions of logical space. As it happens, this approach works uniformly for both polar questions and (multiple) constituent questions.

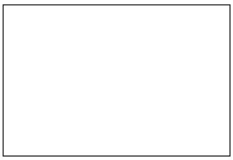
Formally a partition semantics assumes a standard predicate logical vocabulary and a question operator $?\vec{x}$ (where $\vec{x}$ is a possibly empty sequence of variables) that turns an indicative formula φ into an interrogative formula $?\vec{x}\varphi$. If $\vec{x}$ is an empty sequence of variables, $?\varphi$ is a polar (*yes/no*) question; otherwise, $?\vec{x}\,\varphi$ is a (multiple) constituent question. The question operator $?\vec{x}$ queries the possible values of the variables $\vec{x}$ under which the embedded formula φ is true.

Groenendijk and Stokhof's semantics of interrogatives can be stated relative to models of modal predicate logic $M = \langle W, D, I\rangle$, where W is a set of possibilities, D a domain of individuals, and I an interpretation function for the individual and relational constants, relative to each possibility. Variables are dealt with by means of the usual assignments g of values to variables and by $g'[\vec{x}]g$ we mean that assignment g' which is like g except (possibly) for the values it assigns to the variables in $\vec{x}$. In this setting, the interpretation of an interrogative can be defined in two steps:

$$[\![?\vec{x}\,\varphi]\!]_{M,g,w} = \{w' \mid \forall g'[\vec{x}]g : [\![\varphi]\!]_{M,w',g'} = [\![\varphi]\!]_{M,w,g'}\};$$
$$[\![?\vec{x}\,\varphi]\!]_{M,g} = \{[\![?\vec{x}\,\varphi]\!]_{M,g,w} \mid w \in W\}.$$

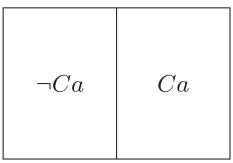
Relative to a particular world w, a question denotes a proposition (set of possibilities) which is true in exactly those possibilities where exactly the same valuations of the variables $\vec{x}$ render φ true, respectively false. The general notion of a question, the *meaning* of an interrogative, is the set of all of these propositions. Each proposition associates each possibility with the complete true answer to the question in that possibility. Upon this definition, $?\vec{x}\varphi$ cuts up the space of possibilities W in non-overlapping propositions (regions of logical space). In all possibilities in one and the same cluster the very same answer is the complete true answer to the question at stake.

The partition theory is conveniently illustrated with pictures. Logical space can be pictured as a geometric space of logical possibilities.



The points in the rectangle should be taken to constitute or cover the possibilities. An indicative sentence like *Anna is in Copenhagen* (formally: *Ca*) is true in some possibilities and false in others. If it is asserted, the claim is that the actual world is among the *Ca*-worlds, the worlds in which Anna is in Copenhagen. This is a region in logical space.

Now consider the question *Is Anna in Copenhagen?* (formally: ?*Ca*). The polar question has a positive and a negative possible answer. The possibilities in which the answer is positive can be grouped together, and the same can be done with the possibilities in which the answer is negative, and the two regions (i.e., propositional answers) have to be distinguished.



$?Ca$

This picture is meant to indicate an interest in knowing on which side of the line the actual world resides: are we in a *Ca*-world, one in which Anna is in Copenhagen, on the right side, or in a ¬*Ca*-world, where she is not there, on the left? The differences between worlds on the same side of the line are immaterial to this question.

We can subsequently add the question whether Ben is in Copenhagen, (formally: ?*Cb*). This leads to an orthogonal distinction, this time indicated by means of a horizontal line:

	$\neg Ca \wedge \neg Cb$	$Ca \wedge \neg Cb$
$?Cb$		
	$\neg Ca \wedge Cb$	$Ca \wedge Cb$

$?Ca$

If we now, for the purpose of exposition, make the simplifying assumption that Anna and Ben are the only relevant individuals, then the last picture is the same as the next one representing the question *Who is in Copenhagen?* (formally: ?*x Cx*):

	$\neg\exists x Cx$	$Ca \wedge \neg Cb$
$?x\ Cx$		
	$\neg Ca \wedge Cb$	$\forall x Cx$

The basic assumption in the partition semantics is that *wh*-questions do not ask for some possible instantiation of the *wh*-term, but that they require a full specification of it, an *exhaustive* answer, that is. In order to answer the question *Who is in Copenhagen?* it is not sufficient to say that Anna is, because that only tells us that the actual world is on the right of the vertical line, and it does not tell us its location relative to the horizontal line. The answer does not tell us whether Ben is there or not. In that sense the mere proposition that Anna is in Copenhagen is at best a partial answer to the *wh*-question. A proper answer, in other words, is a full answer, and directly or indirectly dictates which individuals are, and which are not, in Copenhagen. Fully generally, an answer in a partition semantics specifies which sequences of individuals do, and which do not, stand in a questioned relation. They give a full, propositional specification, of the extension of such a relation.

As we said, in the pictures above, the relevant distinctions are the ones indicated. The question is in which of the blocks of a partition we are, in which *block* the actual world resides. What *kind* of world are we in? It shows no interest in just *any* specification of the kind of world we are in. A certain question, and the picture of it, displays indifference toward the issue whether we are in one of two worlds which both feature in the same block. They simply are, or are not, of the kind that we are interested in. For the purpose of a specific question two worlds in the same block count as equivalent, in a rather literal sense.

It turns out that when questions are formulated as partitions, equivalence relations, we get a neat notion of question conjunction and question entailment in return. Conjunction of questions is intersection of equivalence, and answerhood entailment is subsumption of indifference. The ensuing logic of questions and answerhood has been dealt with in detail in Groenendijk and Stokhof (1984). The logic of interrogatives will be further discussed in the section on inquisitive semantics below.

19.3.4 Comparison

There are interesting connections and differences between the three (types of) theories dealt with in the three preceding subsections. Obviously, most of them relate to the issues of constituent answers, and exhaustiveness.

Considering the proposition set approach and the partition theory first, we may observe that they are focused on propositions as possible answers. Interrogative *sentences* are assumed to be paired with indicative *sentences*. (Cf. *What is the situation? This is the situation!*) The major difference between the two approaches is that the first allows for any basic, positive answer. If one is asked who was at the parade yesterday, mentioning any random visitor may count as a good answer. On the partition theory, this would not be sufficient. The theory requires a full, exhaustive, specification of all who were there – among a relevant set of individuals of course. We will come back to this issue later in this section.

While the structured meanings approach also focuses on a notion of answerhood, it is stated in the mentioned categorial fashion, where questions denote functions which take answers as their arguments. Only the combination of the two, by functional application, eventually yields a proposition. The two types of approach have obvious benefits and drawbacks.

On the one hand, constituent answers (*Who comes? Menno*) are easily dealt with in a structured meanings approach. For a proposition set approach, or a partition theory, such constituent answers require some further work (Krifka, 2001a). As we have seen, in the partition theory, propositional answers are derived from constituent answers, figuring as argument of the so-called abstracts, which are assumed to be present at some underlying level of representation. A similar assumption is conceivable on the proposition set approach.

On the other hand, on the structured meanings approach full propositional answers can only be derived from constituent answers in conjunction with the original questions. Thus, the fact that *Menno comes* may provide the right kind of information in response to the question *Who comes?* only because it is one of the possible, propositional, values that the propositional function $\lambda x\, Cx$ may yield. At some level, then, propositional answers will have to play a role as well. Such a resort to propositions appears, for example, inescapable once it comes to embedded uses of questions. The coordination between *that*-clauses and various kinds of *wh*-clauses in sentences like *John knows that there will be a party, who has been invited and whether Mary is going to come* seems most appropriately dealt with at the propositional level (see Krifka, 2001a, for an account of question embedding in the structured meaning approach).

It may finally be noticed that the structured meanings approach does not uniformly abstract over obvious constituents in polar questions. As we have seen, a question like *Does anybody know the answer*? does not abstract over any constituent of the questioned proposition, but it abstracts over possible (positive or negative) evaluations of the proposition that somebody knows the answer. As we have seen, a typical positive answer *yes* ($\lambda p\ p$) returns the original proposition (that somebody knows the answer); a negative reply *no* ($\lambda p\ \neg p$) negates it.

In contradistinction, the partition theory uniformly applies to polar and constituent questions. For, if $\vec{x}$ is the empty sequence, then relative to some world w, $?\varphi$ denotes the set of possibilities $\{w' \mid [\![\varphi]\!]_{M,w',g} = [\![\varphi]\!]_{M,w,g}\}$, which is the set of worlds w' relative to which φ has the same truth value as in w. So this is the proposition that φ if φ is true in w, and the proposition that not φ, if φ is false in w.

A concern with exhaustive answers sets the partition theory apart from the two other approaches. On the partition approach, the question *Who comes?* ($?x\, Cx$) denotes in w the proposition that (the set of worlds in which it is true that) X come, where X are all and only the individuals who come in w. This way of modeling questions and answers allows for a set-theoretic analysis of conjunction and subsumption of questions. That is to say, for example, that the (constituent) question (9) entails the (polar) question (10).

(9) Who called?

(10) Did Marco call?

For any (full) answer to the first question entails (subsumes) a (full) answer to the second. Likewise, (11) simply amounts to the conjunction (intersection) of the answers to the questions in (12).

(11) Who (among Marco and Menno) called?

(12) Did Marco call? And did Menno?

From a formal logical perspective, this is surely a benefit of the partition approach. As we will see in Section 19.4, the partition approach can also be given a pragmatic, decision-theoretic motivation, precisely because the blocks in a partition can be taken to correspond to an agent's decision options.

Another claimed benefit of the partition approach is that its (exhaustive) semantics of unembedded interrogatives directly applies to embedded interrogatives (Groenendijk and Stokhof, 1984; Heim, 1994b). Consider the following examples of embedded questions.

(13) Marco knows who called.

(14) Muriel wonders who called.

Example (13) can be taken to express that there is a true answer to the question *Who called?* and even though the speaker may fail to know the answer, she expresses that Marco knows it. According to Karttunen (1977), what Marco is said to know is the conjunction of all the true basic answers to the question, so, for example, if Menno and Judy called, Marco must know the proposition that Menno and Judy called. However, imagine a scenario wherein Marco believes that everybody called; in such a situation Marco would know that Menno and Judy called without knowing who called contrary to Karttunen's predictions. For these and other reasons, Groenendijk and Stokhof (1984) argued that what Marco is said to know is not just a conjunction of singular propositions of the form *Menno called*. Rather, (13) says that, relative to a domain of relevant individuals, Marco knows of each of them whether he or she called or not – indeed the exhaustive interpretation. Likewise, in example (14), Muriel is not said to be concerned with the truth or falsity of a conjunction of singular propositions of the form *Judy called*, but with the question which proposition fully answers the question *Who called?*, and trying to figure out which possibly full answer is the actually true one. In both cases, then, the exhaustive interpretation of the embedded interrogative is the right object of knowledge and doubt (see also Heim, 1994b). Recent experiments reported by Cremers and Chemla (2014), however, have shown that *know*, besides a so-called *strongly exhaustive* interpretation (the one predicted by the partition theory, see (15a)), also allows for so-called *intermediate exhaustive* readings, illustrated in (15b) (Preuss, 2001; Klinedinst and Rothschild, 2011), while no clear evidence was found concerning the availability of the reading predicted by Karttunen's (1977) analysis, later labeled as *weakly exhaustive*, see (15c).[4]

(15) John knows who called.
   a. Strongly exhaustive interpretation:
      For each person who called, John knows that she called, and he knows that nobody else called.
   b. Intermediate exhaustive interpretation:
      For each person who called, John knows that she called, and John does not have false beliefs about persons who didn't call.

[4] Other verbs like emotive factive, *surprise* have instead been argued to have only weakly exhaustive readings (e.g., Heim, 1994b; Sharvit, 2002). However, see George (2011) for arguments against the availability of weakly exhaustive interpretations even for emotive factive verbs.

c. Weakly exhaustive interpretation:
For each person who called, John knows that she called.

The above considerations concern exhaustive interpretations of interrogatives. However, certain types of examples appear to favor non-exhaustive interpretations, so-called "mention-some" readings (Groenendijk and Stokhof, 1984; George, 2011). Examples (16) and (17) are typical.

(16) Who has got a light?

(17) Where can I buy an Italian newspaper?

These types of questions are normally (not invariably!) used to ask for one verifying instance only. If I have found someone who has a light, I do not care about who else has got one. Moreover, if I want to buy an Italian newspaper, one close enough place suffices, and a specification of all places around town where you can buy one seems pedantically superfluous. The question now is, do interrogatives have various types of meanings? Are they ambiguous? Or can we derive one of them from the other? Beck and Rullmann (1999) have presented a sophisticated and flexible response to this question, but it still remains an open issue.

19.4 Old and open issues

There are some old and open issues in the theory of questions and answers. We will discuss a few of them in this section in two groups: issues which have to do with identity, and issues which have to with scope.

19.4.1 Knowing who and which

Identity constitutes a perennial problem in the philosophy of language and in epistemology. Questions of identity also cause problems for semanticists, but for some more technical, and, hence, solvable, reasons. One issue is best explained in terms of the partition theory, even though it can be taken to trouble any approach. In a model $M = \langle W, D, I\rangle$ for partition semantics, names or individual constants are usually assumed to be "rigid designators", that is, they denote the same individual in every possibility. There is a solid reason for this assumption. Rigidity of names guarantees that a reply like *Judy called (and nobody else)* counts as a complete answer to the question *Who called?* This can be seen if we compute the denotation of this question in a world w and relative to an arbitrary variable assignment g, according to the partition theory.

$$\begin{aligned}
&\{w' \in W \mid \forall g'[x]g : [\![Cx]\!]_{M,w',g'} = [\![Cx]\!]_{M,w,g'}\}\\
&\quad = \{w' \in W \mid \forall d \in D : [\![Cx]\!]_{M,w',g[x/d]} = [\![Cx]\!]_{M,w,g[x/d]}\}\\
&\quad = \{w' \in W \mid I_{w'}(C) = I_w(C)\}
\end{aligned}$$

The above-mentioned reply expresses the following proposition.

$$\{w' \in W \mid \forall d \in D : d \in I_{w'}(C) \text{ iff } d = I_{w'}(j)\}$$
$$= \{w' \in W \mid I_{w'}(C) = \{I_{w'}(j)\}\}$$

If *Judy* is rigid, say $I_{w'}(j) = d$ for any possibility $w' \in W$, this is the full true answer to the question in any possibility w' such that $I_{w'}(C) = \{d\}$. If, however, *Judy* were not rigid, the reply would not be the true answer in w and would not correspond to any of the possible answers to our question in any world w'.

A rigid interpretation of names thus seems to be required. However, it has a nasty by-effect. Consider the question *Who is Judy?* ($?x\ x = j$), on the assumption that *Judy* is rigid. Then there is a specific $d \in D$ such that $I_{w'}(j) = d$ for any possibility $w' \in W$. The denotation (complete answer) in w then is the following proposition (set of worlds).

$$\{w' \in W \mid \forall g'[x]g : [\![x = j]\!]_{M,w',g'} = [\![x = j]\!]_{M,w,g'}\}$$
$$= \{w' \in W \mid \forall d' \in D : [\![x = j]\!]_{M,w',g[x/d']} = [\![x = j]\!]_{M,w,g[x/d']}\}$$
$$= \{w' \in W \mid \forall d' \in D : d' = d \text{ iff } d' = d\} = W.$$

The question turns out trivial, since it has only one possible answer, which is the trivial proposition, the proposition true in all possibilities. Obviously this is not what we want, because we can ask such questions as *Who is Judy?* in a non-trivial way, and we can make contingent assertions like *Marco knows who Judy is* and *Ben does not know who Judy is.* If *Judy* is interpreted rigidly this remains unexplained. Indeed, we face a dilemma: either we make *Judy* a proper answer to a *wh*-question, but then asking who Judy is becomes trivial; or we try and make sense of questions like *Who is Judy?* but then we cannot properly use the name to reply to a constituent question. We cannot have it both ways, it seems.

Aloni (2001) has shown a way out of this dilemma by a solution independently needed for the analysis of *de re* attitude reports. A detailed specification of the analysis would go beyond the confines of the present chapter, so we will only sketch the outlines. The basic idea is that even though quantification and reference are ultimately concerned with a domain of individuals, they are mediated by the perspective of a *conceptual cover*, by a way of "seeing" the domain.

We can assign names (and variables) a non-rigid interpretation, as *individual concepts*, that is, functions which assign a, possibly different, individual in each possibility as the referent of the name (or variable). Under ideal circumstances, the set of (interpretations of) names constitutes a conceptual cover, in the sense that each individual is named once in each possibility, but such that one and the same name may happen to denote different individuals in different possibilities. As has already been pointed out by Hintikka (1969), there are many other ways of epistemically viewing the domain. The idea then is that individuals are quantified over, and questioned, through the mediation of specific conceptual covers. The net effect is that if the question operator in $?x\ x = j$ is interpreted from a "naming" cover, then indeed the question is trivial. This is like asking *Who among Marco, Judy, . . . , and Muriel is Judy?*, which is quite silly indeed. However, if the question operator is interpreted from another perspective the question is no longer trivial. For instance, if you have a list of the names of the soccer players, about whom you know quite a bit from the newspapers, and if you see all of the players on the soccer field, it is quite legitimate to ask which of the persons you see there on the field is this player so-and-so on your list. This situation is straightforwardly accounted for once one adopts varying conceptual covers.

Aloni's approach explains why the very same answer to the very same question can be appropriate or inappropriate depending on the circumstances, or, more particularly, on the assumed perspective. Thus, to adapt an example from Aloni, a teacher can ask in the classroom:

(18) Do you know who Sandra Roelofs is?

A proper answer in this situation seems to be something like *The Dutch wife of the former Georgian president Mikhail Saakashvili*. However, if you are at a party where Sandra Roelofs is known to be present, and if you want to ask her to open the next Tbilisi symposium, then the very same reply to the very same question does not make much sense. Rather, you would expect or hope your interlocutor points out one of the visibly present individuals. (Conversely, your classroom teacher would not be very happy if, in response to her question, you were to go out, persuade Sandra Roelofs to accompany you to your classroom, and say, *This is Sandra Roelofs.*) With Aloni's conceptual covers, these cases can be smoothly dealt with, even independently of the particular general framework in which the interpretation of questions is formulated.[5]

Which-questions constitute another persistent challenge to any semantic account of interrogatives. Karttunen (1977), for instance, predicts that (19) entails (20):

(19) Ben knows who called.

(20) Ben knows which students called.

The reason is that if, for instance, Marco and Muriel are the only students that called, Karttunen's denotation for (20) will be {Marco called, Muriel called}, which is a subset of his denotation of (19). As a consequence one can be said to know, on Karttunen's interpretation, which students called without knowing which people are students. Groenendijk and Stokhof (1984)

[5] See Aloni (2008) and Aloni and Roelofsen (2011) for a more recent application of conceptual covers to the case of so-called concealed questions (Heim, 1979; Romero, 2005; Nathan, 2006; Frana, 2010).

point out that this result may be correct for a so-called *de re* reading of Example (20), but that it is wrong on its most prominent reading, which they label *de dicto*. So-called *de dicto* knowledge of which students called should include knowing that the student callers are students. Groenendijk and Stokhof analyze the sentence, roughly, as $?x\ (Sx \wedge Cx)$, and upon this analysis the *de dicto* reading is accounted for. Ben is said to know that the students who actually called are the students who called.[6] (Beck and Rullmann, 1999 proposed a quite different representation of the *de dicto* readings which does not use partitions. See Heim, 2011b for a detailed comparison.) The interpretation of *which*-questions is not fully settled, though. The following pair of examples clearly shows that we need to be more distinctive.

(21) a. Which men are bachelors?
b. #Which bachelors are men?

Upon Groenendijk and Stokhof's "flat" analysis, the questions in examples (21) are rendered as $?x\ (Mx \wedge Bx)$ and $?x\ (Bx \wedge Mx)$, which are obviously equivalent. They both ask for a full specification of the male bachelors, i.e., of the bachelors. But obviously the two questions are different. The first (21a) makes sense, while the second (21b) is trivial.

Krifka's structured meanings approach presents us with one way out of the problem. According to Krifka (2001a), question (21a) denotes a *partial* propositional function, which is defined only for individuals that are male. This function is non-trivial because some of the males may be bachelors, and others may not be. In contrast, question (21b) denotes a propositional function that is defined for bachelors only, and, trivially, it assigns to each bachelor the proposition that he is male. Obviously, the idea of using partial functions, or partial interpretations, can be generalized, and exported to other frameworks.

Krifka's proposal neatly squares with the idea that quantified noun phrases in natural language (including, here, *which*-phrases) *presuppose* their domain of quantification. This idea can be taken to derive from Aristotle, and in the linguistics literature it has been independently argued for by Milsark (1974), Diesing (1992b) and Moltmann (2006). If we apply the same idea to *which*-phrases, the facts seem to fall right into place (see Aloni et al., 2007a, among others). Consider again *Which males are bachelors?* According to the previous suggestions, this implies that the domain of males is given, or under discussion, and that it asks for a distinction in that domain between the ones that are and those that are not bachelors. This intuitively makes sense, of course. Conversely, *Which bachelors are male?* implies that we are talking about the domain of bachelors and questions which of them are male and which are not. Given the assumptions about bachelors previously

[6] We, like most authors, here completely ignore problems with knowledge of the identity of these students – see the previous section.

stated, this question is indeed trivial, since all the bachelors are, by definition, known to be male.

We will not dwell further upon this issue here, because domain presuppositions constitute an independent and open subject of a more general theory of presupposition and quantification, and that is beyond the scope of the present chapter.

19.4.2 Questions and scope

An old and actual issue is whether questions can be outscoped and if so under what conditions. In English at least, it appears to be impossible to form the negation of an interrogative sentence, and indeed it is hard to conceive what the negation of a question could possibly mean. However, as we will see, conditional questions like *If Marco goes to the party, will Mona then go as well?* seem to be appropriately characterized, also semantically speaking, as questions in the nuclear scope of a conditional construction. Also, it is hard to see what *Is somebody unhappy*? could mean, assuming that *somebody* would outscope the question. Of course, somebody may say *Yes, I am unhappy*, but this would simply, positively, answer the polar question whether there is anybody who is unhappy. Since, taking *somebody* to have wide scope, it would be indefinite whom the question is about, it would be unclear, indefinite, what an appropriate answer could be. Things are different, however, with a universal quantifier.

Consider the following constituent question with a universal quantifier:

(22) Which book did every girl read?

This example may yield the following characteristic responses, with labels added indicating the assumed reading of the example:

(23) a. [Every girl read] *The Tractatus*. (single const. reading)
b. [Every girl read] Her favorite book. (functional reading)
c. Anna [read] *the Tractatus*, Michelle *War and Peace*, and Muriel *Lolita*. (pair-list reading)

It is particularly the "pair-list" reading, illustrated by the latter response, which is relevant for the current issue on whether questions can be outscoped. The fact that, for each girl, an exhaustive list of books may have to be issued suggests that indeed it is a question that is in the scope of the universal quantifier.

The availability of a pair-list reading depends on both the nature of the quantifier and the syntactic configuration of the sentence.

(24) Which book did most/several/no girls read?
a. *The Tractatus.*
b. Her favorite book.
c. #Anna [read] *the Tractatus*, Michelle *War and Peace*, and Muriel *Lolita*.

(25) Which girl read every book?
  a. Anna.
  b. #The girl that liked it best.
  c. #*The Tractatus* by Anna, *War and Peace* by Michelle, and *Lolita* by Muriel.

There is no generally agreed upon analysis of the data in the literature. We can distinguish two main approaches. Engdahl (1980, 1986) and Chierchia (1993) adopt a functional approach that derives the three interpretations of (22) as special cases of a functional reading and, therefore, deny the necessity of quantification into questions. Groenendijk and Stokhof (1984) and Moltmann and Szabolcsi (1994) argue for a quantificational approach and deem quantification into questions unproblematic. Krifka (2001b) has given this discussion a new twist by suggesting that in sentences like (22) the quantifiers actually take scope over the *speech act* that a question is. Assuming that speech acts can only be conjoined (but not negated or disjoined), a ready account of why only universals can outscope questions – as illustrated in (24) – obtains.

Krifka's proposal thus raises the discussion to a broader level, since the issue no longer is whether questions can be outscoped, but whether other types of speech acts can. Indeed, we observe striking similarities with imperatives that cannot be negated (or so it seems; they can be refused, of course) and that can be conditionalized (see Schwager, 2007, but also Portner, Chapter 20, and further references there).

Questions do seem to occur in embedded positions when they figure under doxastic operators, in *wonder who*- and *know whether*-constructions. Groenendijk and Stokhof distinguished between *intensional* and *extensional* question embedding operators. On their account, intensional verbs (e.g., *wonder*, *ask*) express a relation with a question as such, which is a partition of logical space on their account. Extensional verbs (e.g., *know*, *discover*), instead, express a relation to the proposition that is the value of the question (its true answer) in the actual world. Extensional verbs take both declarative and interrogative complements (26); by contrast, intensional verbs take only interrogative complements (27).

(26) a. Ben knows/discovered who cheated in the final exam.
  b. Ben knows/discovered that Marco cheated in the final exam.

(27) a. Ben wonders/asks who cheated in the final exam.
  b. #Ben wonders/asks that Marco cheated in the final exam.

It appears that only intensional verbs seem to allow for embedded "root" questions, such as we find in (28).

(28) Which novel did she have to read, Muriel wondered / asked / #knew / #discovered.

Krifka (2001b) explains this fact assuming that intensional verbs, like certain quantifiers, actually embed question speech acts rather than plain *wh*-clauses. (Notice that the analogy with imperatives seems to break down here.)

Karttunen (1977) has proposed another characterization of question-embedding attitude verbs, distinguishing between those that are factive and those that are not. Karttunen observed that attitude verbs receive a factive interpretation (that is, presuppose the truth of their complement) even if their non-interrogative variant is not factive. For example, (30), and not (29), implies that Muriel told the truth about what Marco was doing.[7]

(29) Muriel told Ben that Marco is coming.

(30) Muriel told Ben whether Marco is coming.

This observation is explained, on the accounts of both Groenendijk and Stokhof and Karttunen, because they take interrogatives to denote their true (exhaustive) answers. Therefore (30) expresses a relation between Muriel, Ben, and the true answer to the question *whether Marco is coming*. This factivity effect may also serve to explain why a verb like *believe*, which differs from *know* only because it lacks factivity, does not embed questions.

(31) Muriel knows that Marco is coming. $\models$ Marco is coming

(32) Muriel believes Marco is coming. $\not\models$ Marco is coming.

(33) Muriel knows whether Marco is coming.

(34) #Muriel believes whether Marco is coming.

Also Krifka (2011) endorses an explanation along these lines. See, for example, Ginzburg (1995a,b), Sæbø (2007), and Egré (2008) for alternative analyses.

Berman (1991) observed an interesting interaction between questions, question-embedding attitude verbs, and quantifying adverbs. Consider the following example.

(35) Ben mostly knows who cheated in the final exam.

Berman observed that sentence (35) has a reading that can be paraphrased as "For most people who cheated in the final exam, Ben knows that they cheated." Berman deemed this phenomenon an instance of "quantificational variability" (*QV*), after a similar effect observed with indefinites.

(36) A student usually works hard.

[7] Karttunen's observation, however, has been recently challenged by Spector and Egré (2015) who discuss the following cases showing that *tell* can be factive with respect to its declarative complement and non-factive (or non-veridical responsive) with respect to its interrogative complements:

(i) a. Every day, the meteorologists tell the population where it will rain the following day, but they are often wrong.
  b. Did Sue tell anyone that she is pregnant? (presupposes that Sue is pregnant).

Sentence (36) has a meaning that can be paraphrased as "Most students work hard". Inspired by a Lewis/Kamp/Heim analysis of (36) (e.g., Lewis, 1975a), Berman proposed that *wh*-phrases, like indefinites, behave like free variables, which can be bound by a quantifying adverb. Example (35) thus can be rendered as in (37).

(37) For most *x* [*x* cheated][Ben knows that *x* cheated].

Of course, it remains to explain how a tripartite structure like (37) gets generated. Berman assumes a form of presupposition accommodation that puts the presupposition of the nuclear scope of quantificational adverbs in their restriction. He predicts that only factive verbs, which indeed presuppose their complement, allow for *QV*-readings.

Lahiri (2002), however, showed that factivity is not a decisive factor in *QV*. There is a class of non-factive verbs like *agree* or *be certain about* that does allow for *QV* interpretations.

(38) Ben and Marco agree, mostly, on which girls are asleep.

Lahiri assumes that *QV*-structures quantify over propositions (the true answers to the questions) rather than over individuals. Sentence (35) is hence analyzed as in (39):

(39) For most *p* [*p* truly answers "Who cheated?"][Ben knows that *p*].

Questions are here analyzed as in the propositional approach. The denotation of *who cheated* is taken to be the set of possible answers {that Marco cheated, that Michelle cheated, . . .}. This time, the tripartite *QV*-structure is taken to arise not from presupposition accommodation as in Berman but as a result of movement (Interrogative Raising). Movement is invoked to repair the type-mismatch which arises when a question (denoting here sets of propositions) occurs in the scope of a verb like *know*, which is assumed to operate exclusively on propositions.

It may be noticed that the analyses of *QV* by Berman and Lahiri are formulated adopting a propositional approach to questions and seem to be irreconcilable with the partition theory. Groenendijk and Stokhof (1993) and Beck and Sharvit (2002) have proposed alternatives, which do appear to be compatible. All in all, this serves to show that which approach to the semantics of questions is best remains an issue for debate.

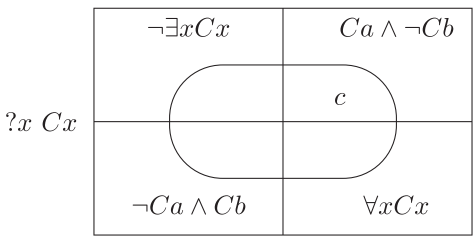
19.5 Recent theoretical perspectives

While philosophers and linguists have been happy for decades to study the semantics of indicatives out of context, for questions it is more difficult to ignore their contextual role. In the first two subsections, we touch upon some insights developed from a pragmatic and dynamic outlook on questions. In the last subsection, which elaborates on this, we introduce in some detail the recent framework of inquisitive semantics.

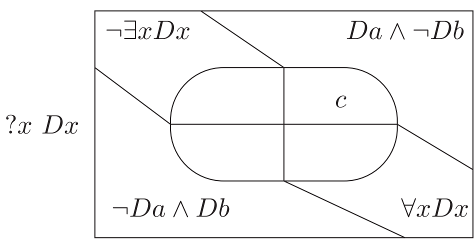
19.5.1 Pragmatics of questions and answers

It is generally acknowledged that utterances (such as assertions, questions) are never or hardly ever evaluated against an empty contextual background. Language is always used against a background of common knowledge or belief, private knowledge and belief, and information the interlocutors have about the information of others. Groenendijk and Stokhof already acknowledged this in their 1984 dissertation and developed a notion of a "pragmatic answer".

Consider the following picture, the same as the one for $?x\,Cx$, but now with an additional oval (labeled c) which is supposed to represent the current state of contextual information:



The oval labeled c must be understood as indicating that the actual world is assumed to be inside of it and that all possibilities outside the oval have been dismissed as being non-actual. The above picture indicates that, while the semantic question cuts up logical space into four big blocks, it is the division of the oval into four parts that is pragmatically relevant (since everything outside the oval is deemed non-actual and therefore irrelevant). This means, however, that a question different from $?x\,Cx$ might do the very same job, pragmatically speaking. Consider the next picture with a different possible question $?x\,Dx$:



The two questions are logically independent. For example, the answer $\neg\exists xCx$ to the question $?x\,Cx$ does not entail any answer to the question $?x\,Dx$, and the answer $Da \wedge \neg Db$ to the question $?x\,Dx$ does not entail any answer to

$?x\, Cx$. So, semantically, there is no entailment relation between the two questions. However, inside the oval the two questions coincide. So, pragmatically speaking, against the contextual background c, the questions are equivalent. This is interesting because it serves to explain how, after all, in certain contexts, (41) can be a sound answer to (40).

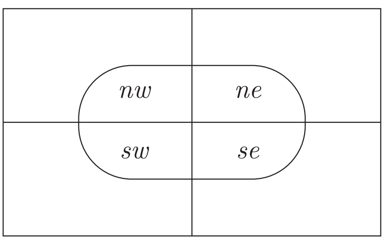
(40) Who wants to join us on a trip to the beach?

(41) Marco came to the party yesterday.

For if it can be assumed, in conjunction with the background information, that Marco visiting a party entails that he does (or does not, for that matter) want to join us on a beach trip, then the reply is surely, pragmatically, felicitous. Thus, if it is common knowledge that Marco is a total loss after having visited a party, a reply with (41) means that we can count him out.

In terms of such semantic and pragmatic notions of answerhood, Groenendijk and Stokhof (1984) developed an overall comparative notion of answerhood depending on contextual background information. The evaluation of answers they propose is guided by considerations directly linked to the Gricean conversational Maxims that make up his Cooperative Principle (Grice, 1975).

Van Rooij (2003b) argued that basic concepts from decision theory, in particular the concept of a decision problem, closely relate to such partitions. Consider an agent who wants to eat in a Thai restaurant and who faces a decision problem: which direction to go? Let us assume she is at a junction, where she could take four directions: northwest (*nw*), northeast (*ne*), southwest (*sw*), and southeast (*se*). Let us assume as well that she has information that there is exactly one Thai restaurant to be found in one of these directions, but that she has no information which direction that is. She could try all directions in some random order, but that is quite troublesome. She could also ask some passer-by for the direction to the restaurant, something displayed by the following diagram.



A full and hopefully true answer to her question would directly help to solve her decision problem. If the restaurant is to be found in direction northeast, then that is the way to go. A partial answer, like *Northeast or southwest*, however, would not help her out. Of course, she could skip considering northwest and southeast, but she still would not know where to go. This example shows that if one has to make a choice, where only one choice can or should be made among alternatives, then a very appropriate thing to do is to pose a question in which every possible answer corresponds to exactly one possible choice, that is, *given the background information*. Van Rooij (2003b) has not only noted this kind of formal correspondence between notions of decision theory and the partition semantics but also worked out decision-theoretic notions for comparing the relevance of questions and of answers.[8]

19.5.2 Questions in discourse

In the final decades of the last century, the meaning of an indicative sentence has been formulated in terms of its so-called context change potential, instead of its familiar truth conditions. Under this dynamic perspective, assertions are made with the intention to update the discourse context, which can be taken to be the "common ground" of the conversation, a representation of the contents of a discourse, or simply the information the interlocutors have of the situation they are in. Interrogatives most naturally fit this picture as well. Simply imagine how utterly awkward it is to disregard a question once it has been posed.

Questions in discourse and dialogue have been studied in a variety of semantic frameworks (Roberts, 1996; Hulstijn, 1997; Asher and Lascarides, 1998b; Cooper, 1998; Ginzburg and Sag, 2000; Büring, 2003; Groenendijk, 2006). In such approaches a discourse is taken to be aimed at the exchange of information, and they are therefore conceived of as games of stacking and answering "questions under discussion" (Ginzburg, 1995a,b) or as processes of "raising and resolving issues" (Hulstijn, 1997). These exchanges are governed by various kinds of rules, ranging from what can be deemed structurally linguistic, discourse configurational principles, to the very pragmatic principles of reasonable or rational coordination. By adopting a dynamic outlook upon interpretation, such systematic principles and effects have been characterized in a transparent manner.

The relevant type of information (of the interlocutors, or in the "common ground") concerns the information that has been established in a discourse up to some point. It can be modeled as a set of possibilities, and updates of information then consist in the elimination of possibilities. If we know or learn more, fewer possibilities turn out to be compatible with the information we have, and in the extreme case we could be left with only one possibility, specifying totally how exactly (we think) things are (Roberts, 1996).

Of course, hardly anybody purchases the specific goal of gaining total information. Updates in discourse are limited to and guided by the questions we actually have, the ones we factually pose, or those that others decide we might be interested in. Here is where Ginzburg's (1995a) and

[8] In van Rooij (2003a) these ideas are extended to account for the felicity of negative polarity items in questions. For an alternative account of this phenomenon, see Guerzoni and Sharvit (2007); Beck (2006); Nicolae (2013).

Roberts' (1996) "questions under discussion" kick in, and, likewise, the "raising and resolving issues" from Hulstijn (1997). At any point in a discourse or dialogue, several questions may be "alive" because they are explicitly or implicitly raised, or assumed to be relevant. In order to account for such a state in discourse, it is not sufficient to only have at our disposal the set of possibilities compatible with the information assumed and exchanged so far. We also need the relevant differences between possibilities which the interlocutors wish to distinguish, or the (discourse) goals they wish to establish.

In the tradition of model-theoretic semantics, updates of information and issues have given rise to dynamic variants of the partition approach to questions (Jäger, 1995; Hulstijn, 1997; Dekker, 2004; Groenendijk, 2006). To be able to model not only the update of a discourse context with information, but also with issues, a context is not identified with a set of possibilities, modeling information, but with an equivalence relation over a set of possibilities, sometimes called an *indifference relation*. That two possibilities in a discourse context are connected by the indifference relation means that the ways in which these possibilities may differ are *not at issue* in that context. So, thus conceived, discourse contexts can model both information and issues.

Unlike the update of a discourse context with an assertion, an update with a question typically does not lead to an *elimination of possibilities*, but to *disconnecting possibilities* that were hitherto connected by the indifference relation, thereby making the differences between the disconnected possibilities an issue in the discourse context.

Since an equivalence relation over a set corresponds to a partition of it, we can also picture a discourse context as a partition of the set of possibilities that are not excluded by the current contextual information. For an assertion to compliantly address the current issue in a discourse context, an update of the context with the information it provides should eliminate all the possibilities within at least one block in the partition.

There is an immediate connection here with the topic of the previous subsection: pragmatics of questions and answers, since to *compliantly address the contextual issue* (or not) is typically a matter of adhering to the Gricean Cooperative Principle, more in particular the Gricean Maxim of Relation. This link between dynamic partition semantics and Gricean pragmatics is discussed in Groenendijk (2006).

Also directly related is the dynamic approach to contextually restricted quantification in Jäger (1995). A minimal pair of the kinds of examples dealt with is provided in (42).

(42) a. Who is wise? Only Socrates is wise.
b. Which Athenian is wise? Only Socrates is wise.

The reply in (42a) typically states that Socrates is the only wise person in the universe of discourse. Restricted by the question preceding it, the same reply in (42b) can be taken to mean that Socrates is the only wise Athenian. (See Aloni et al., 2007a, for an elaboration of this approach and further references.)

Of course, there are alternative dynamic approaches to the semantics of discourse not tied to the partition-style approach and variations thereof. See, for example, Asher, Chapter 4 on discourse semantics and Ginzburg, Chapter 5 on the semantics of dialogue. In the next subsection, we introduce in some detail a semantic framework which is in the spirit of the dynamic variants of the partition semantics but leads to a more general notion of meaning that can accommodate most of the approaches to the semantics of questions discussed above.

19.5.3 Inquisitive semantics

Recently, Ciardelli, Groenendijk, and Roelofsen have developed a general semantic framework, called *inquisitive semantics*, for dealing with informative and inquisitive aspects of meaning in an integrated way (Ciardelli and Roelofsen, 2011; Ciardelli et al., 2012, 2013; Roelofsen, 2013).[9] We introduce the basics of the framework here in relation to theories of questions in discourse, in particular the dynamic variants of partition semantics, as discussed in the previous subsection.[10]

As we have seen above, what generically underlies theories of questions in discourse is that discourse contexts are conceived of as consisting of a certain body of information and certain questions or issues that are contextually relevant. Here we make the simplifying assumption that a single issue is at stake.

So, schematically, a context c can be viewed as a pair $(\mathsf{info}_c, \mathsf{issue}_c)$ of which the two elements represent the *contextual information* and the *contextual issue* respectively. Standardly, info_c is modeled as an *information state*, which is the set of all possibilities that are not excluded by the current contextual information.

As we have seen above, in dynamic partition semantics, issue_c is modeled as an *indifference relation*, an equivalence relation over info_c, which gives rise to a partition of info_c into a number of mutually exclusive substates of it that jointly cover it.

In inquisitive semantics, issue_c is directly modeled as a set of substates of info_c, namely *all of its substates where the contextual issue is settled*. This straightforwardly models a contextual issue from a dynamic perspective: the elements of issue_c directly reflect which *updates* of the current information will settle the current issue. It follows immediately from viewing the contextual issue in this way that issue_c has to be a *downward closed set of states* because, if

[9] These papers concern basic inquisitive semantics and logic. Papers on variations and extensions of the basic system, and on linguistic and logical-philosophical applications, can be found at www.illc.uva.nl/inquisitivesemantics.

[10] This introduction is based on Ciardelli et al. (2013).

the current contextual issue is settled in some state $s \subseteq \mathsf{info}_c$, then that also holds for any more informed state $t \subset s$.

Just as in dynamic partition semantics, every possibility in info_c must be included in one of the blocks in the partition induced by issue_c, in inquisitive semantics it is required, that no possibility in info_c is excluded from *all* possible ways to settle the issue, that is, issue_c is required to be a *cover* of info_c.[11]

Finally, in dynamic partition semantics the contextual issue is *trivial* when the indifference relation that issue_c corresponds to is a *total* relation on info_c, in which case info_c itself is the one and only block in the partition that issue_c gives rise to.

Similarly, in inquisitive semantics the contextual issue is *trivial* when it is already settled by the contextual information, that is, in case $\mathsf{info}_c \in \mathsf{issue}_c$. This means that even in an initial context where no issue has been raised yet, issue_c is *not empty*, which we find as a general constraint in the definition of an issue over an information state in inquisitive semantics:

- $\mathcal{I}$ is an *issue over a state s* iff $\mathcal{I}$ is a non-empty set of substates of s such that:
  (i) $\mathcal{I}$ is downward closed: if $t \in \mathcal{I}$ and $t' \subseteq t$, then $t' \in \mathcal{I}$; and
  (ii) $\mathcal{I}$ is a cover of s: $\bigcup \mathcal{I} = s$.
  $\mathcal{I}$ is a *trivial issue* over s iff $s \in \mathcal{I}$.

We started out by taking a context as a pair $(\mathsf{info}_c, \mathsf{issue}_c)$, but when we take issue_c to be an issue over info_c, then just issue_c suffices to characterize a context, since it determines that $\mathsf{info}_c = \bigcup \mathsf{issue}_c$. In other words, we can *identify* a context with a non-empty downward closed set of states. In the definition we use ω to denote the set of all possibilities.

- A *context* $\mathcal{C}$ is a non-empty downward closed set of states.
  The *contextual information* in $\mathcal{C}$ is $\mathsf{info}(\mathcal{C}) = \bigcup \mathcal{C}$.
  A context is *inquisitive* iff $\mathsf{info}(\mathcal{C}) \notin \mathcal{C}$.
  A context is *informed* iff $\mathsf{info}(\mathcal{C}) \neq \omega$.

A special context, which could be dubbed *the initial context*, is the unique context that is neither informed nor inquisitive. It equals the powerset of the set of all possibilities ω, that is, the set of all states.

Although there are global correspondences in the architecture of contexts in dynamic partition semantics and in inquisitive semantics, there are also crucial differences. One way to illustrate this is by introducing the notion of the *alternatives* in a context $\mathcal{C}$ as the maximal elements of $\mathcal{C}$. These correspond to minimal extensions of the current information where the contextual issue is settled.

- s is an *alternative* in $\mathcal{C}$ iff $s \in \mathcal{C}$ and there is no $t \in \mathcal{C} : s \subset t$.

[11] We can look upon the situation where this would *not* be the case as one where the issue has a certain *presupposition* that is *not satisfied* by the current contextual information. We do not allow for such a situation.

Although, likewise, in dynamic partition semantics, the blocks in a partition are the maximal sets of possibilities that are totally related by the indifference relation, there is a significant difference between the two cases. In inquisitive semantics the alternatives in a context $\mathcal{C}$ may mutually exclude each other and form a partition of $\mathsf{info}(\mathcal{C})$, but they may just as well overlap. This means that the notion of a contextual issue is essentially richer in inquisitive semantics than it is in dynamic partition semantics, as we will further illustrate below.

Having introduced a notion of context that fits a theory of questions in discourse, we now turn to a corresponding notion of meaning, viewed from a dynamic perspective as a contextual update. In the most basic classical versions of update semantics, contexts and propositions are taken to be semantic objects of the same kind, and both are typically conceived of as sets of possibilities, that is, "classical propositions". Then, if $[\varphi]$ is the proposition expressed by a sentence φ, the corresponding update of a context c with φ can simply be taken to be $c \cap [\varphi]$. Moreover, the dynamic meaning of φ is given by the update function $\lambda c.\ c \cap [\varphi]$.

This classical pattern can easily be reproduced in dynamic partition semantics where a context is an indifference relation. Interrogative sentences already correspond to such relations in standard partition semantics, and declarative sentences can be made to fit by associating them with an indifference relation which totally relates all the possibilities in the proposition that it classically expresses.

Contexts and meanings of sentences are semantic objects of the same kind, where declarative sentences share the properties of non-inquisitive contexts. Furthermore, since relations correspond to sets of pairs, and the intersection of two indifference relations is always guaranteed to be an indifference relation itself, we can formulate the update of a context with a sentence in terms of plain intersection.

In inquisitive semantics it holds as well that the intersection of two issues is itself an issue. This means that if we also take the proposition expressed by a sentence to be a non-empty downward closed set of states, updating a context with the meaning of a sentence can be taken to be plain intersection. Moreover, this is, indeed, how propositions are modeled in inquisitive semantics, leading to a notion of meaning in which informative and inquisitive content are fully integrated.

- A *proposition* $\mathcal{P}$ is a non-empty downward closed set of states.
  The *informative content* of $\mathcal{P}$, $\mathsf{info}(\mathcal{P}) = \bigcup \mathcal{P}$.
  $\mathcal{P}$ is an *inquisitive* proposition iff $\mathsf{info}(\mathcal{P}) \notin \mathcal{P}$.
  $\mathcal{P}$ is an *informative* proposition iff $\mathsf{info}(\mathcal{P}) \neq \omega$.

Conceptually, inquisitive semantics takes the utterance of a sentence that expresses a proposition $\mathcal{P}$ to be a *proposal* to the participants in the conversation to jointly cooperate in establishing an update of the current contextual information $\mathsf{info}(\mathcal{C})$, the current common ground, in such a way that a new context $\mathcal{C}'$ results, where $\mathsf{info}(\mathcal{C}') \in \mathcal{P}$. In order to reach this goal, the participants in the conversation have to be able to accept the information that $\mathcal{P}$ provides, if it is informative, and to provide information that settles the issue $\mathcal{P}$ raises, if it is inquisitive. More succinctly put, a proposition is a proposal to the participants in the conversation to update the common ground in one or more ways.

The notion of the alternatives in a context defined above also applies to propositions.[12] Given how inquisitiveness is defined, if there is more than one alternative for a proposition, then it is inquisitive. Conversely, if there is only a single alternative for a proposition, then it is not inquisitive. Such non-inquisitive propositions are called *assertions*, and non-informative propositions are called *questions*.

So in inquisitive semantics we can uniformly assign propositions as meanings to all sentences, but having the properties of assertions in case of declarative sentences, and the properties of questions in case of interrogative sentences.[13]

Whether we view contexts and propositions as indifference relations, as in dynamic partition semantics, or whether we view them as non-empty downward closed sets of states, as in inquisitive semantics, we can straightforwardly define an *entailment* relation between them, which integrates informative and inquisitive content and applies uniformly, irrespective of whether $\mathcal{P}$ or $\mathcal{Q}$ is a question, assertion, neither, or both.

- (*Entailment*) $\mathcal{P} \models \mathcal{Q}$ iff $\mathcal{P} \subseteq \mathcal{Q}$.

Given the following fact, we can also look upon entailment in both cases from an *update perspective*:

- $\mathcal{P} \models \mathcal{Q}$ iff $\mathcal{Q} \cap \mathcal{P} = \mathcal{P}$.

Before we end this introduction to inquisitive semantics by providing a handful of examples, we first make some rather technical remarks concerning the comparison of partition semantics and inquisitive semantics that may also serve to motivate our particular choice of examples.

As is shown in Roelofsen (2013), under the entailment relation defined above, the set of all propositions in inquisitive semantics forms a Heyting algebra, with operators that can be associated in the standard way with the logical constants in a logical language: meet (conjunction and universal quantification), join (disjunction and existential quantification), and relative and absolute pseudo-complement (implication and negation respectively).

12 This use of the term *alternatives* is closely related to its use in the framework of *alternative semantics* (Kratzer and Shimoyama, 2002; Simons, 2005; Alonso-Ovalle, 2006; Aloni, 2007, among others). The connection between inquisitive semantics and alternative semantics is discussed in detail in Roelofsen (2013), Theiler (2014), Ciardelli and Roelofsen (2015).

13 The framework of inquisitive semantics as such does not dictate such a sharp semantic distinction between declaratives and interrogatives. It allows for hybrid cases of sentences, or sequences thereof, which are both informative and inquisitive. The issue is discussed extensively in Ciardelli et al. (2015).

The set of propositions when viewed as indifference relations, as in dynamic partition semantics, has a different algebraic structure under the entailment relation, which lacks a relative pseudo-complement operator. (It forms a pseudo-complemented lattice.) As a consequence, unlike in inquisitive semantics, in partition semantics there is no principled general way to obtain an interpretation of implication that can deal uniformly with conditional assertions and conditional questions.[14] Furthermore, although the algebraic structure we obtain has a join operator, unlike in the case of inquisitive semantics it does not correspond to taking plain unions of propositions. The reason behind this is that a union of indifference relations is not guaranteed to be an indifference relation itself, and is not guaranteed to give rise to a partition. A union of indifference relations will preserve reflexivity and symmetry but may lack transitivity and hence fail to be an equivalence relation. The join operator in the algebra underlying partition semantics corresponds to taking the transitive closure of the relation that results from taking plain unions of propositions as indifference relations.[15]

It is this difference in the nature of the join operator in the two algebras that lies behind the fact that, unlike in inquisitive semantics, partition semantics cannot deal properly with mention-some interpretations of constituent questions, as exemplified by (16)–(17) above,[16] nor can it deal generally with disjunctive questions.

By way of illustration of the inquisitive semantic framework, we depict in Figure 19.1 a plausible assignment of a proposition as its meaning for the five sentences (43)–(47) and discuss the semantic properties of these propositions and the logical relations between them.

In the last example, we use ↑ to indicate rising intonation, which has an influence on how the sentence is interpreted.

(43) Peter will attend the meeting.

(44) Will Peter attend the meeting?

(45) Who of Peter and Maria will attend the meeting?

(46) If Peter attends the meeting, will Maria attend it too?

(47) Will Peter↑ attend the meeting, or Maria↑?

[14] This does not preclude an analysis of conditional questions as such in a partition semantics. E.g., they are dealt with by Isaacs and Rawlins (2008) in a dynamic partition framework which involves stacked contexts.

[15] What naturally suggests itself, see Mascarenhas (2009), is to drop transitivity as a necessary property of indifference relations. One can then look upon an issue as the set of all *pairs of possibilities* where it is settled. As discussed in Ciardelli et al. (2015), such a "pair semantics" actually suffices for an adequate treatment of conditional questions along the lines of Velissaratou (2000). However, as has been conclusively shown in Ciardelli (2009) and Ciardelli and Roelofsen (2011), one has to generalize from pairs to sets of arbitrary size to enable a general proper treatment of disjunctive and mention-some constituent questions.

[16] This does not preclude a pragmatic account of mention-some readings based on a partition semantics, as proposed in van Rooij (2003b).

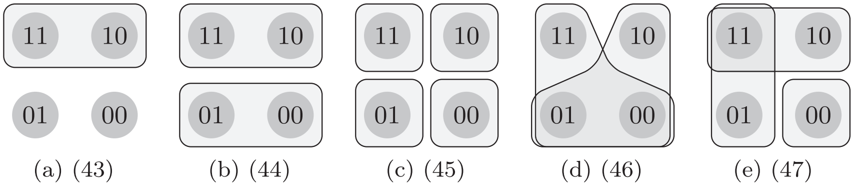


Figure 19.1 *Propositions expressed by examples (43)–(47)*

Whereas with *falling* intonation on its last disjunct (47) expresses a so-called *alternative question*, which is widely taken to presuppose that one and only one of the disjuncts holds, with *rising* intonation on the last disjunct it has no such presupposition and leaves open the options that both or neither of the disjuncts holds. For this reason, the question that (47) expresses is called an *open disjunctive question*.[17]

Since only the two individuals Peter and Maria figure in these examples, and only the property of attending a certain meeting plays a role, a logical space of four possibilities suffices for our illustrations: one possibility where both Peter and Maria will attend, one where only Peter will, one where only Maria will, and one where neither Peter nor Maria will attend. In the pictures in Figure 19.1, these possibilities are labeled 11, 10, 01, and 00, respectively.

The demarcated areas in the pictures of the propositions represent the *alternatives* for each proposition. Only the maximal states in a proposition are depicted explicitly, but keeping in mind that propositions are downward closed sets of states, this fully determines a proposition.

In what follows, we will use the labels of the sentences (43)–(47) also to refer to the propositions assigned to them. And since propositions and contexts are objects of the same kind, we also use these labels to refer to the corresponding contexts.

Of our five examples, only (43) is not inquisitive, since only this proposition has a single alternative. It is an *informative assertion* since its informative content, which coincides with its unique alternative, excludes the two possibilities where Peter will not attend.

The other four propositions (44)–(47) are all not informative, since the union of their alternatives, and hence of all the states they contain, covers the whole logical space. Moreover, since their pictures show more than one alternative, they are *inquisitive questions*. The alternatives for the polar question (44) and for the constituent question (45) form a partition of the logical space. This is not so for the conditional question (46) and the open disjunctive question (47), which have two overlapping alternatives.

[17] We have chosen this example of a disjunctive question because the basic inquisitive semantic framework presented here does not deal with presuppositions. However, there are natural ways to extend the framework in such a way that presuppositions can be captured (see AnderBois, 2011; Ciardelli et al., 2015). (For discussions of disjunctive questions, see, among others, Han and Romero, 2004; Beck and Kim, 2006; Aloni et al., 2013; Roelofsen and van Gool, 2010; Biezma and Rawlins, 2012; Pruitt and Roelofsen, 2013; Uegaki, 2014.)

Consider the relation between the assertion (43) and the polar question (44). As generally holds for assertions, the single alternative for (43) equals its informative content. And since $\mathsf{info}(43) \in (44)$, the information the assertion provides settles the issue the polar question poses. Owing to downward closure, $\mathsf{info}(43) \in (44)$ also means that $(43) \subseteq (44)$, and hence that (43) entails (44). Viewing entailment from an update perspective: if we consider $(44) \cap (43)$, the resulting context equals (43), and hence unlike the original context (44), its update with (43) is no longer inquisitive.

These observations do not hold for this assertion in relation to the constituent question (45): (43) does not entail (45). Showing this from the update perspective, if we update the context where the constituent question (45) is the issue with the assertion (43), the resulting context $(45) \cap (43)$ is still inquisitive. Its picture consists of the top half of (45), and hence there are still two alternatives.[18]

The resulting updated context is informed about whether Peter will attend the meeting, but the issue remains whether Maria will attend as well. However, one can say that although the updated context is still inquisitive, it is *less inquisitive* than the one we started out from.

We now turn to the conditional question (46). There are two overlapping alternatives for (46) which correspond to the informative contents of the two conditional assertions in (48).

(48) a. If Peter attends the meeting, then Maria will as well.
b. If Peter attends the meeting, then Maria won't attend.

Consider the relation between the assertion (43) and the conditional question (46), where the former affirms the antecedent of the lattter. The situation is the same as discussed for (43) in relation to the constituent question (45) insofar as $(46) \cap (43) = (45) \cap (43)$, which we have seen to be inquisitive. However, there is also a difference in that whereas we saw that $(45) \cap (43)$ is *less inquisitive* than (45), this does not hold for $(46) \cap (43)$ as compared to (46). Although less remains of the two alternatives for (46), two alternatives do remain. This relates to the intuition that, by default, a response to a conditional question that affirms the antecedent is not a very happy conversational move.

In a different sense, the latter also holds for the negation of (43), which *denies* the antecedent of (46) and, unlike (43), *does* entail it. In other words, it settles the issue it poses but does so by *dismissing the supposability* of the antecedent.[19]

As for the last example, the relation between the assertion (43) and the open disjunctive question (47) is much the same as we already described for

[18] To see this by inspecting the pictures, you have to take into account that they only explicitly show the alternatives for a proposition, but that due to downward closure, all subsets thereof are elements of the proposition as well.

[19] The special status of the denial of the antecedent of a conditional is not accounted for in the semantics presented here. It is addressed in Groenendijk and Roelofsen (2015).

the relation between this assertion and the polar interrogative (44). In particular, (43) entails (47), as do the assertions in (49). Unlike (43), the assertions in (49) also entail the constituent question (45).

(49) a. Only Peter will attend the meeting.
b. Both of them will attend the meeting.
c. Neither of them will attend the meeting.

However, the same does not hold for the relation between the *negation* of (43), namely (50), and the open disjunctive question (47).

(50) Peter will not attend the meeting.

In this case, whether we update a context where (47) is the issue or a context where (45) is the issue with (50), the result is the same. The resulting context corresponds to the bottom half of the context depicted in (45), that is the resulting context is still inquisitive, but *less inquisitive* than the context we started out with. In case of the open disjunctive question (47), the alternative where Peter will attend has been eliminated from the picture.

A last remark on the question depicted in Figure 19.1e. This proposition can also plausibly be assigned to a mention-some constituent question, exemplified by (16) and (17) above, for the simplified case where the relevant domain consists of two individuals.

This ends our illustration of the basic inquisitive semantic framework. It is a framework, and not a linguistic theory about which meanings are to be assigned to specific sentences in a language like English, if only because such a theory is typically *compositional*. To make it possible to formulate such a theory, one needs to lift inquisitive semantics to a full-fledged intensional type theory. However, given that, despite its novelties, inquisitive semantics is logically rather conservative, as its algebraic features show, there is no need to be skeptical about the possibility of executing this lift. In fact, the first steps have been taken in Theiler (2014) and Ciardelli and Roelofsen (2015).

19.6 Conclusions

In this chapter we have given a concise overview of the findings and insights of the main types of semantic approaches to questions, and of some of the old and current debates on the interpretation of specific questions, as well as on general features of the analyses of questions that have been proposed. For the most part, a common thread has been the notion of answerhood conditions, as a specific semantic dimension of interrogative sentences, distinguishing them from indicatives, whose semantics has been framed in terms of truth conditions.

However, at the end of this chapter, we have also seen that more recent approaches, which are information-based rather than truth-based, have led to a more integrated treatment of the meanings of indicatives and interrogatives, where they are also no longer directly driven by the linguistic notion of answering a question, but rather by the more primary logical notion of settling an issue.

Being slightly biased, perhaps, we have emphasized the logical role that questions play precisely in terms of the notions of answerhood and settling an issue. More practically oriented approaches are dealt with in more detail in Asher, Chapter 4 on discourse semantics and Ginzburg, Chapter 5 on the semantics of dialogue.

No matter how static model-theoretic models may be, we have also given some idea of how the pragmatics and dynamics of questions can be dealt with along fairly classical lines, indicating how partition-style theories, but in principle other theories equally easily, have been extended so as to display the kind of structure relevant in the interpretation of discourse. Of course the exposition could only be indicative of the kind of work done, and we hope the references made, along with the other chapters in this book, may help readers to find their way in the literature.

One point has hardly been addressed. Most semantic theories of questions take their cue from English, with the corpus of examples employed in theoretical debates being in English as well. However, nobody nowadays would deny the importance of cross-linguistic data, and this should surely hold for the (semantic) theory of questions. It seems to be a fair assumption that the existence of questions is a universal across languages and that questions can be assumed to be universally realized syntactically, semantically, pragmatically, and epistemologically. Since different languages and cultures may show variety in these realizations, the cross-linguistic study of question meanings is of great importance. Unfortunately, however, at present we can only point to recent work and findings (see Beck, 2006; Haida, 2007; Cable, 2010; Slade, 2011; AnderBois, 2012; Roelofsen and Farkas, 2015; Uegaki, 2014, among others).

In this chapter we have also said little about the computation of questions, the generation of answers, and (automated) information retrieval. This is a pity in as far as the focus on the semantics and pragmatics of questions and answers should, in principle, allow the prospect of bridging theoretical and practical endeavors. The, modest, moral here can only be that the gap between these two types of approaches is still felt to be too large to be bridged in a single step. We think there is reason for hope, however, since the theoretical work is shifting its focus toward more practical matters, as indeed can be expected from research on the semantics/pragmatics interface.

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20

Imperatives

Paul Portner

20.1 Introduction

Imperatives constitute one of the major clause types of human language; most if not all languages have a grammatically distinctive class of sentences which are associated closely with directive meaning. For example, in English we have (1):

(1) Ben, feed the bird!

The sentence is grammatically distinctive in that it lacks an overt subject (*Ben* here is a vocative) and employs a verb which is nothing but the verb stem (we can say it is the bare infinitive form), both properties which root clauses cannot usually have in standard English. Moreover, the sentence obviously has directive meaning in that it is naturally used with the aim of getting the addressee, Ben, to feed the bird and can barely be used with the aims associated with other clause types (Truckenbrodt, 2006): one cannot use it to assert that someone will feed the bird, has fed the bird, or anything of the sort; one should use a declarative like (2) if that is one's communicative goal. Nor can one use it to ask whether the bird will be or was fed; interrogatives such as (3) stand ready for English speakers with that purpose.

(2) You will feed the bird.

(3) Will you feed the bird?

Although (1) cannot be used to assert or ask for information in the ways that (2)–(3) can, it is possible for (2) to be used more or less as (1) is. The declarative sentence here can easily be used with the aim of getting the addressee to feed the bird, and it is even possible for (3) to be used directively as well (in the situation where the addressee is supposed to feed the bird, yet he has apparently forgotten to).

While the description of imperatives just outlined is nothing surprising, it is worthwhile bringing it up explicitly because the most basic issues for the semantic analysis of imperatives concern how to understand better and make precise the intuitive ideas which underlie it. That is, a student of imperatives should seek to answer the following questions:

1. How, in terms of fundamental syntactic properties, are imperative sentences grammatically distinctive, and why are they distinctive in these ways?
2. What is it to be directive, and what semantic and pragmatic phenomena are connected to the directive nature of imperative sentences?

In order to answer these questions, the linguist (and the linguist here is often a philosopher on detail) aims to employ and improve existing theories to develop syntactic, semantic, and pragmatic analyses of imperatives. This chapter will be organized with reference to the issues which have animated recent theoretical work on imperatives, in particular the work whose main concern is semantics and pragmatics. It is divided into two main parts. In the first, Section 20.2, I will provide an overview of those issues, and in the second, Section 20.3, I will sketch and discuss the main theoretical perspectives on the meaning of imperatives.

20.2 Overview of issues in the semantics of imperatives

We can identify four main empirical areas of focus in recent research on imperatives. Three of these are often treated as if they are independent of one another: the semantic restrictions on the imperative subject, logical properties which distinguish imperatives from simple declarative sentences, and the nature of directive meaning. While it seems unlikely that most researchers believe that these aspects of the meaning of imperatives are completely separate, it has often proven useful to separate them for the purposes of formal analysis, and in this section, we will follow the tradition. We will, to a large extent, look at them in sequence, since this will ease the presentation of key issues. In the next section of the chapter, Section 20.3, as we discuss major theories of imperative meaning, it will be possible for us to see what kinds of integrated pictures of imperative meaning have emerged in semantics. The fourth main area of research, the treatment of complex sentences which contain imperatives as a part, has always been closely related to ideas about the nature of directive meaning (and occasionally to work on the imperative subject). These connections are what one would expect from the perspective of syntactic and semantic theory because when an imperative functions as a subordinate clause, what is at issue is mainly how it integrates with its matrix, and any ways in which this integration differs from other clause types are naturally thought to relate either to the meaning of the imperative as a whole (its directive nature) or to its subject (via theories of pronouns and pronoun-like elements).

20.2.1 The imperative subject

The subjects of imperative clauses have two important typological properties: they are associated in reference with the addressee, and they can be null. In terms of addressee-reference, every language has imperatives whose subjects refer to the addressee, and in some languages it is rather difficult, and maybe even impossible, to find imperatives whose subjects are not associated with the addressee in terms of their meaning. As for the null-subject property, while not every language allows the absence of a phonologically realized subject (e.g., Icelandic; see Kaufmann, 2012), the vast majority do, even languages which do not otherwise allow null subjects in root clauses. The addressee-reference and null-subject properties are linked, in that there are many languages, like English, where a null imperative subject is required to be second person, as in (4a), and imperatives whose subjects do not strictly refer to the addressee(s) must be constructed with an overt subject, (4):

(4) a. Have a seat!
    b. Maître d', someone seat the guests.[1] (Potsdam, 1998)

To a large extent, scholars attempting to explain these two properties of imperative subjects have done so from the perspective of syntactic theory. We have a fairly significant literature trying to explain why imperative subjects can be null based on syntactic theories of null arguments, and these theories typically make use of the same mechanism which they exploit to license the null subject as the core of the explanation for why the subject must be associated with the addressee.

Basically, every approach to the licensing of null arguments in non-imperative sentences has been applied to imperative subjects. Some scholars propose that the subject is a special null element with unique properties; others that it is on the receiving end of a control, binding, or agreement relation (see, for example, Schmerling, 1982; Platzack and Rosengren, 1998 [the imperative subject is a special element]; Downing, 1969; Han, 1998 [control]; Beukema and Coopmans, 1989 [binding]; Rupp,

[1] A reviewer points out that with a negated example we could be more confident that the example is indeed imperative in form. In my judgment, *Maître d', don't anyone seat the guests!* is no less acceptable than (4b).

1999, 2003; Jensen, 2003a,b; Bennis, 2006; Zanuttini, 2008; Zanuttini et al., 2012 [agreement]). This is not the place to explore the details of all of these syntactic theories. What I think is important to point out, though, is a more general point discussed in Zanuttini et al. (2012): one cannot derive the special interpretive properties of the imperative subject solely from the fact (assuming that it is a fact) that the core function of imperatives is to direct the addressee to do something. Let us dwell on this point briefly.

One might think that, because imperatives function to direct the addressee to do something, they must have a subject which refers to the addressee, since that way the sentence will express a proposition to the effect that the addressee does something. In other words, the sentence will express a proposition which is a natural fit for what the sentence functions to do. But while one cannot deny that it is a natural fit in that case, there is no reason from this perspective why it must be the subject in particular which is second person. Why can (5a) not be expressed by (5b), since it would presumably be virtually synonymous with (5a) if it were grammatical?

(5) a. Be kissed by John! (Zanuttini et al., 2012)
b. *John kiss (you)!

Example (5) seems to show that there is something special to be said about the subject of English imperatives which distinguishes it by virtue of its syntactic status as subject.

The traditional view within formal linguistics is that the referent of the imperative subject must be "in a subset relation" to the set of addressees (Downing, 1969), in a sense of "subset" according to which the quantificational subject of (6a), whose domain is the set of addressees, counts.

(6) a. Don't anyone leave!
b. Those children of yours keep out of my garden, or I'll set the dog on them!

Potsdam (1998) argues against Downing's generalization, citing examples including (4b) and (6b). Kaufmann (2012) argues that Downing's generalization is basically correct for English (she thinks that (6b) involves a "marginal repair strategy") and strictly correct for German. However, there are reasons to agree with Potsdam that Downing's generalization is not accurate for English, and in any case it is not applicable across all languages. First, we have English examples like (4b) where the addressee (here, the maître d'), is to make the individual referred by the subject do something; Potsdam says that the addressee must be in a control relation with the referent of the subject. And second, we have examples in languages which have full agreement paradigms for imperatives in which the addressee is to make it the case that a proposition is true, while having no apparent link to any agent referred to within the sentence:

(7) Tebulwa: sa:ph rahe!
table-NOM clean-NOM be-IMP.3SG
'Make it the case that the table is clean!' (lit. 'The table be clean!')
(Bhojpuri: Zanuttini et al., 2012)

If the directive meaning of an imperative is something to the effect that the addressee should make it the case that the proposition expressed by the sentence is true, and there is no other restriction on imperative subjects than what can be derived from the directive meaning, examples like (7) should be possible in all languages. Again, this points to the crucial role played by syntax in explaining the properties of imperative subjects. Finally, we have third person imperatives which do not seem to target the addressee at all, like the Dutch (8):[2]

(8) Laten zij eerst maar eens hun excuses aanbieden.
let.3PL they first PRT PRT their apologies offer-INF
'Let 'em first offer their apologies.'
(Mastop, 2011, Example (22))[3]

The recent semantically sophisticated discussions of imperative subjects have tended to agree that the syntactic relation involved in explaining their interpretation (and probably their extended ability to be phonologically null) is agreement (Zanuttini, 2008; Zanuttini et al., 2012; Kaufmann, 2012). Setting aside forms like (8), the key idea is that there is a person feature [person: 2] on the imperative verb or a functional projection which enters an agreement relation with the subject, thereby making sure that the subject has this feature. In simple cases like (1) and (4a), the second person feature ensures that the subject refers to the addressee. More complex are cases with non-pronominal subjects like (9a) and quantified subjects like (9b):

(9) a. Boys be the cops and girls be the robbers! (Schmerling, 1982)
b. Somebody help me!

Kaufmann's (2012) analysis of quantificational subjects shows how it is possible to integrate a semantics of person agreement with generalized quantifier theory; she provides a meaning for the person feature on which it makes sense to say that the subject of (9b) is second person. While Zanuttini et al. (2012) do not have as complete or precise an analysis of the semantics of the second person feature as Kaufmann does, they aim to explain examples like (7) which are outside of the range of Kaufmann's proposal. Focusing on similar constructions in Italian, they propose that the second person feature of imperatives is introduced into the syntax in a different way from ordinary subject agreement. In English, the former precludes the latter, but in other

2 The English *let*-imperative has a similar meaning, but it feels somewhat archaic. Absent wishes like *Rain!* may require a similar analysis; see Section 20.2.3.

3 Abbreviations in this chapter not covered in Leipzig Glossing Rules: DECL: declarative, IND: indirective, PRT: particle.

languages it is possible for a clause to contain both the "special" (imperative) second person feature and the "regular" subject–verb agreement feature. In such instances, the subject agrees with the verb, and the special second person agreement affects the meaning of the clause, but not the meaning of the subject. The result is a sentence which is addressed to an individual responsible for making it true, but where that individual need not be the referent of the subject (see Platzack and Rosengren, 1994, for a similar idea implemented in Minimalist syntax).

20.2.2 Logical properties

Imperatives are subject to two well-known logical puzzles: the phenomenon of free choice and Ross's paradox. Free choice is exemplified by the fact that sentence (10a) licenses the inference to (10b) and occurs not just with disjunction but also with indefinites (especially special indefinites like *any*). This phenomenon is not limited to imperatives, as shown by (11):

(10) a. Have an apple or a pear!
b. You may have an apple, and you may have a pear.

(11) a. You must/may talk to John or Mary.
b. You may talk to John and you may talk to Mary.

Free choice is not explained by standard theories of modal semantics derived from modal logic. For example, $\Box(p \vee q)$, interpreted as "every accessible world is in the union of the p worlds with the q worlds", does not automatically entail $(\Diamond p \wedge \Diamond q)$, "there is at least one accessible p world and at least one accessible q world", because (for example) it is compatible with the former that all of the accessible worlds are p worlds.

Ross's paradox (1944) is the closely related pattern whereby (12a) does not imply (12b), in the sense (which must be explained more precisely) that someone who uses the former in the normal directive way is not committed to the latter:

(12) a. Have an apple!
b. Have an apple or a pear!

Ross's paradox is not really a paradox, but rather just a logical property which is unexpected from the perspective of standard logic, where p entails $p \vee q$.

There is quite a large literature on free choice, and rather than attempting to survey it here, our focus will be on determining what imperatives in particular have to teach us about choice phenomena, and vice versa. (Some of the important references are Aloni, 2007; Aloni and Ciardelli, 2013; Aloni and van Rooij, 2007; Alonso-Ovalle, 2006, 2008; Asher and Bonevac, 2005; Barker, 2010; Charlow, 2011; Fox, 2007; Franke, 2011; Geurts, 2005;

Kamp, 1973; Lassiter, 2011b; Mastop, 2005; Menéndez-Benito, 2005; Portner, 2011; van Rooij, 2000, 2008, 2010; Ross, 1944; Schulz, 2005; Kaufmann, 2012; Simons, 2005; Zimmermann, 2000.) A key issue concerns the relationship between free choice with imperatives and the parallel phenomena with modal sentences. Except for Portner (2011) and Charlow (2011), existing discussions of free choice imperatives have assumed that imperatives contain modals in their logical form so that the logical form of (10a) is roughly $\Box(p \vee q)$, and the puzzle is identical to that of (11a), namely why it entails $(\Diamond p \wedge \Diamond q)$. These works each develops its theory of (11), and then assumes that the same theory will apply to (10) as well, perhaps with a little modification (Aloni, 2007, is especially relevant to the issue of how to extend an analysis of modal free choice to imperatives).

There are two main issues to keep in mind if one wishes to explain imperative free choice by reducing it to an analysis free choice in modal sentences. One is that not all modal sentences show free choice effects; for example, Portner (2011) mentions the following:

(13) a. At the top of the mountain, you can find snow or ice to make drinking water. (*doesn't entail* You can find snow and you can find ice.)
  b. A: Can any of the students speak Chinese or Japanese?
  B: Chou Wei-han can. (*doesn't entail* Chou Wei-han can speak Chinese and he can speak Japanese.)
  c. All of our students should take logic or stats. (*doesn't entail* All of our students can take logic and all of our students can take stats / All of our students can take logic and can take stats.)[4]

Therefore, if one is to explain free choice in imperatives by assuming that they contain a modal, one must make sure that it is the right kind of modal and in the right position. The second issue is simply the assumption that imperatives contain modals at all. As we will see in Section 20.3, one of the main distinctions among theories of imperatives is between ones that assume the presence of a modal and ones that do not. On the one hand, the existence of free choice in imperatives might be seen as an argument for the modal theory, but on the other, the reasons to deny the modal account throw into doubt an understanding of free choice which relies on the presence of modal operators.

I would like to highlight a couple of points that are important for understanding the status of free choice with imperatives. First is the fact that imperatives are very strongly disposed to show free choice effects. In particular, imperatives that gives orders or commands (such as (10a)) seem to

[4] Magdalena Kaufmann (p.c.) points out that an imperative version of this, *Take logic or stats, depending on whether you're a syntax student or phonology student*, fails to show free choice. This is so, but only when the *depending on* ... phrase is present, and this phrase can remove the free choice inference even for (10) and (11). These points suggest that *depending on* affects the interpretation of disjunction. The semantics of *depending on* is an interesting topic which may be relevant to future work on choice inferences.

always imply choice (i.e., (10b)). Admittedly, Aloni (2007) assumes that such imperatives do not always give rise to a free choice inference, but I find her example (14), drawn from Rescher and Robison (1964), unconvincing. (In any case, Aloni admits that the reading is marginal.)

(14) TEACHER: John, stop that foolishness or leave the room!
(John gets up and starts to leave.)
TEACHER: Don't you dare leave this room!

It seems to me that the teacher's first utterance does imply that John is permitted to leave the room. That is why he gets up to leave. Of course, the teacher did not grant this permission sincerely, and when John turned out to be more impertinent than expected, it had to be retracted, but this does not cast doubt on the fact that, at the literal level, permission was granted. Note how odd it would be for the second utterance to be replaced with *Why are you leaving?*

In contrast to this situation with order-type imperatives, Kaufmann (p.c.) points out that imperatives that give advice or suggestions (goal-oriented, or teleological, imperatives) can fail to license a free choice inference. She gives the following example:

(15) A: How do I get to the city center?
B: Take the U4 or U5, I can't remember which.

It is not well understood why order-type imperatives differ from advice/suggestion imperatives in this way. (We will discuss the various functions of imperatives further in Section 20.2.3.)

In contrast to the case with imperatives, all types of modal sentences, including deontic ones, can fail to show free choice, as seen in (13). Moreover, even those modal sentences that tend to display choice readings, like (11a), have readings where they do not. For example, as is well known, if (11a) is followed by *but I don't know which*, it does not license the inference to (11b). Following (10a) with *but I don't know which* is distinctly odd, unless one switches from an order-type reading to a suggestion-type reading.

The second point, mentioned or implied in some of the literature (e.g., Kamp, 1973; Geurts, 2005; Aloni, 2007; Franke, 2011; Portner, 2011), is that free choice is linked to the sentence having a particular pragmatic status.[5] Portner (2011) describes this as the sentence being "performative", in the sense that the utterance changes the state of the discourse so as to put in place the requirement which it expresses, while Franke describes it as the speaker having authority over the truth of the statement. It seems to me that a modal sentence used performatively in this sense cannot fail to give rise

[5] Note that there is no claim that only performative sentences have free choice readings. The suggestion here is that, *pace* Kamp, all performative modal sentences (like all imperatives), along with some non-performative modal sentences, do so.

to a free choice inference. Note that none of the examples in (13) are performative, while those in (11) are hard to read in a non-performative way. This observation is relevant here because root imperative sentences are typically performative, and as far as I can tell, deontic imperatives are invariably so. These points suggest that performativity is a crucial ingredient in explaining free choice inferences.

We should note a dispute between Barker (2010) and Kaufmann (2012), on the one hand, and Portner (2011), on the other, about whether Kamp (1973) has identified cases of performative modal sentences which lack the free choice interpretation. I believe that performative modal sentences never have a reading on which they fail to license the choice inference; but in any case, if there is such a reading, it is certainly marginal or in need of strong contextual support in a way that the non-choice interpretations of the examples in (13) are not, and this fact in itself would have to be explained. Overall, the picture that emerges is that both imperatives and performative modal sentences give rise to free choice readings, either universally or with some very rare exceptions. The correlation suggests that imperatives show free choice effects for the same reason that performative modal sentences do and that either performativity gives rise to, or at least very strongly prejudices, free choice.

Given the connections among the directive (or performative) meaning of imperatives and their licensing of free choice, we can now see more clearly what is at stake for theories of free choice generally. On the one hand, one might say that imperatives are modal sentences, that these modals are typically performative and that free choice follows from their being modal and performative. This is the approach of Kaufmann (2012), for example. On the other, one might attribute free choice to the performative meaning directly, making it irrelevant whether that performativity is connected to a modal operator or not. This is the approach of non-modal theories of imperatives like Portner (2007a, 2011) and Starr (2010), as well as Charlow's closely related analysis (according to which these examples contain an operator at speech-act level).

Having spent some time on free choice, let us return briefly to Ross's paradox. Most recent discussions of Ross's paradox have assumed that it is to be explained by the same ideas which account for free choice, and with good reason: (12b) is not implied by (12a) simply because (12b) gives rise to the free choice inference, and so it implies that the addressee may have a pear, something which is not automatically permitted by (12a). The additional piece needed to account for Ross's paradox is a formal definition of the implication relation under which (12a) is understood not to imply (12b). We find a closely related set of definitions in papers by Kamp (1973, "p-entailment"), Veltman (1996, "validity$_2$"), Mastop (2005, 2011, following Veltman), and Portner (2011, "warrant"); see also van Rooij (2000), Aloni (2007), and Aloni and Ciardelli (2013) for discussion. Let us consider Veltman's and Portner's definitions:

(16) a. An argument is valid iff updating any information state s with the premises $\phi_1, \ldots, \phi_n$, in that order, yields an information state in which the conclusion ψ is accepted. Formally: $\phi_1, \ldots, \phi_n \Vdash \psi$ iff for every state s, $s + [\phi_1] \cdots + [\phi_n]$ leads to a context s' such that $s' + \psi = s'$. (modified from Veltman, 1996)

b. For any sentences p, q: p warrants $q =_{\text{def}}$ for every context c (in which $c + p$ is defined), $c + p = (c + p) + q$. (Portner, 2011)

The precise status of the concepts defined in (16) depends on the broader semantic/pragmatic framework in which $+$ is defined. Veltman's approach is classic dynamic semantics, and so validity in (16a) is a relation among sentence meanings as they are conceived in that theory. Portner's framework, in contrast, involves static sentence meanings and a conventional, pragmatic linking principle (discussed in Section 20.2.3 below) which connects those meanings to contextual update. In either case, though, the same intuition holds: (12a) does not imply (12b) because $c +$ (12a) does not necessarily represent a context in which the addressee is permitted to have a pear (pears have not even been mentioned), in contrast to ($c +$ (12a)) $+$ (12b).

20.2.3 Directive force

So far in this overview, we have made use of the commonplace observation that imperative sentences have directive meaning. In a non-technical sense, this observation simply covers the fact that it is easy and typical for imperative sentences to be used to try to get someone (the addressee, normally) to take some non-linguistic action. In this section, we will examine ways in which semanticists have attempted to make more clear their descriptions of this directive meaning, and to provide precise formal analyses of it.

The concept of force in imperative semantics and syntax

Discussions of directive meaning are often couched in terms of the concept of "force", in particular the speech act theory notion of illocutionary force and the related notions of sentential force or sentence mood. Illocutionary force refers to the type of communicative effect which a speaker intends to achieve with the use of a sentence; as such, it is tied to utterances, tokens, or uses of linguistic forms. However, illocutionary force groups together linguistically diverse grammatical forms, such as (1)–(3) when each is used with the reasonable intention of getting Ben to feed the bird and thus does not capture the intuition that there is some basic meaning of directivity which distinguishes imperatives from interrogatives and declaratives (e.g., Reis, 1999; Chierchia and McConnell-Ginet, 2000; Zanuttini and Portner, 2003; Schwager, 2005b; Kaufmann, 2012). The concept of sentential force is useful for naming the canonical function which a sentence has in virtue of its grammatical sentence type. In terms of sentential force, we can define directivity as a property that a given sentence has if it is a member of a sentence type with the canonical function of directing someone to do something. On this way of talking about things, we can say that all imperatives have directive sentential force. It may also be that only imperatives (and related forms like exhortatives) are directive in their sentential force, provided that we exclude from relevance "actions" like giving an answer (which the use of an interrogative typically seeks).

This type of terminological refinement can be helpful for some purposes, but in the end the correct theory of the meaning of imperatives (and other sentence types) will provide the correct definitions of concepts like directive meaning and force. In order to develop a better theory of this kind, we must not only think about speech acts from a philosophical perspective but also isolate the important issues of linguistic analysis on which semantic and pragmatic theories in this domain can be judged. The following are two of the fundamental linguistic questions:

The conventionalization question How do imperative sentences come to be associated with directive sentential force? In particular, what are the linguistic principles that associate certain grammatical representations, namely those which we identify as imperatives, with directive force, rather than with some other force, or no force at all?

The representation question What is it to direct someone to do something? In particular, how do we represent what occurs when a successful act of direction occurs?

Classical speech act theory provides a familiar answer to the first of these questions (Searle, 1969; Searle and Vanderveken, 1985; Vanderveken, 1990, 2002). Conventionalization is due to the presence of a force marker which expresses a particular kind of directive illocutionary force; this imperative force marker is assumed to be part of a paradigm of operators that combine with a propositional sentence radical and associate it with an illocutionary force.[6] (It should be noted that the basic concepts of speech act theory, in particular those of the locutionary, illocutionary, and perlocutionary acts, do not imply that there is such a thing as a force marker combining with a forceless sentence radical, but the canonical version of speech act theory has developed that way.) However, speech act theory does not answer the representation question in any clear way. Obviously, according to speech act theory, a successfully used imperative can place the addressee under an obligation; however, what it is to be under an obligation is not itself explained. It seems to me that this may be so because classical speech act theory makes the assumption that "being under an obligation" is a social fact the further analysis of which is not relevant for understanding the semantic and grammatical properties of imperatives.

[6] Kaufmann and Poschmann (2013) present evidence that colloquial German allows *wh*-interrogatives with imperative morphology and the associated directive meaning. They point out that this combination of interrogative and imperative meaning is difficult to account for on the view that sentences are typed through the presence of an operator which assigns them their illocutionary force.

Much work on imperatives within formal syntax has made use of the concept of a force marker. This link between speech act theory and syntactic representation goes back to the performative hypothesis, but it has been reformulated in various ways as syntactic theories have changed. For example, Rivero and Terzi (1995), Rizzi (1997), and Han (1998) propose that the force marker is an abstract feature or operator present in the upper reaches of the imperative's structure, and the syntactic grammar of this element is used to explain some of the distinctive properties of imperatives' syntax. According to Rivero and Terzi, in some languages the imperative feature is in a high (C-, or complementizer-) position, and the verb is required to raise to the feature, explaining why the verb cannot be negated and why it must precede pronominal clitics in these languages.

(17) a. *Den diavase! (Greek: Rivero and Terzi, 1995)
NEG read.IMP
b. Diavase to!
read.IMP it
'Read it!'

However, as pointed out by Zanuttini and Portner (2003), the relevance of this work to our understanding of directive force is limited by the fact that it has focused only on a subset of morphologically distinctive imperatives. In Greek, for example, the meaning of a negative imperative, which cannot be expressed as in (17a) with a verb in the imperative verbal mood,[7] is instead expressed with an indicative verb form:

(18) Den diavases!
NEG read.INDIC
'Don't read!'

Other languages use other verbal forms in cases where the imperative verbal mood cannot be used. For example, Italian uses the infinitive for negative second person singular imperatives:

(19) a. *Non telefona le! (Italian: Zanuttini and Portner, 2003)
NEG call.IMP her
b. Non telefonarle
NEG call.INF-her
'Don't call her!'

[7] Verbal mood must be distinguished from sentence mood, or this statement will not make sense. Imperative verbal mood is a morphosyntactically distinct verb form which is analyzed as being part of the regular mood paradigm (including also, for example, indicative and subjunctive). In languages which have it, imperative verbal mood would typically be used in the most basic imperative sentences (such as second person singular, socially neutral, non-negative imperatives), and perhaps others as well. Imperative sentence mood refers to the grammatical form or forms which distinguish imperative sentences as a clause type, thereby distinguishing them from declaratives and interrogatives. Examples like (18) and (19b) exemplify imperative sentence mood but not imperative verbal mood. To put it simply, imperative verbal mood is opposed to indicative and subjunctive (perhaps among others), while imperative sentence mood is opposed to declarative and interrogative (perhaps among others). (See Han, 1998; Zanuttini and Portner, 2003, for discussion.)

Example (19b) is just as much an imperative by semantic/pragmatic criteria as a sentence with the imperative verbal mood. Therefore, if an abstract feature or operator is to explain the distinct syntactic behavior seen in (17), this feature cannot be the sole expression of directive illocutionary force.

The syntactic diversity of imperative sentences within languages like Greek and Italian shows that there is no simple correlation between grammatical form and the imperative speech act type. This fact poses a problem for speech act theory's approach to the conventionalization question. As pointed out by Zanuttini and Portner (2003), it seems that it is not possible to identify any discrete piece of the morphosyntactic representation with the force marker. If force marker approach to the conventionalization question is to have a chance of working at all, it will have to take a more abstract view of grammatical structure, one according to which different aspects of form can serve as force marker in different circumstances. In other words, it would need to propose something like the following: in Italian, force can be expressed either by imperative verbal mood or by a combination of root position, infinitival verb form, and negation. (Actually, there are other combinations as well, for polite and third person imperatives, so matters would be even more complicated.) Although mainly focused on interrogatives, Ginzburg and Sag's (2000) construction-based analysis of sentence types contains some relevant ideas.

Recent approaches to the analysis of directive meaning

Recent work on imperative meaning has tried to answer not only the conventionalization question but also the representation question. While there are several ways to classify this work, one important distinction lies between accounts according to which the basic function of an imperative is to make a factual claim and those according to which it is to modify a representation of what is permissible. According to the first approach, directive meaning is represented using the same tools as apply to ordinary, assertive declarative sentences, while according to the second, it is represented using some new, imperative-specific tools.

Approaches which answer the representation question using the same tools as assertion

The most well-known approach to representing information in discourse comes to us from the work of Stalnaker (1974, 1978). According to Stalnaker, two basic aspects of the meanings of declarative sentences, presupposition, and assertion, can be better understood in terms of an idealized model of the conversation, the common ground, representing the mutual presuppositions of the participants in the conversation. Assertion is then to propose the addition of a proposition (in the simplest case, the proposition expressed by a sentence) to the common ground, and a successful assertion is the case where the proposition is in fact added. (Often we work with a related concept, the context set, the intersection of the propositions in the common ground. The context set is the set of worlds which could be actual as far as the mutual presuppositions of the conversation go.)

(20) Assertion (with respect to a common ground or context set)
  a. The successful assertion of p in a conversation with common ground cg results in a new common ground $cg' = cg \cup \{p\}$.
  b. The successful assertion of p in a conversation with context set cs results in a new context set $cs' = cs \cap p$.

Example (20a) is simple and well known, and (20b) is just a corollary, but the analysis of assertion in this model is worth laying out explicitly in order to render the comparison with an analysis of imperatives more perspicuous. Note that Stalnaker's model is designed to answer the correlate of the representation question for assertion ("What is it to assert something? In particular, how can we represent what occurs when a successful act of assertion occurs?").

In light of Stalnaker's model, we can understand the distinction between two ways of answering the representation question for imperatives as a distinction between approaches which represent directive meaning in terms of the common ground (or something similar) and those which represent it in terms of something in addition to or more complex than the common ground. The first approach is best represented by the work of Kaufmann,[8] while the second is developed in a tradition which includes the work of Lewis, Han, Portner, and others. We will examine each in turn.

According to Kaufmann, the directive meaning of an imperative is represented by adding to the common ground a modal proposition. For example, if successfully used, (1) would add to the common ground the proposition that Ben should feed the bird. If one assumes Stalnaker's model of assertion, this is probably the simplest approach to the representation question possible. However, it opens up an obvious issue. The successful assertion of (21) also adds the proposition that Ben should feed the bird to the common ground, and yet (1) and (21) are not the same in meaning.

(21) Ben should feed the bird.

Specifically, while (1) has only a directive meaning, (21) has both a directive and a descriptive meaning. On the latter interpretation, the sentence can be described as true or false, whereas (1) and the former reading of (21) cannot be. Moreover, adding a proposition to the common ground would normally be understood as providing a model of the descriptive meaning, in as much as this is the same kind of effect on the common ground as is provided by the assertion of an ordinary, non-modal declarative.

The above discussion shows that, while Kaufmann provides a simple answer to the representation question, she must do some work to answer the conventionalization question. While the details are complex, there are

[8] Much of Magdalena Kaufmann's work was published under the surname Schwager.

two main things I would like to point out here about her strategy. First, she attempts an interesting integration of Stalnaker's common ground with ideas from classical speech act theory, whereby the essential effect of a speech act is modeled in terms of the common ground. In this way, she aims to provide the answer to the representation question within the framework of speech act theory which classical speech act theory failed to provide. Second, she aims to solve the conventionalization question by proposing that (1) is in fact synonymous with (21) except for the fact that imperatives "come with an additional presuppositional meaning component that makes them unfit for assertive use and shields the truth value from being conversationally accessible" (Kaufmann, 2012, Sect. 2.4). It is not easy, however, to craft presuppositions which give the desired effect while maintaining the spirit of the idea that the effect of directive meaning is represented in the common ground. Starr (2012) argues that the difference between (performative) *should* and the imperative in his example (22) is a problem for Kaufmann's strategy of identifying the meaning of an imperative with that of *should* plus presuppositions that guarantee performativity:

(22) a. We all know you are going to cheat, but you shouldn't.
b. #We all know you are going to cheat, but don't!

Charlow (2010, 2011) likewise criticizes Kaufmann's strategy of answering the conventionalization question through a set of special presuppositions, and he also echoes some aspects of Portner's (2007a) critique of her general approach to the representation question.

Setting aside these doubts about the crucial presuppositional meaning component, we can examine Kaufmann's strategy for modeling the force of imperatives. It may help to look at a simplified explanation of (1) in terms of Kaufmann's theory, in order to see how she proposes to represent directive force within the framework of common ground update. Kaufmann's modal analysis employs Kratzer's framework (1981, 1991b) so that a modal sentence is interpreted with respect to two modal parameters, the modal base and ordering source. For an imperative or other "priority" modality (such as a deontic modality), the ordering source is a function g which (applied to a given world w and time t) returns a set of relevant priorities. In the case of (1), these would be some set of requirements to which Ben is subject in w at t, perhaps those imposed by his parents.

Kaufmann's theory assumes an ordering source which represents the fact that, for any world w and time t, that Ben feed the bird is not in the set of requirements at w and t if a parent has not told Ben to feed the bird in w by t, and is in the set of requirements at w and t if a parent has told Ben to feed the bird in w at or prior to t (and, let us say, Ben has not yet fed the bird in w between the time he was told to do so and t). So, according to the theory, when it is uttered at time t, (1) serves to exclude from the context set worlds in which it is not necessary at t for Ben to feed the bird. Given the way the ordering source has been described, it is necessary at t for Ben to feed the bird if Ben's feeding the bird is one of the requirements returned by the ordering source at *t*. So we end up excluding from the common ground worlds for which the ordering source does not return, after *t*, a set including the requirement that Ben feed the bird.

This description of the dynamics of an imperative may seem a bit complex, but what should be attended to is the fact that Kaufmann aims to have the imperative get the proposition "Ben feeds the bird" into the deontic ordering source by excluding from consideration worlds at which the ordering source does not include that requirement. So prior to the use of the imperative, it had to be represented in the ordering source that the parent might order Ben to feed the bird specifically at *t*. Obviously, the same point goes for any other requirement that might have been or might be imposed. Thus, the strategy places a heavy burden on conversational backgrounds by requiring that those which could serve as ordering sources for imperatives anticipate all possible evolutions of the priorities they represent. If one's intuition is that the imperative "creates" or "adds" a requirement for Ben to feed the bird, this intuition is only indirectly represented by Kaufmann's analysis.[9]

Somewhat similar to Kaufmann's analysis is the proposal of Condoravdi and Lauer (2012). For them (1) means roughly "I have an effective preference that you Ben feed the bird", which is to say that the speaker is committed to acting in ways which will get the addressee Ben to feed the bird. (This is the same meaning as the performative use of *I order you, Ben, to feed the bird*.) In addition, according to the proposal, imperatives presuppose that the speaker prefers not to take any further action to get Ben to feed the bird and so prefers that the addressee take full responsibility for fulfilling the preference mentioned by the speaker. Furthermore, in the normal type of context in which an order like (1) would be used, the speaker assumes that declaring these preferences is sufficient reason for the addressee to form an effective preference of his or her own to feed the bird. Seen this way, Condoravdi and Lauer's analysis is like Kaufmann's in using a modal operator: *I have an effective preference that*, parallel to Kaufmann's *should*. It differs from Kaufmann's crucially in that the role of the addressee in the meaning — the fact that imperatives direct the addressee to do something — is derived indirectly, through pragmatic reasoning. In addition it should be noted that they close the paper with a discussion of the possibility of expressing their ideas in a framework where imperatives constrain the speaker's effective preferences directly (committing to an effective preference that Ben feed the bird), and if recast that way, their proposal falls under the second approach to the representation question, discussed next.

[9] Kaufmann might, of course, be open to an imperative having a direct effect on the ordering source beyond the assertion-like effect described above, but if such an effect were regular and conventional, adopting it would be to accept the claim of the opposing approach to directive force. That is, it would be to accept that imperatives affect a discourse component other than the common ground.

Approaches which answer the representation question using tools designed for imperatives

Lewis (1979b) initiated the second major approach to the representation question,[10] and I will briefly provide a summary of his ideas and then outline how later work in the tradition developed it further. Lewis defined a toy language game involving basic (ϕ), command ($!\phi$) and permission ($¡\phi$) sentences spoken among three characters, the Master, Slave, and Kibitzer. The truth conditions and pragmatic effects of these sentences are represented within two discourse components, the sphere of accessibility and the sphere of permissibility. The former arises from a kind of historical accessibility relation: the sphere of accessibility at a time and world $\langle t, w \rangle$ is the set of worlds which could be actual, given the history of w up to t. The sphere of permissibility arises from a kind of deontic accessibility relation: the sphere of permissibility at $\langle t, w \rangle$ is the set of worlds which are permissible at t in w. The sphere of permissibility is not given a more contentful definition, because its shape and evolution are to be explained through the rules of the game; however, its role in the game is crucial: the Slave must make sure that the actual world is in the sphere of permissibility at all times. The truth conditions of sentences are defined as follows:

(23) a. A function f assigns to each basic sentence ϕ a truth value at each $\langle t, w \rangle$.
b. $!\phi$ is true at $\langle t, w \rangle$ iff, for every world w' which is both accessible and permissible at $\langle t, w \rangle$, ϕ is true at $\langle t, w' \rangle$.
c. $¡\phi$ is true at $\langle t, w \rangle$ iff, for some world w' which is both accessible and permissible at $\langle t, w \rangle$, ϕ is true at $\langle t, w' \rangle$.

The key insight of Lewis's paper is that the effects of command sentences can be represented by shrinking the sphere of permissibility: when the Master utters a command sentence, the sphere of permissibility should shrink to make ϕ true (this change is attributed to a principle of accommodation).

(24) For any world w, if P is the sphere of permissibility just before time t in w, and $!\phi$ is uttered by the Master at time t in w, the sphere of permissibility at t in w becomes $P \cap \{w : \phi \text{ is true at } t \text{ in } w\}$.

A significant portion of Lewis's paper is devoted to the fact that there is no obvious analogue of (24) for permission sentences. A principle like (25), in which intersection is replaced by union, will not do, because this would mean that $¡\phi$ (e.g., *Take tomorrow off!*) permits anything compatible with ϕ, such as killing the Master.

[10] Before Lewis, van Fraassen (1973) had proposed that the semantics of *ought* sentences could be given in terms of the set of imperatives in force at a point in time, and he even suggested an understanding of the function of this set based on the ordering over possible worlds it would generate (foreshadowing the ideas of Portner, Charlow, Starr, and Condoravdi and Lauer discussed below). However, this paper seems to have been mostly overlooked in linguistically-oriented work since Lewis.

(25) For any world w, if P is the sphere of permissibility just before time t in w, and $!\phi$ is uttered by the Master at time t in w, the sphere of permissibility at t in w becomes $P \cup \{w : \phi$ is true at t in $w\}$.

Lewis points out that what is needed in order to solve this problem of permission is a notion of comparative permissibility. The problem with (25) is that it enlarges the sphere of permissibility too much; what we want is to enlarge the sphere of permissibility to include some worlds in which ϕ is true, but only the most permissible (or, perhaps more intuitively, least antecedently impermissible) such worlds. This means that, when the Master says *Take tomorrow off!*, the Slave is not permitted to kill the Master, because worlds in which she does are less permissible than other worlds in which she takes tomorrow off. What is needed, then, is a mechanism for determining comparative permissibility at a given point in the evolution of a conversation.

We find important steps toward solving the problem of permission in the work of Han (1998), Mastop (2005, 2011), and van Rooij (2000). Han has the important insight that the analysis of directive meaning requires keeping track of the set of sentences which have been directively used. She proposes that the directive meaning of an imperative should be represented by adding the proposition expressed by the imperative to the addressee's "plan set", a set of propositions which "specifies the hearer's intentions" (Han, 1998, p. 4). However, Han's ideas are left at an intuitive level, and she neither connects them to any theory of discourse meaning (like the works of Stalnaker or Lewis cited above) nor specifies them in a formally precise way. Mastop (2005, 2011) has a similar idea to Han's and implements it formally in a dynamic logic; he proposes that imperatives have a primitive semantic type not based on propositions and that the force of an imperative is to update an "action plan", similar to Han's plan set. However, he does not develop in detail the crucial link between the formal model of the action plan and the actions an agent takes. Specifically, there is a difference between not taking an action in your personal plan and not taking an action which is in your plan because you agreed when someone told you to do it, and this difference is not explained by Mastop's (2011) theory. Turning to van Rooij (2000), he develops an analysis of permission sentences designed to solve Lewis's problem; his insight is that we can formally model the evolution of a comparative permissibility ordering among worlds (or as he calls it, comparative reprehensibility) by checking how many of a designated set of propositions relevant to permissibility are true in each world. However, van Rooij is not clear on what this designated set of propositions is – at one point, he suggests it could be the set of all atomic propositions (van Rooij, 2000, fn. 28), while at another, he says it is contextually determined and constant through a conversation (fn. 29). Thus, we are left without a clear analysis of permission which can be applied to linguistic data.

Portner (2004, 2007a) builds on the insights of Lewis, Han, and van Rooij. Like Lewis, he presents a model with two discourse components: in place of the sphere of accessibility, he utilizes the common ground, and in place of the sphere of permissibility, he uses the To-do List function. The To-do List function T assigns to each conversational participant x a To-do List, $T(x)$, a set of properties which is then used to define an ordering of worlds $\leq_{T(x)}$. The To-do List is similar to Han's plan set but has the status of a discourse object like the common ground, and the ordering relation is analogous to van Rooij's comparative reprehensibility. Portner's proposes that the representation question can be answered by postulating that a successfully used imperative adds its content to the addressee's To-do List in a way parallel to assertion in Stalnaker's model (cf. (20a)):

(26) Directive force (with respect to a common ground and To-do List function)
  a. The successful use of an imperative P in a conversation with common ground and To-do List function $\langle cg, T\rangle$ results in a new context $\langle cg, T'\rangle$, where T' is just like T except that $T'(\text{addressee}) = T(\text{addressee}) \cup \{P\}$.
  b. Given a To-do List $T(x)$, a partial ordering on worlds $\leq_{T(x)}$ is defined as follows: $w_1 \leq_{T(x)} w_2$ iff $\{P : P(x)(w_1) = 1\} \subseteq \{P : P(x)(w_2) = 1\}$.

Portner further explains the pragmatic function of the To-do List in terms of the ordering. An agent A's actions will be deemed rational and cooperative to the extent that they tend to make it the case that there is no possible world compatible with the common ground which is better ranked than the actual world according to $\leq_{T(A)}$. This statement corresponds to the principle in Lewis's theory that the Slave must make sure that the actual world remains in the sphere of permissibility.

The second approach to the representation question can now be summarized as follows: an imperative has successfully directed someone to do something when the content of the imperative has been added to a discourse component which determines an ordering relation. This answer to the representation question is followed in rough outline by subsequent work in the same tradition, such as Mastop (2011), Portner (2011), Charlow (2011), and Starr (2010, 2012). Before moving on to this later material, let us take a moment to see how the work already discussed answers the conventionalization question.

Lewis abstracts away from the conventionalization question by working with a simple formal language; the definitions of his language game state that, when $!\phi$ is uttered by the Master, the sphere of permissibility adjusts in the way described by (24). Given the way the game is formulated, one might suspect that he would adopt the kind of answer given in speech act theory, namely that the imperative is constructed from a propositional part (ϕ) and a force marker (!) and that the force marker conventionally expresses the directive meaning. This is certainly the assumption of Han, although she formulates the idea in syntactically more sophisticated terms. Likewise van Rooij is not explicit, but since he expresses his ideas in terms of sentences like *Must*ϕ and *May*ϕ, we might guess that he accepts a proposition-and-force marker view of directive force.

Portner (2004) provides a rather different answer to the conventionalization question. His work on imperatives was part of a broader project on sentence types (e.g., Portner and Zanuttini, 2000; Zanuttini and Portner, 2000, 2003; Portner and Zanuttini, 2005; Pak et al., 2008a,b; Zanuttini et al., 2012), and a leading idea of this project was that the proposition-and-force marker view is not supported by natural language data. More precisely, as noted above, they find no support for the idea that a sentence type of natural language can be defined by a discrete force marker which is present across sentences of that type in a given language (much less, across all languages). As a result, they argue for a different conception according to which root sentences have ordinary, compositionally derived semantic objects as their semantic values, and the linkage between sentence type and force is determined by basic theses of pragmatic theory. Specifically, in the cases of declaratives and imperatives, they propose that semantic type explains the correlation with force. They assume that declaratives denote propositions and that imperatives denote properties formed by abstracting over the subject; they further propose that a To-do List is a set of properties, in contrast to the common ground, which is a set of propositions. Given this, a basic principle (27) answers the conventionalization question.

(27) a. Given a root sentence S whose denotation $[\![S]\!]$ is a proposition, add $[\![S]\!]$ to the common ground, *cg*.
b. Given a root sentence S whose denotation $[\![S]\!]$ is a property, add $[\![S]\!]$ to the addressee's To-do List, T(addressee).

It should be noted that the principle applies to root sentences; it does not predict that other unembedded structures, such as DPs, *that*-clauses, or prepositional phrases, are assigned force; sentence fragments must be interpreted in some other way. Further, the association of the imperative with the addressee's To-do List in particular is actually not stipulated but rather follows from the semantics of the imperative subject. This approach is further extended to interrogatives, exclamatives, exhortatives, and promissives; see the works cited for details.

Mastop (2011) makes a proposal much in line with others in the tradition of Lewis. However, unlike all of the others, he premises his work on the idea that no semantics based on truth conditions can explain the properties of imperatives. He argues that imperatives denote objects other than (truth-conditional) propositions, namely "instructions". Given that instructions are an altogether different semantic type from propositions, he is able to offer an answer to the conventionalization question similar to Portner's. Instructions can be members of To-do lists and are not appropriate for being on the "fact sheet" (the analogue of the common ground); naturally, then, the dynamic meaning of imperatives places instructions onto a To-do List rather than a fact sheet. Mastop's proposal suffers, however, from the fact that instructions are treated as non-propositional primitives, and so we do not have a clear explanation of their logic properties or the relation between an imperative and what has to happen for it to be followed.[11]

Other recent work in the tradition of Lewis has suggested important refinements to the idea that the discourse component updated by imperatives defines an ordering relation over worlds. Charlow (2011) develops a dynamic framework where sentences modify "cognitive states" containing an information state (similar to the common ground) and a preference state (similar to the To-do List), and where the function of an imperative is to bring about the modification of the preference state. Rather than directly adding the imperative's content to the preference state (as Portner does with the To-do List), he represents the imperative's meaning as a test on the cognitive state, checking whether that state prefers situations of the kind described by the imperative to those described by its negation, and if it does not, he requires that the preference state be modified so that this strict preference (or necessity) condition is met. In simple cases, meeting the strict preference condition is as simple as adding the imperative's content to the preference state (in effect, updating the To-do List in the fashion proposed by Portner), but in more complex situations, such as when the preference state already contains a requirement in conflict with the imperative, a more complex kind of adjustment will have to take place.

This situation just discussed, when an imperative conflicts with some requirement already in place, constitutes the main case in which Charlow's proposal differs in a non-technical way from Portner's. Portner (2011) proposes that the To-do List can be inconsistent and that this situation represents permission for the agent to undertake actions which best serve any maximal consistent subset of the To-do List. (Mastop, 2011, makes a similar proposal: an action plan containing more than one To-do List represents the state of an agent with a choice among actions.) Portner's treatment of free choice hinges on the idea that free choice imperatives generate inconsistent To-do lists; in addition, he suggests that a simple imperative like A's second utterance in (28) can be read as only giving permission (in this case, permission to bring wine), if it is inconsistent with prior context:

[11] Mastop does propose a "result" function which assigns to each instruction a proposition representing its results, and so one might think that instructions are simply correlates in another semantic domain of these propositions. That is, the denotation of an imperative sentence S could be seen as an object i which is mapped by the result function to the propositional denotation $[\![S]\!]$ which would be assigned to the non-imperative version of S. In a way, on this view, instructions would be similar to Chierchia's (1984) concept of the individual correlate. However, such an analysis does not seem to be what Mastop has in mind, and it would make it hard to see substantial content in the claim that imperatives are semantic primitives. In the end, then, we are left without a well-grounded understanding of what instructions are.

(28) A: Please bring some beer to tomorrow's party.
B: But I have some good wine at home.
A: Then sure, bring wine!

For Charlow, in contrast, the use of a simple imperative always brings about a context in which the imperative's core content is necessary, and so the sequence in (28) should not bring about mere permission to bring wine. While I feel that (28) does imply permission to bring wine or beer, it is certainly often true that an imperative which is inconsistent with prior requirements often does not just grant permission and instead may cause an adjustment or retraction of prior requirements. This fact is difficult for Portner to explain.[12]

Although Charlow's theory places a clear necessary condition on the update of a cognitive state by an imperative (the state should strictly prefer the truth of the proposition to its negation), he is skeptical of the idea that semantics should provide a functional definition of that update. In other words, he thinks that it is not a matter for semantics what one does to the preference state in order to necessitate the imperative. Rather, the theory of the update should provide heuristics concerning what an appropriately conservative update would be, in various circumstances. ("In slogan form: speech act theory furnishes a theory of cognitive directives. Epistemology furnishes a substantive theory of diachronic compliance for cognitive directives", Charlow, 2011, p. 104.) He is pulled toward this perspective because he is not able to describe a general update function which he is confident reaches the appropriate set of preferences no matter what set of preferences are in the input context. He does, however, discuss at length specifications of the update which would be appropriate in various logically interesting situations. His nondeterministic stance about the semantics of imperative update is a key contrast with Portner's approach, as well as the later proposal of Starr. Portner takes what goes on in the simplest case (namely the addition of the content of an imperative's content to a To-do List with which it is consistent, relative to the common ground) as defining the sentential force of imperatives and sees the more complex updates, such as the retraction or modification of existing requirements, as the result of additional strategies which language users may employ in specific situations.

Starr (2010, 2012) also develops a theory of imperatives according to which their function is to modify an ordering relation, and like Portner (and opposed to Charlow) he analyzes permission as the creating of a order

[12] Portner could achieve the same predictions as Charlow by requiring that the To-do List remain consistent. I think that the correct generalization is that language users assume that speakers do not intend to introduce inconsistency into any particular sublist (see the discussion of (29) below), unless there is an explicit indication (like *or*) that the speaker intends inconsistency. However, distinct sublists can be inconsistent with one another – for example, the orders which have been given to an individual may conflict with the things he needs to do in order to achieve his goals – and therefore the overall To-do List easily becomes inconsistent. We can refer to the situation where a single sublist is inconsistent as "free choice" and the situation where distinct sublists are inconsistent as a "dilemma".

with multiple sets of "best" worlds.[13] Like Mastop (2005), Portner (2007a), but not Portner (2004), and Charlow (2011), Starr's analysis is cast within a dynamic semantics framework; more so than the others, Starr argues that the dynamic semantics approach in and of itself conveys crucial advantages over theories, like Portner's (2004), in which the shift from static to dynamic meaning is mediated by general conventions or pragmatic principles. Crucially, Starr thinks that there are reasons to represent within the (dynamic) semantics the potential for an imperative to modify the preferences associated with an agent in discourse, rather than having the semantics be traditional and static and letting the function of updating the To-do List be stated as a separate principle like (27).

Starr answers the conventionalization question in the traditional manner of classical speech act theory, by building the imperative logical form $!A$ out of a sentence radical A and an element ! which associates it with the right kind of update (namely, preference update).[14] He answers the representation question in (generally speaking) the same way as other preference-update approaches, but he develops an innovative, integrated formal model of the discourse context which aims to represent the effects of all major sentence types. This contrasts with Portner's theory, in which the common ground and To-do List are separate modules of the discourse model. Whereas (simplifying somewhat) Portner models the discourse as a triple $\langle cg, qs, T\rangle$,[15] Starr treats it as a single set-theoretic object, the preference state, on which assertive, interrogative, and directive acts can all be defined. While the model itself is too complicated to examine here, the question in evaluating it will be whether it succeeds in being truly integrative, or whether it merely distributes the effects of declaratives, interrogatives, and imperatives into different parts or aspects of one complex set-theoretic object.

A final approach which can be seen as treating imperatives as modifying an ordering relation is that of Condoravdi and Lauer (2011, 2012). As mentioned above, most of their presentation is based on the idea that imperatives assert something, namely that the speaker has an effective preference that the addressee take some action (e.g., that Ben feeds the bird). However, they discuss the possibility that the imperative creates a commitment on the

[13] This is only one subtype of permission. The other occurs when the imperative places a requirement on the addressee to do something which he wanted to do anyway and which the speaker has the authority to prohibit; this idea is seen in Hamblin (1987), Wilson and Sperber (1988), Portner (2004), Condoravdi and Lauer (2012), among others.

[14] A reviewer suggests that the dynamic approach sidesteps the conventionalization question. The idea is that a sentence with the right kind of preference-update dynamic semantics would by definition be counted as imperative. However, the point of the conventionalization question is why particular sentences have directive meaning (*Feed the bird!*) while others do not (*He is feeding the bird*). Apparently, if a sentence looks like the former but not the latter, it can have a ! prefixed to it in logical form. The dynamic theory does not by itself offer insight into the question of why this is so. Any suggestion that ! is present because it is represented atomically in the morphosyntax runs into problems with the diversity of forms that can serve as imperatives within a single language, as mentioned above.

[15] The component qs (for "question set") is designed to account for interrogatives (see Ginzburg, 1995a,b; Roberts, 1996).

part of the speaker to having an effective preference (rather than asserting this commitment), and since effective preferences are modeled in terms of an ordering relation (similar to (26b), but an ordering of propositions rather than worlds), this would be a version of the "ordering update" approach. It would be quite different from all of the other approaches in this family, though, because the ordering is connected to the speaker, rather than the addressee.

Varieties of directive meaning

Before leaving the topic of directive force, there is one final empirical issue which should be discussed. While we have given some attention on the distinction between permission and non-permission imperatives, this is not the only pragmatically relevant difference among speech acts performed by imperatives. Much of the literature has also focused on further subtypes of directive meaning, such as orders, suggestions, invitations, advice, and instructions. Portner (2007a) discusses the examples in (29a)–(29b), Charlow (2011) talks about the instruction imperative (30a), and Kaufmann the "absent wish" (30b) (see also, e.g., Schmerling, 1982; Davies, 1986; Han, 1999; Schwager, 2007; Condoravdi and Lauer, 2012):

(29) a. Sit down right now! (order)
 b. Have a piece of fruit! (invitation)
 c. Talk to your advisor more often! (suggestion)

(30) a. A: How does one get to Union Square from here?
 B: Take Broadway to 14th (for example). (instruction)
 b. Please, be rich! [On one's way to a blind date] (absent wish)

Let us begin by focusing only on the examples in (29), since the issues they raise are slightly less difficult than the ones in (30). In (29), we have imperatives which are all used with the intent to get the addressee to do what they say – they are straightforwardly directive, and so any of the ideas about directivity outlined above can apply to them. What they need is an account of how they differ. What is it to be an order, as opposed to a suggestion, for example? Most of the works which offer formal analyses of such differences do so in terms of one of the analyses of imperative meaning based on ordering semantics. Thus, for example, Portner separates the To-do List into various sublists, and this accounts for the various flavors of imperatives in (29a)–(29c); for example, when an imperative updates the sublist associated with the speaker's authority, the result is an order, while when it updates a sublist associated with the addressee's goals, the result is a suggestion. Likewise, since her basic theory of imperatives treats them as modal sentences, Kaufmann associates each imperative subtype with a particular variety of ordering source. Han's idea, while given in less detail than either of these, is very similar, and Charlow essentially follows the same account.

An advantage of this family of approaches to (29) is that it makes clear why there is such a close connection between the varieties of imperatives, on the one hand, and flavors of priority modality, on the other. Note how (29a) is closely related to, and in some sense makes true, the deontic modal sentence (31a), based on Portner (2007a); there are similar relations between (29b)–(29c) and (31b)–(31c):

(31) a. Noah should sit down right now. (deontic)
b. Noah should have a piece of fruit. (bouletic)
c. Noah should talk to his advisor more often. (teleological)

For Portner or Charlow, the ordering relations updated by the imperatives in (29) are identical to the ones used as ordering sources by the corresponding modals in (31); for Schwager/Kaufmann the corresponding pairs of sentences in (29) and (31) involve modals which utilize identical ordering sources. In contrast to this neat picture, I do not see any way to account for this close connection between imperatives and modals within a classical speech act theory, since the effect of a directive act is not given a linguistically relevant representation. It is also not clear how the link between imperatives and modals should be established in Mastop's or Starr's frameworks, since the preference relations created by imperatives are not immediately utilizable as ordering sources.

The examples in (30) present a deeper challenge to ideas about the directive meaning of imperatives. Someone uttering these sentences does not really intend to get the addressee to do what they say; for example, it seems incorrect to say that an utterance of (30a) aims to put *Take Broadway to 14th* on the addressee's To-do List. (In this case, the speaker doesn't really care.) For this reason, Kaufmann and Charlow argue that these imperatives, which are in a sense not fully directive, provide a strong reason to prefer their accounts to Portner's (and presumably likewise to Starr's). For Kaufmann, for example, they would have roughly the semantics of *You should take Broadway to 14th (if you want to get to Union Square)* and *You have to be rich (if I am to be pleased)*.[16] In order to account for such examples, Portner would need to broaden the concept of the To-do List to include sets of priorities which are not immediately taken to circumscribe the addressee's actions (in the case of (30a)) and which are not tied to an addressee present in the context (in the case of (30b)).[17]

The examples in (30) can profitably be related to Mastop's (2011) analysis of conditional, third person, and counterfactual imperatives in Dutch. For Mastop, there is a "practical commitment function" which indexes action

[16] Of course, the analyses of these modal paraphrases are themselves not simple. For example, the first is an anankastic conditional (Sæbø, 2001a; von Fintel and Iatridou, 2005; Lauer and Condoravdi, 2012, among others).

[17] Example (30b) is tricky because it is unclear whether it represents (i) a third person imperative like (7) or (10), or (ii) a second person imperative directed at an absent addressee who has no control over whether he or she fulfills the speaker's desire or not.

plans (and hence to-do lists, which make up action plans) to possible worlds. In this approach, (30a) can be thought of as a case in which the instruction to take Broadway is only on those action plans that are associated with a world in which the addressee wants to go to Union Square. (Starr, 2012, could follow a similar strategy, though his approach to conditional imperatives is rather different.) The absent wish in (30b) combines properties of the *let*-imperative exemplified by (8), repeated here as (8′), and the counterfactual imperative (32):

(8′) Laten zij eerst maar eens hun excuses aanbieden.
let-PL they first PRT PRT their apologies offer-INF
'Let 'em first offer their apologies.'

(32) Was toch lekker thuisgebleven.
was PRT PRT at.home.stay-PP
'You should just have stayed at home.'
(Mastop, 2011, Example (27))

Mastop (2011) proposes that (8′) shifts the context to one at which an absent person is addressee (though he does not give a formal model of this shifting). He analyzes (32) as expanding the set of possible worlds at which the practical commitment function is defined beyond the (analogue of the) common ground, and adding "you stayed home" to the addressee's action plan at every world at which it is defined. (Although it is not explained what it means to have the instruction to stay home on one's action plan at worlds which are known to be non-actual and at worlds where it is no longer possible to stay home, the idea is clearly that this situation represents one of failure and potentially regret.) Perhaps (30b) could be thought of as a case of expanding the set of possible worlds at which the practical commitment function is defined to include some at which the absent addressee has control over whether he is rich.

20.2.4 Complex sentences involving imperatives

Imperatives can be used as constituents of several kinds of complex sentences, and these constructions pose numerous puzzles for semantic theory. While limitations of space prevent me from considering analyses of these in detail, it may be useful to give an overview. The examples in (33) show some of the main types of constructions in which imperatives figure as a component part:

(33) a. Speech act conjunction
You bring the bread, and Hans will bring the wine.
(Based on Kaufmann, 2012)
b. The "Imperative and Declarative" (IaD) construction
Be late and you'll lose your job! (Kaufmann, 2012)
c. The "Imperative or Declarative" (IoD) construction
Get out of here or I'll kill you! (Kaufmann, 2012)

d. Conditional imperatives
If you see something, say something! (Kaufmann, 2012)
e. Imperative complement clause

Emma-ka	Inho-eykey	kongpuha-la-ko	hasiess-ta. (Korean)
mother-NOM	inho-DAT	study-IMP-COMP	said(honorific)-DEC

'Mother told Inho to study.'
(Zanuttini et al., 2012)

As pointed out by Kaufmann (2012), the IaD construction in (33b) must be distinguished from sentences in which an imperative and a declarative are truly conjoined, as in (33a). Whereas (33a) entails that Hans will bring the wine, (33b) does not entail that the addressee will lose his job. (33a) is analyzed as a case of speech act conjunction: first a request is made that the addressee bring the bread, and then it is asserted that Hans will bring the wine. Within a dynamic semantics framework, this speech act conjunction is simply a sequential update of the context (Krifka, 2001b; Kaufmann, 2012; Starr, 2012). Although there seems to be agreement within the field that such a sequential update analysis is unproblematical for (33a), analyses differ according to whether speech act conjunction is understood to be something special, or rather to represent normal sentential conjunction.

The IaD and IoD constructions have meanings which are intuitively quite similar to conditionals. (33b) means "If you are late, you'll lose your job", while (33c) means "If you don't get out of here, I'll kill you." A theory of these constructions should first face the question whether they are semantically conditional, in the sense that they have a logical form equivalent to a conditional logical form, or whether they give rise to a conditional meaning by some type of pragmatic inference. There is no agreement in the literature on this point (a few of the many works discussing IaDs and IoDs are Bolinger, 1967; Davies, 1986; Clark, 1993; Han, 1998; Franke, 2005; Russell, 2007; Kaufmann, 2012).

The arguments that IaDs have a truly conditional interpretation are fairly strong. On the one hand, the difficulties for a pragmatic account can be seen by considering an IaD with a dispreferred imperative part like (33b). Such an example cannot be understood to request that the addressee be late, so it is difficult to analyze in terms of a speech act conjunction followed by some pragmatic inferencing. To turn (33b) into a conditional via pragmatics will require a very powerful pragmatic theory, such as that proposed by Asher and Lascarides (2003a), and one must be concerned that such a theory will fail to be sufficiently restrictive. On the other hand, Kaufmann (2012) points out several structural properties shared by IaDs and hypothetical conditionals. However, although a pragmatic account faces problems, it is not easy to derive a conditional logical form for (33b) either. As noted by Culicover and Jackendoff (1997), conjunctions can frequently receive a conditional, subordinating interpretation, as in *I get this job and I'm happy*, and so one strategy is to attribute the conditional IaD meaning to the presence of this "subordinating conjunction" (e.g., Franke, 2005; Kaufmann, 2012). Still, because the conditional logical form is quite different from the surface syntactic structure of these sentences, various pragmatic inferences and operations on logical form seem to be required in addition to the special subordinating conjunction. Therefore, it is not entirely clear that any analysis which derives a conditional logical form for IaDs is more restrictive than pragmatic accounts.

In contrast to discussions of IaDs, there is greater consensus that the conditionality of IoDs is pragmatically derived (Franke, 2005, is an exception). We do not find IoDs with an imperative part which is dispreferred by the speaker (Clark, 1993; Franke, 2005; Kaufmann, 2012), a point which suggests that the imperative retains its directive meaning. Analyses differ, of course, in terms of where the pragmatic inference arises. Kaufmann assumes a particular non-classical account of disjunction (Geurts, 2005) and so connects IoDs to the problems discussed in Section 20.2.2.

Conditional imperatives have been extensively discussed, recently by Asher and Lascarides (2003a), Mastop (2005, 2011), Kaufman (2007 [as Schwager], 2012), Starr (2010, 2012), and Charlow (2010, 2011). According to a modal theory of imperatives like Kaufmann's, a conditional imperative can receive the same analysis as a conditional sentence with a modal in the matrix clause; within the framework of modal semantics assumed by Kaufmann, namely Kratzer's, this amounts to restricting the space of possible worlds relevant to the modal operator. It is certainly an advantage of the modal theory that it comes with a ready-made analysis of conditional imperatives, and the concerns one can raise about this account are essentially the ones which apply to the modal theory of imperatives generally (see Section 20.3 below). Opposed to the modal view are a number of dynamic theories, especially Mastop (2005, 2011), Charlow (2010, 2011), and Starr (2010, 2012). As dynamic theories, these works propose that the meaning of an imperative is to update a component of the discourse context which represents agents' preferences or requirements, but in order to encode the dependency of a given preference/requirement on a condition presented by an *if*-clause, they argue in favor of more complex representations of the discourse context than the simpler dynamic theories of Lewis (1979b) and Portner (2004, 2007a). Indeed, conditional imperatives have become a major tool for testing the details of formal theories of imperatives semantics.

Although imperatives cannot occur in complement clauses as freely as other clause types, they clearly do embed in many languages (Pak et al., 2004; Chen-Main, 2005; Rus, 2005; Platzack, 2007; Crnič and Trinh, 2009; Kaufmann, 2012; Lee, 2012; Zanuttini et al., 2012; Kaufmann and Poschmann, 2013; Thomas, 2014. Maier, 2010 argues that apparently embedded imperatives are actually quoted). The field has not yet developed a good understanding of why certain languages allow the construction in (33e), while others either do not or do so only in a limited way. From the perspective of semantic theory, embedded imperatives of this sort pose a problem for dynamic theories in which directive force is encoded in the logical form, like Charlow (2011) and Starr (2012). These theories would either have to assume that the embedding operator accepts an essentially discourse-oriented meaning in its complement, or find a way to strip the force from the embedded clause. In contrast, theories which assign more ordinary semantic values as the meaning of imperatives, like Portner (2004) and Kaufmann (2012), can modify a standard semantics for embedding to account for (33e). This is what we see in Zanuttini et al. (2012) and Kaufmann (2012).

20.3 Theories of imperative meaning

In discussing the nature of the imperative subject, the logical properties of imperatives, and the analysis of directive force, we have encountered most of the important proposals in the literature concerning the semantics of imperatives. We will now turn things around and make explicit how existing theories of imperative semantics attempt to account for some or all of the data outlined above. Our overview will follow a basic division between analyses which propose that imperatives contain a modal element which accounts for the essential properties of the clause type and theories which explain the properties of imperatives as resulting from the nature of an imperative-specific update function within dynamic semantics.[18] There are other reasonable ways to divide theories up; for example, another recent overview article, Han (2011), makes a main distinction between theories in which imperative force is encoded in logical form, and those in which it is pragmatically derived. (This groups together the modal theory with some of the dynamic theories, on the one hand, and opposes it to Portner's analysis, on the other.)

20.3.1 The modal approach

I will discuss two analyses which propose that imperatives contain a modal element, and these two may be distinguished in terms of how close the proposed modal is to being a "regular" modal such as a modal auxiliary. According to the analysis of Han (1999, 2011), an imperative contains a special kind of modal element which causes the proposition expressed by the imperative to define a domain of modal quantification; specifically, it does this by being added to a relevant (e.g., deontic) ordering source which, in combination with the modal base, defines a set of accessible worlds. As Han (2011, p. 1797) says: "In a way, an imperative is like a defective conditional that only has an *if*-clause, but not the consequent. Both an imperative and an *if*-clause restrict the domain of quantification. The difference is that the *if*-clause restricts

[18] As mentioned above, Condoravdi and Lauer (2012) mainly develop their ideas in terms of a variant of the modal theory (where the modal-like component is "I have an effective preference that"), but discuss the option of an imperative-specific pragmatic effect which creates commitments to effective preferences.

the modal base, whereas the imperative restricts the ordering source." Han's proposal has some intuitively appealing features. It seems helpful in explaining the IaD construction, since the imperative does function like an *if*-clause in a sentence like (33a). It makes concrete the idea that imperatives are connected to deontic modality. And it explains why imperatives cannot be evaluated for truth or falsity. I might also mention that it could hold promise for explaining free choice effects, since *if*-clauses also show choice:

(34) If you eat an apple or a pear, I'll be happy.
(If you eat an apple, I'll be happy, and if you eat a pear, I'll be happy.)

(The fact that conditionals show free choice effects is exploited by several theories of choice, such as Asher and Bonevac, 2005, and Barker, 2010, but these are not focused on imperatives.)

Despite these intuitive advantages, Han's modal analysis leaves unclear what the semantic type and normal function of the imperative denotation is. If we suppose that a domain of modal quantification is a proposition (a set of accessible worlds), and the imperative denotes that, why isn't it evaluable for truth or falsity? Moreover, if it is of another type, how is it integrated into the discourse in those cases where there is no continuation of the kind seen in (33b)–(33c), for which it can serve as the antecedent? Of course, as mentioned above, Han (1998) has another idea about how the imperative functions, namely the proposal that its content is added to the addressee's plan set. However, this dynamic analysis does not fit with the proposal under consideration here. It seems to me that, to the extent that we make all of the ideas in Han (1998, 1999, 2011) compatible with one another, we would end up with a theory similar to Portner's or Charlow's, in as much as this would be a dynamic theory wherein the imperative updates a feature of the discourse which can serve as an ordering source. The difficulty for Han is that she does not connect the ordering source affected, in her view, by the "modality" of imperatives, with the plan set which she uses to model their discourse effect.

The second variety of modal theory is represented by the work of Kaufmann (2012; 2005a, 2005b, 2007, as Schwager, among others). Kaufmann treats imperatives as containing a modal very similar to *should*, the main difference being that the imperative modal is associated with a set of presuppositions which ensure that it has a performative, not a descriptive, use. Therefore, Kaufmann proposes that the meaning-in-context of the imperative (35a) is the same as that of (35b) in a context in which the latter is used performatively to impose a requirement:

(35) a. Sit down right now!
b. You should sit down right now!

Since the logical properties of imperatives are largely shared by modal sentences, this approach will aim to explain those properties by extending an account of them which works for ordinary modal sentences. This type of modal theory will also have an obvious approach to conditional imperatives like (33c). It explains the variety of pragmatic functions of imperatives (orders, suggestions, advice, and so forth) as following from the different flavors of modality which the imperative modal, parallel to *should*, can have. Since the imperative modal is a strong modal, like *should*, permission readings must be derived pragmatically, and Kaufmann (2012) presents interesting ideas about permission. Kaufmann has an extensive discussion of imperative subjects, as noted above. An important challenge for her theory is to properly explain the nature of directive force, and we have seen in Section 20.2.3 some of the criticisms of her way of answering the conventionalization question and the representation question.

One significant difficulty for Kaufmann's version of the modal theory is the status of the imperative modal element itself. Note that, by and large, imperative sentences do not contain overt modals, or indeed any overt material in a projection associated with modality. When imperatives are overtly marked, it is often a particle-like element, such as Korean *-la*, which is in a paradigm with particles which mark interrogatives, declaratives, and the like – crucially, not with elements expressing classically modal concepts like epistemic modality. Of course, there are cases where imperative meaning is expressed by sentences containing material which is plausibly modal (such as an element which otherwise marks futurity); however, these are not typically deontic forms, but rather elements with irrealis or intentional meaning. (See Aikhenvald, 2010, for a detailed typological study.) Given this picture, Kaufmann is committed to the idea that dedicated imperatives, across the wide variety of languages which have them, contain a modal element which always lacks phonological content and that other languages never (at least, as far as we have discovered) encode the same universal lexical meaning with an overt element. This would be an unprecedented status for a morpheme to have; for example, as far as I know, there is no known tense or aspectual meaning whose lexical exponent can only be phonologically null.

20.3.2 The dynamic approach

We have already traced the development of the dynamic approach in our discussion of directive force in Section 20.2.3. Here we will summarize how the approach aims to explain the range of data outlined in Section 20.2, focusing on the most fully developed versions of Portner (2004, 2007a, 2011), Charlow (2010, 2011), and Starr (2010, 2012). These recent dynamic theories all share the core intuition that an imperative updates the discourse in a characteristic way which can be modeled by imposing an ordering relation on the set of worlds compatible with the common ground.

Portner (2011) aims to explain the logical properties of imperatives by developing a particular theory of permission interpretations and then using it to account for free choice effects; an explanation of Ross's paradox follows from the analysis of choice. The basic idea, already discussed in

Section 20.2.3, is that a permission reading occurs either when the speaker is directing the addressee to do something which he wants to do anyway (in a context where the speaker could prohibit the action), or when the use of the imperative results in an inconsistent To-do List. Given the ordering pragmatics of the To-do List, inconsistency leads to multiple sets of "best" worlds, and therefore choice on the part of the addressee concerning how to achieve what's best. Free choice then follows as a particular case of permission; the idea is that (36) gives permission to have an apple and permission to have a pear:

(36) Have an apple or have a pear!

Making this idea work out compositionally requires Portner to adopt a Hamblin-style analysis of disjunction and indefinites (e.g., Kratzer and Shimoyama, 2002; Menéndez-Benito, 2005; Simons, 2005; Alonso-Ovalle, 2006; Aloni, 2007) so that the disjunctive imperative expresses a pair of imperative meanings {"have an apple (and not a pear)", "have a pear (and not an apple)"}, each of which can be added to the To-do List, creating an inconsistency.

We have already seen how Portner's theory explains directive force, the various pragmatic subtypes of imperatives, and the connections to explicit modal discourse. He does not say anything about IaD, IoD, and conditional imperative constructions (although it seems open to him to adopt the proposal of Charlow). Portner develops a detailed theory of imperative subjects in collaboration with colleagues (Zanuttini et al., 2012), and the goal of explaining why imperative subjects have special grammatical and interpretive properties provides one of the main motivations for his approach to the conventionalization question.

There are two main differences between Portner's theory and Charlow's, and both have to do with the analysis of directive force. First, concerning the conventionalization question, Charlow follows the standard approach of speech act theory, assuming that the clause is marked in a way which allows its conventional force to be directly encoded; we have discussed the challenges for such a view in Section 20.2.3. Portner (2004), in contrast, aims to derive the association of sentence type with force through pragmatic reasoning based on the semantic types of different kinds of clauses.[19] I would evaluate this difference by saying that the standard approach certainly can be made to work, in that one can always define the force marker via a list of constructional patterns which we observe to have directive meaning, but it is an open question whether it can work in a way which meets the criteria of explanatory adequacy, since there is no linguistic evidence for any piece of grammatical material present across all examples of the imperative type (even with a single language). In contrast, Portner's approach has the risk

[19] As noted above, in later work Portner is less committal as to whether the form–force relation is derived in this way, or whether the dynamic meaning of an imperative is directly encoded in its semantics.

of not working at all (that is, if the clause types are not, in fact, properly classified by semantic type), but if it does work, it will have an explanatory character.

The second main difference between Portner's and Charlow's views concerns the representation question. Whereas Portner treats the imperative update in a simple way (the imperative's regular meaning is added to the addressee's To-do List), Charlow uses necessitation to constrain the update function. These differences become empirically significant in the analysis of permission and choice. Charlow treats permission as an indirect speech act and free choice as the result of a special operation at the speech act level. In these ways, his approach is more complex than Portner's and can be challenged on the grounds that permission sentences do not behave like indirect speech acts and that free choice imperatives for all appearances contain ordinary constituent disjunction or indefinites.

Besides these differences in the treatment of directive force, one should note that Charlow's work does not attempt an analysis of imperative subjects; clearly it would have to enrich the logical form and say more about the syntax–semantics interface in order to have the tools to do so.

Starr's work is similar in a general respect to Charlow's. Starr answers the conventionalization question by assuming the presence of a force marker in logical form, and his approach therefore inherits the challenge of explaining the status of this element at the syntax–semantics interface. His formal semantic framework is that of dynamic semantics, specifically an extension of inquisitive semantics (see also Aloni and Ciardelli, 2013), and he argues intently that the normal function of an imperative on the dynamic approach, namely to update a discourse ordering relation by preferring the truth of the imperative, is modeled entirely in its (dynamic) semantic value. In this respect, he differs from Portner and Charlow, according to whom this function arises from the interaction between the meaning and other factors; specifically, for Portner, the linking principle (27), and for Charlow, the principles which guide necessitation. Based on his analysis of simple imperatives, Starr then makes interesting proposals concerning the logical properties of imperatives and various complex sentences containing them.

Starr leaves as open ends a number of the puzzles we have discussed above: the functional variability seen in (29)–(30) and the relation between imperatives and priority modals illustrated in (29) and (31). Since the work is generally philosophical and logical in its concerns, like Charlow's it does not say anything about the status of the imperative subject.

20.4 Conclusions

Research on imperatives has proceeded at several levels of generality, with some important work focusing on specific phenomena (in particular, the interpretation of the imperative subject and the logical puzzles), other work seeking to develop an overarching theory of imperative semantics, and even more ambitious work aiming to understand clause type systems in general. This diversity of approaches will obviously be most healthy and productive when scholars remain attentive to the ideas coming out of other sectors of the field of imperative semantics, whether or not those ideas would tend to support or cast doubt on their own agendas. It is my hope that this chapter can serve this community of researchers interested in imperatives and clause types by making it easier to know the full range of issues, problems, and theories which are relevant to understanding what imperatives mean, and how they come to mean it.

Part V

The interfaces

21

The syntax–semantics interface

Manfred Sailer

21.1 Introduction

The basis of all considerations of the interface between syntax and semantics is that we can understand novel sentences provided we know the meaning of the words used in the sentence and that we can understand its syntactic structure. This seems rather obvious: We do not understand the text in (1) because we have no idea what some of the words could mean – though it all looks like perfect English syntax. On the other hand, if we reorder the words of an ordinary sentence in an arbitrary way, say alphabetically, we cannot understand a sentence – even if it is one that we might know very well, see (2).

(1) 'Twas brillig, and the slithy toves
Did gyre and gimble in the wabe;
All mimsy were the borogoves,
And the mome raths outgrabe.
(Jabberwocky, from L. Carroll's *Through the Looking-Glass*[1])

[1] www.gutenberg.org/ebooks/12.

(2) a able and at be brotherhood day down dream former former Georgia have hills I of of of of on one red sit slaves slave-owners sons sons table that the the to together will
(alphabetically ordered from M. L. King's speech *I Have a Dream*[2])

Frege (1892b) is usually credited with the introduction of this insight into the modern logical and semantic discussion, though versions of it have been around for many centuries and in various cultures, as briefly elaborated on in Pagin and Westerståhl (2011). This basic observation is summarized in the form of a *Principle of Compositionality* as in (3).

(3) The meaning of a complex expression is composed from the meaning of its component parts and the way in which they are combined.

Compositionality certainly describes the easiest case of when we can understand a sentence, but our everyday experience is more flexible by far: Even if we do not know the meaning of the word *cruciverbalist*, we understand sentence (4) and, in fact, infer the meaning of the word from it. We can also understand varieties of English that use slightly different syntax, even if we are not able to produce well-formed sentences of these varieties. Examples are given in (5) for "Yoda English", dialects such as Singapore English, or older varieties such as Shakespeare English.

(4) And then there's the "Get Today's Puzzles" button, a simple but indispensible tool that makes being a lunatic cruciverbalist that much easier.[3]

(5) a. Yoda-English: When nine hundred years old you reach, look as good you will not, hm.[4]
b. Singapore English: Must buy for him, otherwise he not happy. (Wee, 2008)
c. Shakespeare, *Hamlet*: Then saw you not his face?[5]

As cases like those in (4) and (5) have not influenced research on the syntax–semantics interface in an important way, I will adopt the classical view on compositionality for the rest of this article. I will also not attempt to give an encyclopedic overview of the data and theories that have played a role in the discussion of the syntax–semantics interface, as this would be a Herculean, if not a Sisyphean task. Instead, I will characterize, using basic examples, which types of phenomena are relevant for this discussion and what kinds of analytic options have been used.

To do this, I will first present a number of empirical phenomena at the syntax–semantics interface in Section 21.2. In keeping with the aim of this

[2] www.archives.gov/press/exhibits/dream-speech.pdf, 9.5.2014.
[3] www.wordnik.com/words/cruciverbalist, 15.4.2014.
[4] http://images.wikia.com/starwars/images/5/56/900YearsOld-ROTJ.ogg, 15.4.2014.
[5] www.gutenberg.org/ebooks/2265.

contribution, the selected phenomena will be quite elementary so that it is possible to characterize them without relying on many theory-dependent assumptions, and it is reasonable to expect that they will be addressed in many approaches to the syntax–semantics interface. I will use these data to characterize three prominent theoretical concepts in Sections 21.3 to 21.5: *Montague Grammar*, approaches using a level of *Logical Form*, and *Categorial Grammar*. The choice of frameworks is somewhat arbitrary, reflecting on the one hand major research trends of the last decades and on the other the personal experience and preference of the author.[6] The main concern in the presentation of the frameworks is to exemplify how mismatches at the syntax–semantics interface can be resolved in syntax, semantics, or in the mapping between the two. A syntactic solution would, for example, propose a syntactic structure that is not exclusively motivated on the basis of syntactic facts but takes semantic considerations into account. A semantic solution may consist in making particular assumptions about the model. Finally, an interface solution would impose restrictions on the mapping between syntax and semantics.

I will briefly mention some other approaches in Section 21.6 and close with a conclusion.

21.2 Interface phenomena

The task of any theory of the syntax–semantics interface is to link a syntactic and a semantic analysis. This characterization suggests that we have an idea of what the syntactic analysis and the semantic analysis should be – or that it is possible to treat a syntactic and a semantic analysis independently of one another and then connect them by some interface mechanism. While neither is necessarily the case, I consider it useful for an understanding of the interface to distinguish between syntax and semantics and to start with some neutral or default types of analysis for both. These are summarized in (6).

(6) Default assumptions for syntax and semantics:
  a. Syntax: The syntactic analysis of a sentence reflects the structure of a sentence as justifiable through constituent tests, and, usually, through further considerations of syntactic theory.
  b. Semantics: The semantic analysis of a sentence is expressed in predicate logic with generalized quantifiers.

The assumptions in (6) have emerged as a minimal standard over the past decades. Their existence can be seen in particular in the fact that they are reflected in introductory teaching material in formal grammar. We can also

[6] Partee (2014) and Partee, Chapter 1 provides a more exhaustive picture based on the historical developments in the research of the syntax–semantics interface.

observe that we typically find debates and theoretical innovations whenever a deviation from them is proposed. Finally, they can be taken as a basis for comparing different approaches by considering in which ways they depart from this standard. This means that I will not use the assumptions in (6) to exclude particular frameworks from the discussion, but rather as a baseline for the discussion. In the present section they will serve to characterize phenomena and challenges at the syntax–semantics interface.

21.2.1 Argument identification

In the basic case, there seems to be a clear correspondence between morphosyntactic and logico-semantic vocabulary: We can translate/interpret a proper noun as an individual and a verb with a subject and n complements as a predicate with $(n + 1)$ arguments. If we apply this to a simple sentence as in (7), we have the syntactic structure sketched in (7a), and the truth conditions expressed by the formula are given in (7b).

(7) a. $[_{\text{S}}$ $[_{\text{NP}}$ Alex] $[_{\text{VP}}$ $[_{\text{V}}$ helped] $[_{\text{NP}}$ Chris]]].
b. $\mathbf{help}(\mathbf{alex}, \mathbf{chris})$

The syntactic structure is very different from the semantic structure. In particular, even though we can identify a mapping between the words and their meaning and we know what the truth conditions of the overall sentence should be, we do not have any subexpression of the predicate-logical formula that corresponds to the meaning of the VP node.

The syntax–semantics interface has the additional task of ensuring that the direct object's referent is associated with the second semantic argument slot of the predicate **help**, whereas the subject referent must be associated with its first argument slot. Matters become even more intricate if we have a language with free word order.

Further problems of argument identification arise when the semantic arity of a predicate does not correspond to its syntactic valence. The verb in (8a) needs an overt subject in English, but semantically there is no participant of an event of "raining". Similarly, the verb *seem* in (8b) is a *raising verb*. At the surface it has a subject, but this subject is not a semantic argument of the predicate **seem** but rather only a semantic argument of **win**.

(8) a. Expletives: It rained. $\mathbf{rain}$
b. Raising predicates: Alex seemed to win. $\mathbf{seem}(\mathbf{win}(\mathbf{alex}))$

Finally, argument identification must be guaranteed in all possible argument realization constructions in which a verb can occur. This can be illustrated in (9) with a passive version of example (7).

(9) Chris was helped by Alex.

21.2.2 Quantifiers

In our first example in (7), the syntactic dependents of the verb translated into semantic arguments of the verb's translation. This is not always the case. If the dependents are quantificational, as in (10), the verb's translation is rather acting as an argument of the subject's translations. So we could assume that *everyone* translates into a higher-order predicate $\mathbf{Forall}$ which takes one-place predicates such as $\mathbf{snore}$ as its arguments. This is sketched in (10a).

(10) Everyone snored.
  a. $\mathbf{Forall}(\mathbf{snore})$
  b. $\forall x[\mathbf{person}(x) \rightarrow \mathbf{snore}(x)]$

In a more standard predicate-logical representation, as in (10b), the semantic contribution of the subject is even dispersed within the overall representation: that is, if we assume that the verb contributes the predicate $\mathbf{snore}$, all the rest must come from the subject. However, some part of this is taken as an argument to $\mathbf{snore}$, and, at the same time, the formula $\mathbf{snore}(x)$ is in the scope of the quantifier $\forall$.

21.2.3 Ambiguity

A number of different types of ambiguity exist. In some cases the syntactic ambiguity goes hand in hand with a semantic ambiguity. Classical examples involve coordination, as in (11a), and ambiguity in the attachment of adjuncts, as in (11b).

(11) a. good wine and cheese
    (i) Structure 1: [[good wine] and cheese]
    (ii) Structure 2: [good [wine and cheese]]
  b. I saw the man with a telescope.
    (i) Structure 1: I saw [the man [with a telescope]]
    (ii) Structure 2: I saw [the man] [with a telescope]

The two structures in (11a) differ as to whether the adjective *good* adjoins to the noun *wine* or to the coordination *wine and cheese*. The syntactic ambiguity in adjunction corresponds to a semantic ambiguity as to which element is semantically modified. Similarly the structures in (11b) encode different attachment positions for the PP *with a telescope*. The PP can either be an adjunct inside the NP headed by *man* or be a modifier of the verb *saw*. The two structures correlate with a reading in which the man has a telescope and one in which a telescope is used to see the man.

In these cases there is evidence for distinct syntactic structures, using constituent tests. The pronominalization and *it*-cleft formation in (12) show that *the man with a telescope* can be treated as a constituent. Similarly, the sentences in (13) show that *the man* forms a constituent on its own, excluding *with a telescope*. The versions with the *it*-cleft lose the ambiguity of the original example.

(12) a. I saw him.
b. It is [the man with a telescope] that I saw *e*.

(13) a. I saw him with a telescope.
b. It is [the man] that I saw with a telescope.

In (11) syntactic ambiguity corresponds to a semantic ambiguity. There are also cases of syntactic ambiguity where no difference in reading emerges. One constellation of this type is the coordination with more than two conjuncts as in (14).[7]

(14) I talked to [Alex and Chris and Kim].

Two syntactic analyses can be justified for this sentence: [Alex and [Chris and Kim]], [[Alex and Chris] and Kim]. Clearly the two analyses do not correspond to distinct truth conditions.

Cases where a structural ambiguity corresponds to clearly truth-conditionally distinct readings are used as arguments for a hierarchical organization of syntax, and as a motivation for considering syntactic structure as important for the relation between form and meaning, not just the words that occur in a sentence. However, it is possible to construct syntactically parallel examples that are also semantically ambiguous. This is the case if distinct coordinating particles are used, such as *and* and *or*. Such an example is given in (15).

(15) I talked to Alex and Chris or Kim.
a. Structure 1: I talked to [[Alex and Chris] or Kim].
b. Structure 2: I talked to [Alex and [Chris or Kim]].

In this chapter we will primarily be concerned with a type of ambiguity that presents a challenge at the syntax–semantics interface, *scope ambiguity*. Sentence (16) has two readings, given in the paraphrases. Contrary to the situation in the previous examples in this subsection, there are no constituent tests that would clearly justify distinct syntactic structures corresponding to these two readings, that is, there is no obvious empirical evidence for a structural ambiguity of the example, even though there clearly are distinct truth conditions.[8]

(16) Most linguists speak two languages. (Pinkal, 1995)
a. Reading 1: For most linguists *x*, it is true that there are two languages such that *x* speaks them.
b. Reading 2: There are two languages (say English and Latin) such that most linguists speak these two languages.

[7] I am grateful to a reviewer for mentioning this case.
[8] This case is also discussed with a more exhaustive overview of various analytic options in Partee, Chapter 1.

21.2.4 Discontinuity

When we compare a sentence and its truth conditions or its paraphrase, we sometimes find that what might intuitively be seen as the meaning of a single word is split over the paraphrase of other words. For example, the intuitive meaning of the determiner *no* contains both a negation and an existential quantifier, that is, it is paraphrasable as "it is not the case that there exists", or representable in logic as $\neg\exists x\phi$. In (17) we provide a sentence in whose most natural reading the meaning of the modal auxiliary *need* (given as "it is necessary that...") intervenes between the two parts of the meaning of *no*.

(17) Alex need wear no tie.
It is not the case that it is necessary that there is a tie *T* such that Alex wear *T*.

In this case we say that the determiner *no* makes a *discontinuous* semantic contribution. This terminology might not be completely standard, as discontinuity is often taken as a syntactic notion, that is, where words that belong to one constituent do not occur as a continuous string. A reviewer suggested speaking of *decomposition* instead, as the existence of readings with intervening logical material is a strong argument for decomposing the semantic contribution of *no* into a negation and an existential quantifier rather than assuming that it is a single quantifier, **no**. With this clarification in mind, I will continue using the term *discontinuity*.

Sentences with modals and the negative determiner *no* readily give rise to discontinuous interpretations. A reviewer provided the following additional examples.

(18) a. He could do nothing.
Discontinuous reading: It is not the case that it was possible for him to do anything.
b. He could answer none of her questions.
Discontinuous reading: It is not the case that he was able to answer any of her questions.

There are also cases of discontinuity with *no* and an intensional verb like *look for*, as illustrated in (19).

(19) they will come to learn and accept this style as the only possibility and look for no greater interpretation.
Discontinuous paraphrase ... and it is not the case that they look for greater interpretation.
(from the *Corpus of Contemporary American English*: Davies, 2008)

While there might be semantic analyses for this particular example that avoid a discontinuous analysis,[9] we will pursue it further in this chapter, assuming that there will be other analogous cases of the problem of semantic discontinuity.

One type of cases of discontinuity involves the interpretation of *how many* questions, as discussed in Fox (1999), and questions with *was für* ('what for') in German (Beck, 1996). Beck provides the example in (20) with the indicated paraphrases. In this case the semantic contribution of the NP *was für ein Papier* ('what for a paper') is interrupted by a modal operator in the discontinuous reading.

(20) Was für ein Papier muss Susanne abgeben?
what for a paper must Susanne hand-in
(Beck, 1996, p. 47, spelling adapted)
a. Continuous reading: For which property: there is a paper that Susanne has to hand in and that has that property.
b. Discontinuous reading: For which property: Susanne has to hand in a paper that has that property.

In what follows, I will primarily use the examples with the determiner *no* in the discussion of discontinuity.

21.2.5 Concord and cross-linguistic variation

A further widespread phenomenon in natural language is *negative concord*. It comes in a variety of different subcases, but they all share the following property: a negated sentence may contain more than one expression each of which may express negation. In (21) these are the two so-called *n*-words *nikt* ('nothing') and *nikomu* ('nobody') and the preverbal negative marker *ne*.

(21) Nikt ne pomaga nikomu. (Polish)
nobody not helped nobody
'Nobody helped anybody.'

The inherent negativity of the *n*-words and the preverbal negative marker can be shown when they appear as the only overt marker of negation: In (22a) the short answer contains only an *n*-word, in (22b) only the verb is negated.[10]

(22) a. Kto pomaga ojcu? Nikt.
Who helped father? Nobody
'Who helped the father? Nobody.'

[9] One example being Abels and Martí (2010). They assume a choice-function analysis that can roughly be paraphrased as in (i).

(i) There is no choice function f such that for all (obligatory) worlds w', you pick a tie ($f(\mathtt{tie}_{w'})$) and wear it.

[10] See Richter and Sailer (2004), from which the data are taken, for a more elaborated presentation of this reasoning.

b. Janek ne pomaga ojcu.
Janek not helped father
'Janek didn't help the father.'

So, if we assume that the *n*-words and the preverbal marker contribute a negation to the semantics, we would expect that each of these negations has an influence on the overall interpretation. However, a Polish sentence expresses only one negation, independently of whether there is more than one n-word in it. This is an immediate problem for a syntax–semantics interface that assumes a version of compositionality as specified above.

Languages show an impressive amount of variation when it comes to expressing semantic operators.[11] Looking at negation and tense, it is very common in languages to mark the operators once or several times. We saw multiple marking in the case of Polish negation in (21). In standard French, a sentence with two *n*-words can have a single-negation reading or a double-negation reading; see (23a). In standard English, only a double-negation reading is possible; see (23b).

(23) a. Personne (n')a rien dit.
nobody has nothing said
'Nobody said anything.' or 'Nobody said nothing.'
b. Nobody said nothing.

The study of cross-linguistic variation is important because it allows us to see which mechanisms theories use to capture the differences in the interpretation of sentences that look so similar. In some theories, these differences will be treated by assuming distinct syntactic structures for the various languages; other theories may analyze this variation as a difference in the mapping between syntax and semantics.

21.2.6 Summary

In this section I presented a small set of phenomena at the syntax–semantics interface. The phenomena have the advantage that we could assign the relevant sentences a relatively simple surface syntactic structure and a relatively simple semantics. I argued that it is, nonetheless, not a trivial task to connect syntax and semantics in these cases.

- Argument identification: The number of syntactic arguments of a head need not be the same as the number of semantic arguments of the corresponding predicate. Furthermore, argument identification must be possible in all argument realization constructions in which a head can occur.
- Quantifiers: Syntactically, quantifiers may occur as dependents of verbs, but semantically they act as operators that take scope over a proposition.

[11] See Grønn and von Stechow, Chapter 11 on tense and de Swart, Chapter 16 on negation.

- (Scope) ambiguity: Some sentences may be associated with various readings even though there is no empirical evidence for a structural ambiguity.
- Discontinuity: Sentences may have a reading in which it seems that the semantic contribution of a word or a constituent is interrupted by an intermediate element.
- Concord and cross-linguistic variation: More than one word in a sentence seems to express the same semantic operator, but the operator is interpreted only once. The interpretation of such sentences with multiple exponents of a semantic operator may differ across languages.

In the next three sections we will look at three frameworks and their respective approaches to the above-mentioned phenomena. We will focus on the question of whether they propose an analysis that is syntactic, semantic, or interface-based. A syntactic solution would deviate from the default assumptions on syntax as formulated in (6a), that is, a syntactic structure would be assumed that is not exclusively motivated on the basis of syntactic arguments. A semantic solution, on the other hand, would deviate from (6b). As such it may consist in making particular assumptions about the model. Finally, an interface solution would impose restrictions on the mapping between syntax and semantics.

Rather than trying to evaluate the individual proposals, I will focus on the nature of the proposals and, where possible, the motivation for one or the other solution. This motivation turns out to be sometimes empirical, sometimes based on theoretical decisions about the architecture of grammar.

21.3 Montague Grammar

The single most influential paper in the area of the syntax–semantics interface is certainly Richard Montague's *The Proper Treatment of Quantification in Ordinary English*, PTQ for short (Montague, 1973b).[12] Montague's main concern, according to Partee (2013), was the development of a semantic theory that is fine-grained enough to capture the distinctions and phenomena attested in the interpretation of natural language, primarily intensionality and its interaction with quantification. This was his *Intensional Logic* (IL). In doing this, he developed a fully formalized mapping from syntax to denotation, which will be the focus of the present summary of his work.

Montague (1973b) pursues a strictly compositional relation between the syntactic derivation and its semantic interpretation: Every syntactic category is associated with a fixed semantic type. So any common noun (category: CN, which is short for $t//e$) has a denotation of the type $\langle\langle s, e\rangle, t\rangle$.

[12] See also the discussion of Montague's approach in Partee, Chapter 1 and Pagin, Chapter 3. The reader is referred to Partee's (1997b) handbook article for a detailed discussion of many aspects of Montague's publication and later developments in Montague Grammar.

Full NPs, be they proper nouns, personal pronouns or quantified NPs, are of the syntactic category T (short for $t/(t/e)$), and their denotations are of type $\langle\langle s, \langle\langle s, e\rangle, t\rangle\rangle, t\rangle$. Montague, then, defines syntactic rules and provides an interpretation rule for each of these syntactic rules. So, if we know the words of a sentence and the syntactic derivation, we can compute the denotation of the sentence fully compositionally.

There are considerable differences within Montague's publications, reproduced in Montague (1974), and between Montague's original work and further analyses proposed in the framework of Montague Grammar (MG). As I primarily want to illustrate the types of mechanisms that Montague uses to deal with phenomena at the syntax–semantics interface, I will stick to the system of PTQ.

In PTQ, Montague glosses over some quirks of English. For example, he treats *try to* as one lexical item, which spares him an analysis of the infinitival marker *to*. Syntactic rules can also add material or change phonological material. To give just one example, there is a syntactic rule that combines a subject noun phrase with a verb phrase and replaces the form of the verb with its third person singular negative form. This rule turns *sleep* into *doesn't sleep* (Montague's rule S17, function F_{11}). Montague proceeds analogously in the semantic translation: The output of S17 is interpreted by the translation rule T17. T17 has the effect of semantically negating the result of the (intensional) functional application of the translation of the subject to the translation of the VP. So, negation is introduced in the translation in addition to functional application.[13]

It is a relevant architectural feature of Montague (1973b) that expressions of IL are used merely for illustration but do not have a theoretical status beyond this. Montague assumes that the syntactic units can be interpreted directly. As a consequence of this, we will not find in PTQ any constraints on the structure of a particular IL expression. However, as we will see, constraints can be formulated that restrict the available semantic models.

Let us now go through the checklist of phenomena from Section 21.2.

21.3.1 Argument identification

The syntactic category of a verb indicates how many arguments it takes. By the homomorphism between syntactic category and semantic type, this directly reflects the number of semantic arguments. The order of the semantic arguments is, then, determined by syntax. There is no treatment of expletives, nor is there any mention of valence alternation processes such as passive. I will leave expletives aside, but I will briefly turn to passive.

Partee (1973b) and Dowty (1978) propose extensions of PTQ that contain analyses of passive and other valence alternation processes. Partee (1973b,

[13] As pointed out by a reviewer, Montague uses this mechanism to guarantee that there is at most one sentential negation in an English clause. He uses a different method to achieve this in *English as a Formal Language* (Montague, 1970a).

p. 524) proposes an analysis in which a syntactic rule maps an active sentence onto its corresponding passive sentence, while leaving the meaning unchanged. This solution captures the identity of meaning in an active–passive pair; however, it places a considerable burden on the rule that expresses the necessary mapping with all its morpho-syntactic adaptations. Dowty (1978) proposes more local analyses: He assumes that English has a syntactic (verbal) and a lexical (adjectival) passive. For the syntactic passive, the passive participle morpheme *-en* (or the agentive preposition *by*, if present) combines with a transitive verb to yield an intransitive one. For the lexical passive, he assumes a rule that changes a transitive verb into an adjective and adjusts the verb's semantic arguments. In both cases, a VP that contains a verbal or adjectival passive combines with the subject in an ordinary way. Both Partee's and Dowty's analyses deal with passives at the level of the syntax. In Partee's case, passive is a clause-level phenomenon, in Dowty's it is a VP-level or a word-level phenomenon, depending on the type of passive.

21.3.2 Quantifiers

The solution to the problem of quantifiers in PTQ is at the same time groundbreaking and illustrative for the combination of syntactic and semantic tools that Montague applied to model the interface. We will look at Example (24a), for which Montague provides two possible derivations.

Let us start with the simpler derivation. Montague assigns a meaning to verbs that allows them to take (the intension of) quantifiers as their semantic arguments directly. In other words, the translation of sentence (24a) is (24b).[14]

(24) a. Pat read a book.
b. $\mathbf{read}(\mathbf{pat}, {}^\wedge\lambda P.\exists x[\mathbf{book}(x) \land P(x)])$

The translation in (24b) reflects a *de dicto* reading, that is, a reading which does not imply the existence of a read book. While such a reading is required for intensional verbs like *seek*, it is not what we need for an extensional verb like *read*. According to Montague, such a translation is fine at the syntax–semantics interface, but any model of English is such that whenever a reading occurs, an object that is being read exists, as well. This is achieved by a *meaning postulate*. So, in any model of English in which (24b) is true, so is the formula in (25).

(25) $\exists x[\mathbf{book}(x) \land \mathbf{read}(\mathbf{pat}, {}^\wedge\lambda P.P(x))]$

A meaning postulate is a constraint on possible models of English. As such, it is a purely semantic constraint which, however, interacts in an interesting

[14] The intensionality operator "ˆ" (hat) is used in this section, though not in the rest of the presentation of PTQ.

way with grammar: There is no surface difference between a sentence with an intensional verb and a sentence with an extensional verb. Consequently, there is no difference in their syntactic category or in the derivation of sentences containing such verbs. The difference between the two types of verbs is located in their model-theoretic interpretation.[15]

As mentioned at the beginning of this section, there is a second derivation. We can derive the reading in (25) directly in the following way: An indexed pronoun, he_n – which translates into $\lambda P.P(x_n)$ – , is inserted instead of a quantified NP. This pronoun combines with the verb *read*, and the resulting expression combines with the subject. For example, the sentence *Pat read* him_{12} is translated as $\mathbf{read}(\mathbf{pat}, \lambda P.P(x_{12}))$.

The quantifier is then added at the level of the clause by PTQ's rule S14. The effect of the rule is the following:

- a quantified NP combines with a clause,
  (In our example, *a book* and *Pat read* him_{12} combine.)
- the first occurrence of he_n or him_n in the clause is replaced by the quantified NP,
  (We get the sequence *Pat read a book.*)
- all other occurrences of he_n are replaced by the appropriate form of the personal pronoun regarding case and gender.
  (This does not have an effect in our example.)

The corresponding semantic rule (T14) leads to the following: If α is the translation of the quantified NP and β that of the clause, then $\alpha(\lambda x_n.\beta)$ is the translation of the combination. For our example sentence, we get the following result:

(26) a. *a book*: $\lambda Q.\exists x[\mathbf{book}(x) \wedge Q(x)]$
b. *Pat read* him_{12}: $\mathbf{read}(\mathbf{pat}, {}^\wedge\lambda P.P(x_{12}))$
c. combination:
$\lambda Q.\exists x[\mathbf{book}(x) \wedge Q(x)](\lambda x_{12}.\mathbf{read}(\mathbf{pat}, {}^\wedge\lambda P.P(x_{12})))$
$= \exists x[\mathbf{book}(x) \wedge \mathbf{read}(\mathbf{pat}, {}^\wedge\lambda P.P(x))]$

This derivation shows the power of the syntactic rules used in PTQ, which can make context-sensitive adjustments in the string of words. It can also be seen from the derivation that the point in the derivation at which the quantified NP is introduced determines its scope.

We have seen two different derivations for the same surface string. Each of them specifies a way in which the meaning is combinatorically computed, though – as we saw in the difference between intensional and extensional verbs – the two ways need not lead to truth-conditionally distinct readings.

It should also be noted that Montague's analysis relies on the assumption that nominal complements are all of the semantic type of a generalized

[15] Zimmermann (1999a) gives a good overview of possible constraints on the power of meaning postulates and a criticism of using model theory to avoid unavailable readings.

quantifier. This means that the model-theoretic objects that correspond, for example, to transitive verbs are considerably complex. This complication at the semantic side allows Montague to keep the syntactic categories of verbs and noun phrases uniform.

21.3.3 Scope ambiguity

The example in (24a) illustrated the way in which ambiguity is treated in Montague Grammar. If we use an intensional verb, such as *seek*, instead of the extensional *read*, the two possible derivations for the corresponding sentence would, in fact, lead to two distinct readings. This is illustrated in (27). For each reading we show the derivation in (i) and the resulting reading in (ii). Whereas the quantified NP combines directly with the verb in (27a-i) to get the *de dicto* reading, we use a pronoun first in (27b-i) to derive the *de re* reading.

(27) Pat sought a book.

a. *de dicto* reading:

(i)
- Pat sought a book
  - Pat
  - sought a book
    - sought
    - a book
      - a
      - book

(ii) $\mathbf{seek}(\mathbf{pat}, {}^\wedge\lambda P.\exists x[\mathbf{book}(x) \wedge P(x)])$

b. *de re* reading:

(i)
- Pat sought a book
  - a book
    - a
    - book
  - Pat sought him_1
    - Pat
    - sought him_1
      - sought
      - he_1

(ii) $\exists x[\mathbf{book}(x) \wedge \mathbf{seek}(\mathbf{pat}, {}^\wedge\lambda P.P(x))]$

Similarly in the case of two quantifiers, as in (16), the order in which the quantified NPs enter the derivation will determine their relative scope.

Montague's treatment of quantifiers captures the double nature of a quantified noun phrase in a particularly transparent way by means of its interaction between the use of a pronoun and the use of a quantifier. This is an elegant way to distinguish between the local contribution and the scopal contribution of a quantifier.

21.3.4 Discontinuity

There is no case of discontinuity discussed in Montague's work or in subsequent work within MG. For this reason, the present section and Section 21.3.5 are necessarily oversimplified and speculative.

In the case of the example in (17), we could use the ability of syntactic rules to change phonological form. So we would derive the sentence as a combination of the subject expression *Pat* with the VP expression *need wear a tie*. In the combination, just as usual with sentential negation, the negation is introduced syncategorematically. The negation can have two distinct effects on the phonology: One option would be that we simply turn *need* into its negated form, *need not*, and leave the rest unchanged. Alternatively, the rule is more complex and, leaving the verb form unchanged, turns the first quantifier of the form *a N* into *no N* and the others into *any N* or leaving them unchanged.

21.3.5 Concord and cross-linguistic variation

The brief sketch of an analysis of sentence (17) above already indicates which part of a Montague Grammar might be used to model negative concord and cross-linguistic variation: neither the derivation steps nor the interpretation, but rather the functions that determine the surface phonological form. This kind of approach is fully in line with earlier proposals in Generative Grammar, such as the one in Klima (1964), which derive the variation between the English determiners *some*, *any*, and *no* from context-sensitive mappings. More recently, Hoeksema (2000) argued that a theory that relies on such context-sensitive changes in the phonological form, though not very popular nowadays, might be reasonable for expressions that form a negation-sensitive paradigm, with *no* indicating that it is the first element in the scope of negation in a clause, *any* indicating that it is in the scope of negation, though not the first element, and, finally, *some* marking absence of negation.

This type of analysis can also account for cross-linguistic variation in a natural way: For a language like Polish, the mapping to the form that corresponds to English *no* would not be restricted to the first indefinite in the scope of a negation. An optional concord language like French would have both an English-type and a Polish-type rule.

21.3.6 Summary

Montague presented a precise formal system that generates the right surface strings and associates them with the available readings. There are three points in the system that allow for manipulation and to address apparent mismatches of the syntax–semantic mapping. First, the syntactic rules allowed for relatively powerful rewriting of the resulting string. We saw this at work in cases when a quantified NP is introduced into a sentence. We also alluded to this analytic option in the cases of discontinuous semantic contribution and concord and cross-linguistic variation. Second, the translation rules can take various forms, but are restricted by the compositionality requirement that the translation of the resulting combination be a function of the translations of its components. In many cases, the translation rule specifies intensional functional application of the translations of the components, but it can also be used to adapt type mismatches or to introduce semantic operators syncategorematically. Third, there are restrictions on the possible models of English that are expressed by meaning postulates. Montague's decision that all transitive verbs take a direct object of the type of a generalized quantifier was motivated semantically, by the existence of intensional verbs. As we saw, he put additional requirements on the models, rather than on syntax or on the interface, to eliminate *de dicto* readings for extensional verbs.

21.4 Logical Form

In this section we will characterize an approach to the syntax–semantics interface that assumes a syntactic level of *Logical Form* (LF). In particular, we will use the version of this theory that is referred to as *Transparent Logical Form* and presented in von Stechow (1993), but also in Heim and Kratzer (1998).[16]

In an LF approach, syntax is seen as a set of syntactic representations, starting from D-structure, which is mapped to S-structure and then to *Phonological Form* (PF) and to LF at the same time. Each of these representations is a syntactic tree. The PF tree is special in that it is the input to the phonological interpretation. Similarly, the LF tree is the structure that will receive a model-theoretic interpretation. Following von Stechow (1993), we will assume that an LF of a sentence can be interpreted directly by a relatively simple compositionality assumption: The interpretation of lexical elements is given in the lexicon, the interpretation of phrasal nodes is the result of the combination of the interpretation of its immediate daughters, where this combination is usually functional application, but a small number of other operations are allowed, too.

On the semantic side, it is common to assume a version of Montague's *Intensional Logic*, such as the one developed in Gallin (1975). Words are typically interpreted as complex functions, which are stated as lambda terms – though, strictly speaking it is assumed that the syntactic tree is

[16] The reader should be reminded that this chapter does not intend to provide a historical overview of the developments but rather to pick out particular theories and to use them to illustrate how challenges at the syntax–semantics interface can be addressed. For the historical perspective, the reader is referred to Partee (2014) and Partee, Chapter 1.

interpreted directly and that the lambda expressions are just there for ease of readability.[17]

This view of the syntax–semantics interface provides us with an explicit interface level and the theoretical assumption that it can be derived from the S-structure of a sentence. Ideally this comes with the strong claim that the operations needed to map from S-structure to LF are similar in a non-trivial way to the operations needed to get from D-structure to S-structure. A sentence or a particular reading of a sentence can be shown to be unavailable at any of the following levels: A genuine syntactic representation (D- and S-structure) can be ill-formed, the interface level of LF may violate a syntactic constraint, or the LF representation cannot be interpreted, for example due to a type-clash among the interpretation of sub-constituents.

21.4.1 Argument identification

Argument identification is an important issue within LF-based theories. Von Stechow (1991b), following the architecture outlined in Chomsky (1981), assumes that every word comes with a grid that specifies its semantic roles, the Θ-grid. If, for example, a verb occurs with too few arguments, as in (28b), or with too many arguments, as in (28c), the corresponding string of words is excluded because the verb's semantic roles could not be exhaustively distributed over subject and complements.

(28) a. Alex devoured a steak.
b. *Alex devoured.
c. *Alex devoured Pat a steak.

In a less syntax-based variant of this framework, including Heim and Kratzer (1998), the pattern in (28) might be derived from the fact that the verb *devoured* is interpreted as a two-place predicate and, consequently, a sentence with just one or more than two elements can never receive an interpretation. We would, then, be in a situation where a (well-formed) LF cannot be interpreted due to a type-clash.

The syntactic side of argument-alternation is typically handled by syntactic movement in Chomskyan analyses. For example, in a passive clause, the subject originated in the structural position of the direct object. It is then moved toward the subject position. According to von Stechow (1991b, 1993), a trace leaves a variable, say y_i, in the semantics. The variable can be either of the same type as the moved constituent or of a lower type. The moved constituent (YP) combines with a constituent XP that contains the trace. In

[17] Whether or not a semantic representation language has a theoretically important status is a matter of debate. May (1991) calls such a representation a (lower-case) *logical form* in contrast to LF. The LF approach in Heim and Kratzer (1998) clearly rejects such an additional level, but others, such as Kamp (1981b), argue in favor of it. For the present discussion, not assuming a *logical form* reduces the analytic options and simplifies the presentation of the LF architecture. For this reason, I will side with Heim and Kratzer (1998) for the discussion of the LF approaches.

this combination, the translation of YP, YP′, and the term $\lambda y_i.\mathrm{XP}'$ are combined by functional application. It depends on the semantic type of y_i which one of the two will be the functor, and which the argument (von Stechow, 1991b, p. 133).

In a passive sentence with a proper noun as subject, the trace and the moved constituent are usually of the same semantic type, and $\lambda y_i.\mathrm{XP}'$ will be the functor. If the moved constituent is a quantifier or a *wh*-expression, the trace can also be taken to be of the type of the variable that is bound by the moved operator. In this case, we will have $\mathrm{YP}'(\lambda y_i.\mathrm{XP}')$ as the interpretation of the combination.

21.4.2 Quantifiers

The sketched treatment of valence alternation does not necessitate the assumption of a level of LF as it only relates D- and S-structural positions. Quantifiers and their scope potential can be seen as a key motivation for the assumption of LF. A quantified NP is moved syntactically from its S-structure position and adjoined to the node that defines its scope position, usually the next dominating S node. This movement is called *Quantifier Raising* (QR). The interpretive effect of QR is just as described for passive: The trace is interpreted as a variable. When the moved quantifier appears as the sister of the S node containing the trace, there is a lambda abstraction over this variable, and the quantifier is applied to this predicate.

QR is very similar to the quantifier analysis in PTQ, illustrated in Section 21.3, because the surface position of a quantifier is interpreted as a variable and the quantificational meaning enters the derivation at the position where the quantifier's scope is determined. There are, however, a number of important differences. First, if one assumes that all quantifiers need to undergo QR, as von Stechow (1991b) does, the *de dicto* readings of subjects and objects of intensional verbs require a rather complex syntactic structure.[18] Von Stechow (1991b) illustrates this with the *de dicto* reading of *A unicorn seems to be approaching*. There, the raised NP, *a unicorn* leaves a trace of the quantifier type, $\langle\langle e,t\rangle,t\rangle$. When the raised subject combines with the matrix VP, it will take scope within the embedded infinitival clause. This semantic analysis requires a sentential analysis of the complement of *seem*, which is, of course, exactly the syntactic analysis in Chomsky (1981) and usually favored within Generative Grammar.

It is, however, unclear how Montague-style *de re*/*de dicto* readings of direct objects of intensional verbs such as *seek* can be derived.[19] If we assume that

[18] A reviewer pointed out that quantified NPs might not need to undergo QR if they occur in an argument position of an intensional verb.

[19] As in the previous paragraph, this reasoning depends on the assumption, not necessarily shared among all LF-theoreticians, that all quantified NPs need to undergo QR.

seek is translated as $\lambda\mathcal{Q}\lambda x.\mathbf{seek}(x, \mathcal{Q})$, with $\mathcal{Q}$ of the type $\langle\langle e, t\rangle, t\rangle$ of a quantifier, then the trace cannot be of a lower type than $\mathcal{Q}$. Consequently, we would only derive the *de dicto* reading. Alternatively, if the verb is translated with a lower type for its direct object, we only get the *de re* reading. Within this framework, it is not desirable to assume two distinct translations for the verb *seek*. A way out is to assume that the verb *seek* is inserted into a complex tree that corresponds to the decomposed meaning *try* [$_S$ PRO *to find* NP]. A quantifier in the direct object position of *seek* would, then, undergo QR to the embedded infinitival S node for the *de dicto* reading and to a higher S node for the *de re* reading. Den Dikken et al. (1996) provide syntactic arguments to support such an analysis.[20] This illustrates how the LF approach typically encodes in syntax what Montague put into semantics. It also shows that if abstract syntactic structure is postulated, attempts are being made to justify this additional structure.

Let us turn to the second difference between an LF approach and MG. With QR being a syntactic movement, we expect it to satisfy the usual constraints on movement and we expect that there can be syntactic constraints on it. Such an expectation is very natural within an LF theory and, in fact, a key motivation for this type of approach. It is less obvious why there should be a strong parallelism between syntactic movement and quantifier scope in a Montagovian framework, even though the constraints under discussion can be included. Let us briefly look at two such constraints: First, if a quantifier is overtly topicalized, it cannot take scope higher than in its surface position. So the indefinite NP *a new secretary* can have both a *de dicto* and a *de re* reading in (29a), but only a *de dicto* reading in (29b). Since Montague's system does not distinguish between the semantic type of quantifiers and pronouns, a *de re* reading would be derivable for the second sentence as well. In an LF approach, we can say that there is no QR from a topicalized position. This, then, immediately fixes the scope possibilities of the direct object NP.[21]

(29) a. I believe that they hired a new secretary last week.
b. I believe that it is a new secretary they hired last week.

A second constraint is that it is often said that QR is clause-bound. With this assumption, a bound reading for the possessive pronoun in the matrix clause can be excluded in (30).

(30) * [That Mary seems to know every$_i$ boy] surprised his$_i$ mother. (Barker, 2012, p. 624)

[20] I am grateful to an anonymous reviewer for this reference.

[21] A reviewer suggested the option of treating *a new secretary* as a predicative NP in (29b). As predicative phrases are generally not scope-taking, we would not expect a *de re* reading in this case. However, I do not think that the fronted NP must be analyzed as a predicative constituent in this example. An important argument here is that we find proper names as clefted constituents in *it*-clefts (*It was Alex who helped me*).

21.4.3 Ambiguity

All analyses of scope ambiguity as in (16) formulated within the LF approach are based on QR. There are, however, two distinct types of proposals. First, May (1977) – and most of the current research – assumes that each scope possibility is reflected by a distinct LF. Second, May (1985) assumes a single LF representation that captures both readings. These two approaches differ in exactly what type of approach is chosen, a syntax-based one or an interface-based one.

If we follow May (1977), we have the following two LFs, each of which represents one scope possibility. These LFs can be interpreted straightforwardly. However, the movement paths in (31a) cross. Such a crossing is not allowed in genuine syntactic movement. This means that this type of analysis is willing to allow for special movement operations to build LF (or different constraints on movement operations to LF). By this, it keeps the mapping from LF to a model-theoretic interpretation as simple as possible.

(31) Most linguists speak at least two languages.
  a. **most** > **at-least-2**:
    [$_S$ [Most linguists]$_x$ [$_S$ [at least two languages]$_y$ [$_S$ t_x speak t_y]]]
  b. **at-least-2** > **most**:
    [$_S$ [at least two languages]$_y$ [$_S$ [most linguists]$_x$ [$_S$ t_x speak t_y]]]

In contrast to this, May (1985) emphasized the idea that movement to LF should be parallel to movement to S-structure. For this reason, he assumes a single LF for both readings, the one in (31b). Consequently, he can no longer use an equally simple model-theoretic interpretation for the resulting structure. Instead, May, following Higginbotham and May (1981), assumes that the two quantifiers can undergo a further LF operation, *absorption*, which leads to a structure like the one in (32).[22]

(32) [$_S$ [at least two y, most x: [$_{\bar{N}}$languages](y) & [$_{\bar{N}}$ linguists](x)]
    [$_S$ t_x speak t_y]]

It is important that the two quantifiers, *at least two languages* and *most linguists*, now form one constituent. This constituent is, then, interpreted as a polyadic quantifier, that is, as a quantifier that binds more than one variable. In the present case, there are two possible polyadic interpretations: We can choose a polyadic quantifier that is equivalent to interpreting *at least two* first and then *most*, or one that is equivalent to the other order of the participating monadic quantifiers.

This approach simplifies the syntactic structure, but it complicates both the mapping from syntax to semantics (by introducing the absorption operation and a mapping to two different polyadic quantifiers) and the semantics

[22] The structure in (32) combines syntactic structure and a semantic representation in an improper way. Unfortunately, Higginbotham and May (1981) or subsequent papers such as May (1985, 1989) are not more explicit about the exact formulation of the mapping from (31b) to (32).

(by requiring polyadic quantifiers, whereas the structures in (31) can be interpreted using just monadic quantifiers). However, May provides further motivation for his position. First, so-called *Bach-Peters sentences* as in (33) show that any of the two restrictors may contain a variable bound by any of the two quantifiers. Simpler assumptions on the interpretation of LFs would not be able to derive a reading in which both pronouns, it_j and him_i are bound.

(33) [Every$_x$ pilot who shot at it$_y$] hit[a$_y$ Mig that chased him$_x$]
[[every x, some y: [pilot who shot at it$_y$](x) & [Mig that chased him$_x$](y)]
[t_x hit t_y]]

The second argument relies on *resumptive* interpretations. Sentences with several identical determiners can have a reading in which this determiner is interpreted only once but as binding more than one variable. The following examples are from May (1989).

(34) a. Nobody loves nobody.
b. Exactly one person loves exactly one person.
c. Two detectives solved two crimes.

May argues that the sentences in (34) have (among others) a reading in which the determiners *no*, *exactly one*, and *two* quantify directly over pairs of individuals. This means that there is no pair of people $\langle x, y\rangle$ such that x loves y for (34a), and analogously for the other examples. Again, these resumptive readings would not be derivable under the simpler assumptions of interpreting LF as made in May (1977).

This discussion again illustrates different strategies for solving mismatches at the syntax–semantics interface: In May (1977) and much of the literature on quantifier ambiguity, it is assumed that QR allows for crossing movement paths, but the interpretation of the resulting LFs is taken to be rather simple. In May (1985) the movement constraints on QR are just as on other movement operations. However, the complication lies in the mapping to semantics and in the kind of semantic objects that are used in the analysis. This is motivated by further data that cannot easily be captured under the interface assumptions in May (1977).

I would like to address yet another case where QR may be subject to constraints that are alien to genuinely syntactic movement. May and Bale (2005) describe the theoretical development of the accounts of *inverse linking*, that is, in sentences such as (35) in which one quantified NP is embedded inside another one and the embedded quantifier outscopes the higher one.

(35) At most two senators on every committee voted to abolish it.

There are two main observations. First quantifiers that are syntactically embedded inside another quantifier may take scope over the higher quantifier. So, the most natural reading of (35) is that within every committee there are at most two senators that voted in the described way. It is also important for this example that the VP contains a pronoun, *it*, bound by the embedded universal quantifier. Second, while such a wide scope is possible, still, the two quantifiers of the complex NP may not be separated by an NP-external quantifier. So, (36) does not have a reading in which for every city there are two policemen spying on someone (not necessarily the same person) from that city, that is, a reading $\forall > \mathbf{Two} > \exists$ is excluded.

(36) Two policemen spy on someone from every city. (Larson, 1985)

Heim and Kratzer (1998) argue that QR from inside the embedded NP should be possible to capture the binding possibility of (35). This theory leaves standard assumptions intact about the interpretation of LFs and a c-command restriction on the binding of pronouns. However, May and Bale (2005) argue that this would make it difficult to block the intervention reading for (36). They favor a theory in which the embedded quantifier attaches to the NP that contains it. While such an analysis can derive the ban on quantifier intervention straightforwardly, it must develop a new theory of pronoun binding and must show how NP-internal QR can be interpreted.

This discussion shows that constraints on scope-taking do not necessarily follow easily from making it a syntactic operation. In particular, these constraints may be distinct from constraints known for genuinely syntactic movement operations. Furthermore, a syntactically more conservative analysis may require a more flexible – and maybe also more complex – mapping between syntax and semantics and even a different semantics.

21.4.4 Discontinuity

I will briefly sketch an account of Example (17) in the spirit of the analysis of corresponding German data in Penka and von Stechow (2001). The LF approach has a further interesting consequence for the syntax–semantics interface. Discontinuous interpretations lead to the postulation of more syntactic structure than meets the eye at first. Not only do quantifiers mark their scope by their LF position, but so do negation, tense, and other operators. Consequently, it is impossible to derive the discontinuous reading of (17) if we assume that the determiner *no* contributes both negation and existential quantification. Instead, *no* is simply interpreted as being existential. At the same time, the structure contains a (phonologically) empty node that is interpreted as negation. This leads to the following syntactic structure: (i) There is an abstract NEG-node in the appropriate place in the matrix clause.[23] (ii) Epistemic *need* is a raising verb, so the subject of its infinitival complement clause, *Alex*, is raised into the matrix subject position, leaving behind the trace t_x. (iii) The NP *no tie* undergoes QR within the embedded infinitival clause, leaving the trace t_y. The S-structure and the LF are sketched in (37).

[23] I am agnostic here as to where exactly the NEG-node is. Penka and von Stechow (2001) assume a NegP for English, following Pollock (1989). In the present context, the most straightforward assumption would be that NEG is adjoined to S.

(37) Alex need wear no tie.
a. S-structure: $[_S$ NEG Alex$_x$ need $[_S\ t_x$ wear [no tie]]]
b. LF: $[_S$ NEG Alex$_x$ need $[_S$ [no tie]$_y$ $[_S\ t_x$ wear $t_y]]]$

Semantically, the empty NEG-node is interpreted as logical negation ($\lambda p.\neg p$), the NP *no tie* as a non-negative indefinite quantifier, $\lambda P.\exists y[\mathbf{tie}(y) \wedge P(y)]$. With these assumptions, the desired interpretation can be derived.

For the approach to work, it must be guaranteed that the NEG-node co-occurs with the non-negatively interpreted determiner *no* and the other way around. Penka and von Stechow (2001) classify the determiner *no* and all English *n*-words as *strong Negative Polarity Items* (NPIs), adopting ideas from Ladusaw (1992). While they do not provide a fully formulated theory of such NPI licensing, this at least shows how they intend to prevent *n*-words from occurring in non-negative sentences. However, they do not have a story that forbids the empty NEG from occurring in clauses that lack an overt (apparent) marker of negation.

The analysis of discontinuity shows how the existence of particular readings has immediate consequences for the syntactic structure. In practice, the kind of syntactic structures required will contain a number of additional projections and nodes which may lack direct syntactic evidence. Since such nodes are in any case often postulated in Generative Grammar for theory-internal conceptual reasons, this property of the LF theory of the syntax−semantics interface provides additional motivation for such abstract syntactic structures. Nonetheless, it remains to be seen whether the occurrence of empty operators can be restricted in the required way.

The strong connection between syntactic processes and semantics within the LF approaches can also be illustrated with the second type of discontinuity that was mentioned in Section 21.2.4: cases like (20) where parts of an overtly moved constituent do not take uniform scope. Von Stechow (1993) and Beck (1996) assume that overt syntactic movement needs to be undone at LF to account for the scopally low reading of parts of the fronted constituent. With the advent of the *copy theory of movement* in the Minimalist program, it became possible to interpret parts of a copy at the intended position. This is done, for example, in Fox (1999). While a reconstruction movement as such is not easily justifiable on syntactic grounds, the copy theory of movement does not require the introduction of specific movement operations, alien to syntax proper, but can build on the intermediate copies for interpretation.

21.4.5 Concord and cross-linguistic variation

Negative concord is another empirical domain in the debate over and the motivation of LF structures. The basic problem is that while there might be several expressions in a clause that appear to be negative, a sentence is interpreted as containing only one negation. Given the combinatorial system assumed in LF-based theories, there are very few proposals that allow the elimination of semantic operators once introduced.[24] There have been several proposals over the last few decades, of which I would like to summarize just two: the Neg Criterion approach of Haegeman and Zanuttini (1991), and the feature-checking approach of Zeijlstra (2004).

Haegeman and Zanuttini (1991) look at both the syntax and the semantics of the expression of negation, in particular in West Flemish and Italian. They assume that all *n*-words that participate in negative concord are moved to a particular syntactic position at LF, the specifier of a projection NegP. Similarly, preverbal negative markers, if a language has them, are moved to the head of NegP. NegP is taken as the place of interpretation of the negation. The *n*-words are assumed to be negative, but their negations are fused so that a polyadic quantifier is formed that binds one variable for each *n*-word. The movement is triggered by a syntactic NEG feature that needs to be checked. This checking has the semantic effect of forming such a polyadic quantifier.

An important empirical motivation for the account is the following observation. In West Flemish, PP complements follow adjectival heads at D- and often also at S-structure. If an *n*-word inside such a PP is to express sentential negation, however, it needs to be moved out of the AP. The theory says that the landing site for this movement is the specifier of NegP.

(38) Haegeman and Zanuttini (1991)
a. da Valère [$_{AP}$ ketent [me niets]] (*en)-is
that Valère satisfied with nothing (NM)-is
b. dat Valère [me niets]$_i$ [$_{AP}$ ketent *t*$_i$] (en)-is
that Valère with nothing satisfied (NH)-is
'that Valère is not satisfied with anything'

Further positional observations are also captured in this approach: *n*-words in fronted position (*Vorfeld*/ specifier of CP) do not participate in negative concord with *n*-words that occur later in the sentence. So sentence (39) only has a double-negation reading.[25]

(39) Niemand eet-er geen boeken gelezen.
nobody has-expletive no books read
(Haegeman and Zanuttini, 1996, p. 146)
(Double negation)

The Neg Criterion approach is a classical LF analysis in the sense that it combines syntactic arguments (such as differences in word order or

[24] One such exception is the above-mentioned polyadic quantifier approach of May (1989).

[25] Other word order contrasts, such as the difference between preverbal n-words in Italian (which do not participate in negative concord) and postverbal ones (which do) are expressed by assuming different layers of NegP or different places to check features. See Zanuttini (1997).

grammatical function) with semantic aspects (the absence of a multi-negation reading).

Finally Zeijlstra (2004) develops a theory of negative concord that uses a more elaborated version of a feature-checking mechanism than Haegeman and Zanuttini (1991), but a simpler semantics. Zeijlstra uses an interpretable NEG feature, [iNEG], which is interpreted as logical negation. In addition, he assumes an uninterpretable NEG feature, [uNEG], that is just a syntactic feature. The dichotomy of interpretable and uninterpretable versions of the same feature is the basis of the Minimalist theory of agreement, and it comes along with the assumption that if a clause contains an uninterpretable feature [uF], it must also have its interpretable counterpart [iF]. There is an agreement relation between the two features, though it is not the type of specifier-head agreement of Principles and Parameters, as in Haegeman and Zanuttini (1991), but rather a Minimalist version of agreement, in which the feature [iF] needs to c-command all occurrences of the feature [uF].

The plausibility of Zeijlstra's account depends heavily on the question of whether the agree mechanism needed for negation is identical with agreement in general. This is, in fact, what many of Zeijlstra's subsequent papers argue for.

The account of cross-linguistic variation is one of the main aims of current Generative Grammar. This is also true for LF-based approaches to the syntax–semantics interface. Haegeman and Zanuttini (1991) assume that the Neg Criterion is universal, but languages may differ as to whether it needs to be satisfied at S-structure or at LF.

Based on a cross-linguistic study, Zeijlstra arrives at the following generalization:

> All languages with a negative marker X^0 are NC languages, whereas only a subset of the set of languages that have a negative marker XP are NC languages. (Zeijlstra, 2004, p. 165)

To capture this, Zeijlstra (2004) assumes that only languages that show Negative Concord have a formal NEG feature. The existence of an X^0-category negative marker is evidence for the existence of a formal NEG feature and, consequently, leads to negative concord. Other languages, such as the standard varieties of Dutch, English, and German, neither have morphological evidence for a NEG feature (such as a preverbal X^0 negative marker) nor exhibit Negative Concord readings. Therefore, these languages do not have a formal NEG feature, but rather interpret n-words and negative adverbials directly.[26]

[26] Or by a mechanism such as the one in Penka and von Stechow (2001), as discussed in Penka and Zeijlstra (2005).

21.4.6 Summary

The LF approach is based on the assumption of a level of syntactic representation that is potentially distinct from the surface structure and serves as the input to a direct semantic interpretation.

While the strength of the LF approach is that it allows us to express syntactic constraints on possible interpretations, it is the more attractive the closer these constraints are to constraints found in syntax proper. We saw how analytic innovations of Generative syntax such as the copy theory of movement, functional projections, or the Minimalist agreement theory have been used to model phenomena at the syntax–semantics interface.

Turning briefly to the main thread of this chapter, I would like to summarize instances of syntactic, semantic, and interface-based solutions that I mentioned in my presentation of LF-based approaches. All assumptions that involved the introduction of additional functional projections are clearly syntactic amendments. Additional syntactic structure provided the basis for a semantic decomposition in the treatment of discontinuity. The same is true for the copy theory of movement. I have also mentioned more semantic adjustments: The polyadic interpretation of quantifiers proposed in May (1985, 1989) is a case in point here. The possible translations of a trace, mentioned in connection with the interpretation of movement in von Stechow (1991b), can be seen as use of an interface-based mechanism.

21.5 Categorial Grammar

We will look at a theory of the syntax–semantics interface that is less concerned with a constituency-based syntactic analysis but puts more emphasis on the semantics: *Categorial Grammar* (CG). The main basic formalism and operations for a CG syntax were formulated in Lambek (1958), with origins reaching back to Ajdukiewicz (1935). There are various incarnations of CG, many of which are summarized in Wood (1993) and in an overview article in Moortgat (1997). Wood (1993), but also Partee (1997b), emphasizes the direct connection between Montague Grammar and CG: MG can be seen as a categorial grammar and the success of MG has increased the popularity of CG.[27]

CG approaches range from more logically oriented approaches to more linguistically oriented ones. To achieve a maximal diversity within the exemplary frameworks used in this chapter, I will use primarily the system presented in Carpenter (1997), which has its origins more in the logical and computational tradition of CG. Among the more linguistically oriented

[27] A system such as *Flexible Montague Grammar* (Hendriks, 1993) is clearly both a further development of MG and a proposal within CG.

recent versions, we find, for example, Barker (2012), Steedman (2012), and Jacobson (2014).

Carpenter (1997) is just one of many possible choices, which has been chosen because it uses a rather standard version and covers a large syntactic and semantic fragment. In Carpenter's system, a sentence is well-formed if we can find an interpretation in a step-by-step derivation, starting from the lexical entries of the words in the sentence.[28] Lexical axioms relate a phonological form (or, in practice, an orthographic form) of a word to a pair consisting of a lambda expression and a syntactic category. For example, the proper noun *Dana* comes with the lexical entry: *Dana* $\Rightarrow$ **dana** : np. In this case, *Dana* is the orthographic form, **dana** is a name constant that refers to a person called Dana, and np is a syntactic category. Any syntactic object of the category np is interpreted as an object of the type entity (usually written as e). In addition to np, Carpenter uses the category s (describing objects of type truth value, t), and the category n, describing properties, that is, objects of type $\langle e, t\rangle$. Complex (functional) categories can be built from these basic categories using operators such as (at least) "/" and "\" (with $(np\backslash s)$ for the traditional VP and (n/np) for the traditional category P).

Having established the lexical mapping from orthography to pairs of semantics and syntax, sequences of such pairs can be combined based on simple combinatoric rules, called *application schemes* in Carpenter (1997, p. 118). The two schemes are given in (40).

(40) Application schemes (Carpenter, 1997, p. 118)
a. $\alpha : A/B, \quad \beta : B \Rightarrow \alpha(\beta) : A$
b. $\beta : B, \quad \alpha : B\backslash A \Rightarrow \alpha(\beta) : A$

The two rules have the effect of combining expressions semantically by functional application, given that the syntactic categories match appropriately. A derivation is successful if all words in the sentence have combined so that, eventually, a single semantic expression is arrived at.

21.5.1 Argument identification

Carpenter (1997) builds argument identification directly into the combinatorics. A transitive verb, such as *see*, has the following lexical axiom: *see* $\Rightarrow$ **see** $: (np\backslash s)/np$, where **see** is a function of type $\langle e, \langle e, t\rangle\rangle$ and the first argument that it combines with is its patient, the second one its agent/experiencer. With this and appropriate lexical entries for the proper names, we get the following derivation:[29]

[28] I will present CG proofs in this "reversed order" rhetorics, starting from the lexical entries and leading to the full sentence. Usually, however, CG is interpreted the other way around: A sentence is proven if it can be reduced to lexical axioms in a step-by-step way.

[29] Wood (1993, pp. 132–134) summarizes approaches to free word order languages within CG.

(41) Alex saw Dana.

a. Lexical entries:
Alex $\Rightarrow$ $\mathbf{alex} : np$, *saw* $\Rightarrow$ $\mathbf{see} : (np\backslash s)/np$,
Dana $\Rightarrow$ $\mathbf{dana} : np$

b. *saw Dana* (schema (40a)):
$\mathbf{see} : (np\backslash s)/np, \mathbf{dana} : np \Rightarrow \mathbf{see}(\mathbf{dana}) : (np\backslash s)$

c. *Alex saw Dana* (schema (40b)):
$\mathbf{alex} : np, \mathbf{see}(\mathbf{dana}) : (np\backslash s) \Rightarrow \mathbf{see}(\mathbf{dana})(\mathbf{alex}) : s$

Valence alternations, such as passive, can be modeled by particular lexical entries for the passive auxiliary: $be_{passive} \Rightarrow \lambda V \lambda x.\exists y(V(x)(y)) : (np\backslash s)/((np\backslash s)/np)$.

(42) Dana was seen.

a. *was seen*:
$\lambda V \lambda x.\exists y(V(x)(y)) : (np\backslash s)/((np\backslash s)/np), \mathbf{see} : (np\backslash s)/np$
$\Rightarrow \lambda x.\exists y(\mathbf{see}(x)(y)) : np\backslash s$

b. *Dana was seen*:
$\mathbf{dana} : np, \lambda x.\exists y(\mathbf{see}(x)(y)) : np\backslash s \Rightarrow \exists y(\mathbf{see}(\mathbf{dana})(y)) : s$

In a system like Carpenter's, a lexical rule, very much like those introduced in Dowty (1978), should be used for valence alternations that do not have an overt syntactic marker like $be_{passive}$, such as the intransitive use of transitive verbs or the dative alternation.

21.5.2 Quantifiers

To account for the double nature of quantifiers – that they act as entities in their surface position, but as operators at the sentence level – Carpenter (1997), following Moortgat (1988), uses an additional syntactic category operator, "$\uparrow$". A quantifier is of the category $np \uparrow s$. The syntactic category $np \uparrow s$ is associated with the semantic type $\langle\langle e, t\rangle, t\rangle$. A quantifier such as *everyone* comes with the following lexical entry: *everyone* $\Rightarrow$ $\mathbf{everyone} : np \uparrow s$.

A derivation with a quantifier contains two special steps. First, there is a rule that introduces a variable in the place in which the quantifier occurs, i.e, we get: $\mathbf{everyone} : np \uparrow s \Rightarrow x : np$. This rule is a rule of hypothetical reasoning as it introduces new material, the new variable x. Later in the derivation, this hypothetical reasoning needs to be undone. So a second reasoning step tells us that at some point in the derivation where we have $\beta : s$, we can infer $\mathbf{everyone}(\lambda x.\beta) : s$. This is illustrated in (43).[30]

(43) Alex observed everyone.

a. *everyone* $\Rightarrow$ $\mathbf{everyone} : np \uparrow s$

b. (Step 1): $\Rightarrow x : np$

[30] As emphasized by a reviewer, this last step is the direct CG analogue to Montague's quantifying-in and to QR.

c. *observed everyone*:
$\mathbf{observe} : (np\backslash s)/np, \quad x : np \Rightarrow \mathbf{observe}(x) : np\backslash s$
d. *Alex observed everyone*:
$\mathbf{alex} : np, \quad \mathbf{observe}(x) : np\backslash s \Rightarrow \mathbf{observe}(x)(\mathbf{alex}) : s$
e. quantifier "retrieval" (Step 2):
$\mathbf{observe}(x)(\mathbf{alex}) : s \Rightarrow \mathbf{everyone}(\lambda x.\mathbf{observe}(x)(\mathbf{alex}))$

Carpenter can distinguish between an "ordinary" NP (of category np) and a quantified NP (of category $np \uparrow s$). This can be used to identify intensional verbs (*seek* $\Rightarrow$ $\mathbf{seek} : (np\backslash s)/(np \uparrow s)$) and an extensional verb such as *see*, which combines with an NP of category np as seen above. This brings us to an important difference between the three systems considered in this chapter: In Montague Grammar in its PTQ version, there is a uniform correspondence between the syntactic category of an expression and the semantic type of its translation. CG approaches like Carpenter's, and later work within MG, is more flexible in the correspondence between the traditional categories and the CG categories, allowing, as we saw, different categories for extensional and intensional transitive verbs. Finally, the LF approach can use syntactic categories exclusively as motivated on the basis of syntactic tests and there is no necessary correspondence between the syntactic category of an expression and the semantic type of its denotation.[31]

21.5.3 Ambiguity

Ambiguity arises in CG if there are different derivations for the same sequence of words. There can be various ways that this comes about: First, corresponding to structural ambiguity, there might be a choice in the order in which adjacent expressions are combined. This is illustrated in (44).

(44)	good	cheese	and	wine
	$\mathbf{good} : n/n$	$\mathbf{cheese} : n$	$\mathbf{and} : (n\backslash n)/n$	$\mathbf{wine} : n$

a. Reading 1: $\mathbf{and}(\mathbf{good}(\mathbf{cheese}))(\mathbf{wine})$
b. Reading 2: $\mathbf{good}(\mathbf{and}(\mathbf{cheese})(\mathbf{wine}))$

Second, a word may be assigned more than one category. This concept has been worked out in detail in Partee and Rooth (1983) for Montague Grammar and adapted into many frameworks and analyses, including Carpenter (1997). Coordinating particles such as *and* have a flexible category of the form $A\backslash A/A$ for each Boolean category A, i.e., for each A that denotes either a truth value or a function that maps to a Boolean category. In addition, there are type-raising rules that may alter the semantic type. A simple example of this is so-called *type lifting* (or *value raising*), that, among others things, turns a name (such as $\mathbf{dana} : np$) into something that looks like a quantifier ($\lambda P.P(\mathbf{dana}) : (np \uparrow s)$).

[31] To give an example, it is possible in an LF theory to have noun phrases that denote quantifiers, individuals, events, or propositions.

Third, ambiguity can also arise by the relative order in which rules are applied. Scope ambiguity, for example, is captured by the order in which the "retrieval" part of the quantifier treatment is applied (what we called "Step 2" in (43)).

21.5.4 Discontinuity

I am not aware of an analysis of examples like (17) in CG.[32] I will sketch one out of several possible analyses.

As in the case of the other frameworks, discontinuity needs to be captured indirectly. The semantic contribution of an expression is always a lambda term. What could be done is to introduce additional variables to abstract over to capture potentially intervening elements. To be concrete, the negative determiner *no* should be assigned more than one translation. So in addition to $\lambda P \lambda Q.\neg\exists x[P(x) \wedge Q(x)]$, there should also be a translation that contains additional lambda prefixes: $\lambda P \lambda Q \lambda \mathcal{R} \lambda y.\neg(\mathcal{R}(\exists x(P(x) \wedge Q(x)(y))))$. In this expression the variable y is associated with the semantic argument that corresponds to the subject, and the variable $\mathcal{R}$ corresponds to additional operators that can take intermediate scope between the negation and the existential quantifier.

The trick is to introduce an additional argument, here the variable $\mathcal{R}$, between the negation and the existential quantifier. As far as the syntactic category is concerned, the determiner is such that it will act as a functor all the way up. This sketched hypothetical analysis of discontinuity relies on a type-shifting operation that can map the basic translation of *no* to the shifted one. Since type shifting is one of the basic techniques of CG, this seems to be a justifiable proposal.

A potential drawback of a type-shifting approach is that it might be too general, that is, it might allow for any modifier of the appropriate semantics type, $\langle t, t \rangle$ in this example, to take intermediate scope between the negation and the existential quantifier. It is an empirical question whether this prediction is problematic.

21.5.5 Concord and cross-linguistic variation

Similar to the problem of discontinuity, any CG analysis of negative concord needs to be compatible with a continuous, non-interruptable semantic contribution for words. Dowty (1994) assumes that n-words in negative concord languages are usually not negative themselves but require to be in a negative environment. For this reason, he annotates each category with respect to its polarity. For example, the negated auxiliary *didn't* is of the category $(np\backslash s)/(np\backslash s)^-$, where the superscript "$^-$" indicates that the argument

[32] The data discussed as *discontinuity* in CG usually involve cases where the phonology of an expression that is a unit in semantics is interrupted (as for *ring up* in *Mary rang John up*). See Morrill (1995) for a discussion and a proposal for such cases.

of *didn't* is of negative polarity. N-words are sensitive to occur only in contexts of negative polarity. In (45) I illustrate this analysis with a hypothetical example sentence from a non-standard variety of English that has negative concord. I sketch the syntactic categories of Dowty (1994), adapted to the current notation and with simplified category labels.[33]

(45)	Alex	didn't	read	no	book.
	np^+	$(np\backslash s)^+/(np\backslash s)^-$	$(np\backslash s)^-/np^-$	np^-/n^-	n^-

If there is no negation in the sentence, that is, if we had an auxiliary of the type $(np\backslash s)^+/(np\backslash s)^+$, the overall sentence would be of the type $(np\backslash s)$. Consequently, the VP *read no book*, which is of the category $(np\backslash s)^-$, would not combine directly with the auxiliary. Dowty's analysis illustrates that it is possible to add feature specifications to the syntactic category label.

Dowty (1994) discusses some dialectal or regional variation. For example, concord varieties of English differ as to whether they allow subjects to participate in negative concord or not. In case they may, the type of auxiliary would be $(np^-\backslash s)/(np\backslash s)^-$.

Hoyt (2006) models negative concord in Palestinian Arabic in CG. Palestinian Arabic has a negation system similar to Standard Italian: Preverbal *n*-words express negation on their own, but postverbal *n*-words require the presence of a negation marker on the verb. In other words, there is obligatory concord in the postverbal domain. This shows that this type of analysis of cross-linguistic variation can be adapted to language-particular properties quite easily.

21.5.6 Summary

The strength of Categorial Grammar lies in its formal precision and its clear bridging function between logic, computational linguistics, and theoretical linguistics. For the more logically oriented version of CG, Moortgat (1997) gives the following clear summary of the CG view of the syntax–semantics interface:

> Categorial type logics offer a highly transparent view on the relation between form and meaning: semantic interpretation can be read off directly from the proof which establishes the well-formedness (derivability) of an expression. The principle of compositionality . . . is realized in a particularly stringent, purely deductive form, leaving no room for rule-to-rule stipulated meaning assignment. (Moortgat, 1997)

This quote emphasizes the differences between CG and both MG and LF approaches: Contrary to the LF approach, in CG there is a simultaneous syntactic and semantic derivation and a sentence cannot be syntactically well-formed and at the same time semantically ill-formed. An important

[33] For simplicity, I treat the quantified object as non-quantificational here.

difference from MG is that the syntax–semantics interface is not based on a rule-by-rule correspondence but rather on very flexible assignment of categories to words and a free application of a small set of operations.

We could see that mismatches at the syntax–semantics interface can be handled in CG by manipulating syntax, semantics, or the mapping between them. A syntactic solution is the introduction of new types of syntactic categories – which do not necessarily lead to new semantic types. We saw that A/B, $B\backslash A$, and $A \uparrow B$ are all of the same semantic type. There are also interface-based solutions. These are expressed in rules such as the application schemes in (40), which relate the syntactic derivation and a corresponding semantic operation. While the structure of the rules at the syntactic side is usually motivated by general steps of reasoning, such as *modus ponens* or hypothetical reasoning, complex effects can be specified at the semantic side – as we saw in the second step in the analysis of quantification. Finally, the CG approach is in principle open to manipulate the semantic side. An example is Ben-Avi and Francez (2004). The authors want to ban the derivation of sentences that are syntactically well-formed but violate semantic selection restrictions, such as **Every table smiled*. They achieve this by imposing an ontology on the domain of the type *e*. This results in refined types. For the concrete example, the universal quantifier binds a variable of the ontological type *furniture*, which is incompatible with the type *animate* that is required by the verb *smile*. Consequently, the combination is undefined semantically.

This rather brief illustration of one particular incarnation of a Categorial Grammar allows us to see where and how CG can use syntactic, semantic, or interface-based techniques to account for phenomena at the syntax–semantics interface.

21.6 Additional perspectives

A more or less arbitrary restriction of the chapter was the choice of three particular frameworks, Montague Grammar, LF approaches, and Categorial Grammar, and of only a very small number of analyses within each of these. Other types of theories could have been used equally well. I will briefly mention some of them, which should be seen as invitations to evaluate these theories based on the empirical phenomena used in the present chapter. The theories listed below are, in part, compatible with the approaches mentioned in the chapter. However, they contribute a particular perspective that might shed a different light on some phenomena at the syntax–semantics interface.

Discourse Representation Theory (DRT) This theory, presented in Kamp and Reyle (1993) and Kamp et al. (2011), emphasizes the relevance of semantic representations. This is a clear difference from the three approaches described above, all of which either make no commitment to whether a semantic representation is needed or straightforwardly reject it. DRT is relevant for the perspective taken in this chapter as it allows us to formulate constraints on the semantic representations. Such constraints are distinct from constraints on the syntactic structure and also distinct from constraints on possible models (such as meaning postulates). Phenomena for which such constraints have proven particularly useful are dynamic aspects of meaning (Kamp, 1981b), presuppositions (Geurts, 1999; Kamp, 2001), and the licensing of Negative Polarity Items (Sailer, 2009). A further important aspect of DRT is that lexical semantics plays an important role in it; see, for example, Kamp and Rossdeutscher (1994).

As far as the questions discussed in this chapter are concerned, DRT representations have been combined with various approaches to the syntax–semantics interface – a mapping of syntactic structures by construction rules in Kamp and Reyle (1993) or a combinatorics that is primarily based on functional applications in Muskens (1996).

Cooper store Explicit storage mechanisms, such as so-called *Cooper store* going back to Cooper (1975), can be used at the syntax–semantics interface. Such a store allows us to "remember" a particular quantifier and the variable that it binds without having to change the syntactic structure. Approaches based on Cooper store do not need QR-like syntactic operations, nor do they need special semantic representations; however, they must allow for special material at the interface, like the stores that contain semantic information. Consequently storage-based approaches mostly use interface-based mechanisms to capture mismatches in the syntax–semantics mapping. A storage-based approach to quantifier ambiguity has been combined, for example, with *Head-driven Phrase Structure Grammar* in Pollard and Sag (1994).

Dynamic Syntax (Kempson et al., 2000) This is a theory of natural language interpretation. It does not rely on a phrase structure tree that is interpreted, nor does it follow a proof-theoretic perspective on well-formedness. Instead, it is a model of parsing that assumes a left-to-right stepwise parsing and interpretation of sentences. The approach is based on a number of empirically interesting formal decisions such as a left-to-right order of interpretation that provides a natural distinction between leftward and rightward movement in natural language (Gregoromichelaki, 2013).

Underspecification Another approach to the syntax–semantics interface is by *underspecification*. In this context, it means that syntactic structure and semantic representation are assumed to be connected through interface principles that do not necessarily determine a unique semantic representation for a given syntactic structure. This use of underspecification has its roots in computational linguistics (Pinkal, 1995; Bos, 1995) but has also found a number of theoretically interesting applications, see Egg (2010); Underspecification approaches take ambiguity and discontinuity as their basic empirical motivation. Such approaches are typically confined to surface-oriented syntactic frameworks. Proposals for an underspecification-based syntax–semantics interface have been made, for example, for *Tree Adjoining Grammar* in Kallmeyer and Romero (2008) or, in a number of papers, for *Head-driven Phrase Structure Grammar* including Egg (1998), Copestake et al. (2005), and Richter and Sailer (2004).

Bi-directional Optimality Theory This theory shares the basic idea of a rather flexible relation between syntax and semantics with underspecification approaches. However, it assumes that the mapping is moderated by optimality constraints, that is, by a set of ranked constraints. De Swart (2010) develops such an approach for negative concord, capturing in particular the cross-linguistic variation. The approach has been applied to other cases of cross-linguistic variation; see, for example, de Swart and Zwarts (2008) for definite articles and Le Bruyn (2010) for indefinite articles.

21.7 Conclusions

I started the present chapter taking the Principle of Compositionality as a central research strategy. None of the three theories of the syntax–semantics interface discussed in more detail here questions the validity of the principle, and they all attempt to capture both its intuitive content and apparent problems in its application. While some of the theories mentioned in Section 21.6 question aspects of the Principle of Compositionality, any development that goes beyond it needs to be based on knowledge of the merits and limits of systems that rely on it.

I used some core examples of interface phenomena for illustration in this article: argument identification and alternation, quantifiers, ambiguity, discontinuity, concord, and variation. The motivation for this choice was that the corresponding syntactic structures are based on canonical structures and, as such, are part of almost any fragment of syntax. So these would be a good starting point for any comparative evaluation of approaches to the syntax–semantics interface, a topic that is also beyond the present chapter. For the same reason, the underlying semantics was kept constant throughout the chapter, and the particular semantics can be considered to represent a certain lingua franca standard.

Other choices could have been made. More advanced syntactic structures could have been used, including, for example, *antecedent-contained ellipsis*, which has played an important role in theory formation. As mentioned briefly in footnote 9, if we use choice functions in the interpretation of quantifiers, the particular instance of semantic discontinuity used in this chapter may no longer be a challenge to compositionality.

We have seen that different approaches to the syntax–semantics interface determine whether a particular problem is approached more from the point of view of syntax, semantics, or a mapping between the two.

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22

The semantics–pragmatics interface

Philippe Schlenker

22.1 Introduction

22.1.1 Goals

The informational content conveyed by utterances has two sources: meaning as it is encoded in words and rules of semantic composition (often called *literal* or *semantic meaning*) and further inferences that may be obtained by reasoning on the speaker's motives (the conjunction of these inferences with the literal meaning is often called the *strengthened* or *pragmatic meaning* of the sentence). While in simple cases the difference can seem obvious enough, in general this is not so, and the investigation of the semantics–pragmatics interface has proven to be one of the most vibrant areas of research in contemporary studies of meaning. We will survey three domains – *scalar implicatures*, *presuppositions*, and *conventional implicatures* – in which there are considerable empirical benefits to be obtained from this enterprise. However, it is also of foundational and methodological interest: knowledge of semantic meaning is part of knowledge of language; by contrast, pragmatic inferences are derived in part from the assumption that the speaker obeys certain rules of behavior – typically ones dictated by rationality (which may, for instance, lead to the maximization of the utility of an utterance to the speaker or to others). Owing to foundational interest in the interaction between language and reasoning, the study of the semantics–pragmatics interface originated in philosophy; however, it quickly became a central topic within linguistics and psycholinguistics, and the convergence of results from these last two fields has resulted in rich cross-disciplinary exchanges. For reasons of space, we do not consider psycholinguistic results in this survey, but it should be said at the outset that they have changed the face of the field by providing new and more reliable data (for instance, on processing and language acquisition) and sometimes by challenging data that had too quickly become solidified on the basis of unsystematic introspection alone.

As we will see, the debates are more open than ever. Scalar implicatures, which were usually considered a staple of pragmatic reasoning, have recently been reassigned to the semantics or even to the syntax by proponents of *locally computed implicatures* ('localists' for short). For their part, presuppositions were in the 1980s one of the success stories of dynamic semantics, with its program of *semanticization* of large parts of pragmatics, but they too have recently been reassigned, with some researchers claiming, in a Gricean vein, that presuppositions should be viewed as part of the post-semantic component. Finally, conventional implicatures were originally left by Grice in a somewhat informal state because his primary interest was in scalar implicatures; their formal study was pioneered by Chris Potts, who took them to argue for a multi-dimensional semantics, but other researchers have sought to develop pragmatic alternatives. In each case, there is a very fruitful tension between considerations of empirical adequacy and explanatory depth: pragmatic approaches are often considered to be deeper (all other things being equal) than semantic ones, at least to the extent that they can be grounded in a theory of communicative rationality; however, the data do not always fit such patterns ('all other things' usually *aren't* equal!), and the rational foundations are only beginning to emerge rigorously (the latest developments, based on game theory, will not be reviewed in this survey; see Franke, 2011 and Rothschild, 2013, for two recent discussions).

22.1.2 Quality, quantity, and Grice's maxims

Two examples will immediately illustrate the importance of pragmatic reasoning.

Moore's paradox

Moore (1942) noticed that conjunctions of form *p, but I don't believe that p* are decidedly odd; an example is given in (1a):

(1) a. #It's already past midnight, but I don't believe/know that it is.
    b. It's already past midnight, but John doesn't believe/know that it is.

Certainly a conjunction of the form *p and x doesn't believe that p* is not a logical contradiction – and in fact the third person version of the statement, provided in (1b), does not sound nearly as odd as (1a). This first vs. third person asymmetry can be explained on the assumption that, in normal circumstances, speakers believe (or present themselves as believing) the content of their statements. Under this assumption, (1a) is deviant because its utterance leads to the inference that the speaker has contradictory beliefs. The contradiction is derived on the basis of the *Principle of Quality* in (2), combined with standard assumptions about the logic of belief (we write $B\varphi$ for *the speaker believes that* φ, an abbreviation we use in both the object- and meta-language).

(2) *Principle of Quality*: If the speaker uttered φ, the speaker believes that φ.

1. The speaker uttered *p and not-Bp*.
2. By (2), the speaker believes this; hence: $B(p$ and not-$Bp)$.

3a. *Assumption*: Someone who believes a conjunction believes each conjunct. Formally: $B(\varphi \wedge \psi)$ implies $B\varphi$ and $B\psi$.
3b. By (2) and 3a, we have Bp and $B($not-$Bp)$.
4a. *Assumption*: Someone who believes something is aware of this, i.e., believes that he believes it. Formally: $B\varphi \rightarrow BB\varphi$ – hence BBp.
4b. By 3a and 4a, BBp and also $B($not-$Bp)$. In other words, the speaker holds inconsistent beliefs.
This accounts in a simple way for the contradictory nature of (1a); importantly, it is a *pragmatic contradiction*, which was derived on the basis of the pragmatic principle in (2).

Conversational implicatures

Grice (1975) discussed the example in (3):

(3) *A* is writing a testimonial about a pupil who is a candidate for a philosophy job, and his letter reads as follows: "Dear Sir, Mr. *X*'s command of English is excellent, and his attendance at tutorials has been regular. Yours, etc."

We clearly infer that Mr. *X* is a terrible philosopher; this momentous inference is not derived from the fact that the speaker believes what he said, but from the observation that he *failed* to say something which would have been more useful, e.g., that Mr. *X* is a good student. Our reasoning falls under a broad principle which we will, for the moment, state in a vague fashion:

(4) *Principle of Quantity*: If the speaker uttered φ, φ is optimally informative within a class (to be defined) of alternative utterances.

That our inference is not due to an *entailment* of (3) can be checked: if the discourse – call it *D* – entailed that Mr. *X* is a bad philosopher, we would expect any *strengthening* of *D* to yield this inference as well. But such is not the case – although (5) contains *D* as a subpart, it certainly does not yield the inference that *X* is a bad philosopher.

(5) Dear Sir,
Mr. *X*'s command of English is excellent, and his attendance at tutorials has been regular. I mention these secondary facts at the outset because Dr. Wittgenstein, with whom *X* is always – and rightfully – compared, lacked either of these qualities. In my view, Mr. *X*'s philosophical talent surpasses that of Dr. Wittgenstein; but he will also prove to be a considerably more reliable colleague, and a far better teacher.
Yours, etc.

An analysis of (3) can be developed on the basis of the principle in (4).[1]

1. In a letter of recommendation, one is supposed to describe the greatest academic qualities that an applicant has.
2. Example (3) only mentions *X*'s command of English and attendance at tutorials.
3. Hence *X* probably lacks greater academic qualities, such as talent as a philosopher.

22.1.3 Grice's maxims of conversation

Grice sought to state general "maxims of conversation" of which *Quality* and *Quantity* are just sub-cases. They fall under a general rule of *cooperative rationality* in discourse. They are listed here in Grice's formulations:

(i) *Quantity*
   1. "Make your contribution as informative as is required (for the current purposes of the exchange)."
   2. "Do not make your contribution more informative than is required."

(ii) *Quality* "Try to make your contribution one that is true", and more specifically:
   1. "Do not say what you believe to be false."
   2. "Do not say that for which you lack adequate evidence."

(iii) *Relation* "Be relevant."

(iv) *Manner* "Be perspicuous", and more specifically:
   1. "Avoid obscurity of expression.
   2. Avoid ambiguity.
   3. Be brief (avoid unnecessary prolixity).
   4. Be orderly."

In the present survey, we will be solely concerned with sub-cases of (i), (ii), and (iv).[2]

[1] Here we depart from the letter of Grice's text, whose analysis is based on the flouting of a maxim.

[2] See Sperber and Wilson (1995) for an attempt to get all of pragmatics to follow from a broader version of (iii). When we discuss presuppositions, we will also consider an additional maxim that was later proposed in Grice (1981) (in our terms, *Be Articulate*). See also Davis (2010) for other maxims.

22.2 Scalar implicatures

22.2.1 The neo-Gricean picture

Basic picture

Scalar implicatures are a species of quantity implicatures characterized by the fact that the class of alternatives of a given sentence is obtained by replacing any number of words with members of their *scales*, which are contextually provided sets of lexical alternatives (traditionally, these sets are ordered by logical strength, but this ordering turns out to be redundant because informativity considerations must play a role anyway when implicatures are triggered; see, e.g., Geurts, 2011). A well-worn example is offered by the behavior of the word *or*. Traditionally, it was thought that natural language disjunction is ambiguously inclusive or exclusive. In (6a), an exclusive paraphrase (*I will invite Ann or Mary but not both*) seems plausible enough; by contrast, in (6b) an inclusive paraphrase seems more appropriate (*I bet you $5 that John will invite Ann or Mary <u>or both</u>* – and in particular I'll win if he invites both).

(6) a. I will invite Ann or Mary.
   b. I bet you $5 that John will invite Ann or Mary.

The alternative, however, is to posit that *or* is semantically inclusive, but that in some cases a scalar implicature is derived by drawing inferences on the speaker's informational state, along the following lines (see Horn, 1989, for further arguments and a historical perspective):

(7) a. *Sentence uttered*: $\varphi =$ I will invite Ann or Mary.
   b. *Scalar alternative*: By replacing *or* with *and* in φ, we obtain an alternative $\varphi' =$ I will invite Ann and Mary.
   c. *Informativity*: φ' asymmetrically entails φ and thus would have been a more informative sentence to utter.
   d. *Primary implicature*: The speaker decided not to utter φ', presumably because he was not in a position to do so: not-$B\varphi'$.
   e. *Secondary implicature*: On the assumption that the speaker had an opinion ($B\varphi'$ or B(not-φ')), this implies: B(not-φ').

It is important to note that it is traditionally held that implicatures are usually *optionally* derived (but see Section 22.2.3 for an argument that some implicatures are obligatory). However, two steps must be distinguished in this reasoning:

(i) An analysis based solely on informativity and cooperative behavior will only yield the inference in (7d), namely that *the speaker does not hold the belief that φ'* – which is compatible with a situation in which the speaker does not know whether φ' is true. This inference is often called a *primary implicature* in the literature (e.g., Sauerland, 2004; see also Hirschberg, 1985, for qualifications).

(ii) Researchers have posited that one often derives a stronger inference, namely that *the speaker believes that* φ' *is false*, as shown in (7e). In the present framework, this clearly requires a further assumption; one possibility is that one assumes (for whatever reason) that the speaker is 'opinionated', i.e., believes φ' or believes *not* φ' – which allows us to infer from the primary implicature that the speaker holds the belief that *not* φ', i.e., what is often called a *secondary implicature* (e.g., Sauerland, 2004).

So we now have two candidates to explain the variable behavior of disjunction: an analysis based on lexical ambiguity, and one based on scalar implicatures combined with a single ('inclusive') lexical entry. How can we decide between the contenders? One important argument is that the ambiguity view predicts some readings that the scalar view does not. The idea is that scalar implicatures are only generated in case the informativity condition in (7c) is satisfied. However, it systematically fails in non-positive environments.[3] For instance, in (8a) and (8c), *or* appears in a *downward-monotonic* context, and thus the version with the sentence with *or* is more (rather than less) informative than the version with *and*: (8a) and (8c) are therefore strictly more informative than (8b) and (8d) respectively.

(8) a. I doubt that John will invite Ann or Mary.
b. I doubt that John will invite Ann and Mary.
c. Whenever John invites Ann or Mary, his parties are a success.
d. Whenever John invites Ann and Mary, his parties are a success.

The implicature-based analysis predicts that no scalar implicature should be triggered when (8a) and (8c) are uttered and that we should obtain the behavior of an unadorned inclusive disjunction. This appears to be correct: unless a very special intonation is used, it seems that (8a) implies, *a fortiori*, that I doubt that John will invite both Ann and Mary; and similarly the prediction in (8c) appears to hold of cases in which John invites both Ann and Mary: in those cases too, his parties are predicted to be a success. There are also more theory-internal arguments in favor of the implicature-based view.

Lexical accidents: On an unadorned version of the ambiguity view, it is an accident that we systematically find expressions that are ambiguous between an inclusive and an exclusive reading (in fact, cross-linguistically it appears that purported *exclusive disjunctions* turn out to have an inclusive reading after all; see Horn, 1989, for discussion).

Semantic universals: A possible generalization about lexical determiners found in the world's languages is that all of them are *monotonic*, either positive or negative. If p entails p', and if Op is a positive operator, then

[3] We slightly revise this view in Section 22.2, where we argue that it is only in downward-monotonic environments that these implicatures are not generated (the difference concerns non-monotonic operators, which are discussed in due course).

Op p entails Op p'; while if Op is negative (for instance Op is negation), Op p' entails Op p. It is clear that inclusive *or* is positive in both of its arguments: if p entails p', (p or q) entails (p' or q), and (q or p) entails (q or p'). However, exclusive *or* would crucially fail to yield such patterns; for instance, if p entails p', in a situation in which p is false, q is true, and p' is true, then we have that p or^{excl} q but p' or^{excl} q is false. Hence, if the broader generalization about possible lexical determiners is correct, we might want to extend it to logical operators quite generally, which would yield an indirect argument against the existence of exclusive disjunction.[4] (Another empirical argument against ambiguity-based treatments is discussed in the following section 'On alternatives'; it is based on truth-conditional intuitions but requires a more sophisticated way to compute alternatives.)

We can now state the procedure to derive scalar implicature in a somewhat more precise fashion. This analysis is 'neo-Gricean' because it adds to a Gricean analysis a precise definition of alternatives (Horn, 1972; as can be seen, informativity plays a role in (9b) but is not needed in (9a)).

(9) a. *Alternatives of* φ: Alt(φ) = {φ' | φ' can be obtained from φ by replacing one or more expressions with one of their lexical alternatives}.
  b. If φ was uttered, φ' is a member of Alt(φ), and φ' is more informative than φ (i.e., asymmetrically entails it), then
    (i) one may derive a *primary implicature*: not-$B\varphi'$:
    (ii) on the assumption that ($B\varphi'$ or B(not-φ')), this yields a *secondary implicature*: B(not-φ'). With the content of the secondary implicature, an utterance of φ yields a strengthened meaning akin to: φ and not-φ'.

It is often thought that the relation 'is a lexical alternative of' is symmetric (a point we revisit below): if *and* is a lexical alternative of *or*, it should also follow that *or* is a lexical alternative of *and*. This immediately yields an interesting prediction: we noted above that (8a) and (8c) asymmetrically entail (8b) and (8d), respectively. Focusing now on (8b) and (8d), we predict that these should implicate the negation of (8a) and (8c), respectively. This seems correct (to simplify the discussion, we focus our attention on secondary implicatures):

[4] The details matter: Barwise and Cooper (1981) state, more cautiously, that "the simple NP's of any natural language express monotone quantifiers or conjunctions of monotone quantifiers"; the second disjunct is motivated by the behavior of *few NPs*, which they analyze as meaning *some but not many NPs*, obtained from a conjunction of monotonic determiners. Still, the NPI-licensing behavior of *few* casts doubt on this analysis, and the stronger statement might be preferred. Note that P or^{excl} Q could be analyzed as (P or^{incl} Q) and not (P and Q), i.e., as a conjunction of monotonic constructions. (Note also that when applied to the determiner *most*, generalizations about monotonicity would have to be stated cautiously: while *most* is upward-monotonic in its VP-argument, it is non-monotonic in its NP-argument.)

(10) Predicted implicatures for (8b) and (8d)
Strengthened meaning of (8b): I don't doubt that John will invite Ann or Mary, i.e., I believe that John will invite one of them (but not both due to the assertion).
Strengthened meaning of (8d): It's not the case that whenever John invites Ann or Mary, his parties are a success, i.e., sometimes when John invites just one of them his parties are not a success.

For clarity, we have conducted the discussion on the scalar set {or, and}, but the analysis has considerable bite in much richer empirical domains. To give but one example: it has been argued that {some, most, all} form a scalar set (though sometimes we will simply discuss the scalar set {some, all}). This correctly predicts the secondary implicatures in (11):

(11) a. Some Frenchmen are clever.
(i) $\Longrightarrow$ Some Frenchmen are not clever – because of the inference: not[All Frenchmen are clever]. (redundant given (ii))
(ii) $\Longrightarrow$ A minority of Frenchmen are clever – because of the inference: not[Most Frenchmen are clever].
b. Most Frenchmen are clever.
$\Longrightarrow$ Some Frenchmen are not clever – because of the inference: not[All Frenchmen are clever].
c. I doubt that most Frenchmen are clever.
$\Longrightarrow$ Some Frenchmen are clever – because of the inference: not[I doubt that some Frenchmen are clever].
d. I doubt that all Frenchmen are clever.
(i) $\Longrightarrow$ Most Frenchmen are clever – because of the inference: not[I doubt that most Frenchmen are clever].
(ii) Some Frenchmen are clever – because of the inference: not[I doubt that some Frenchmen are clever]. (redundant given (i))

Horn, the pioneer of the neo-Gricean approach, provides quite a few other examples of scales (see Horn, 1989 and Hirschberg, 1985; the case of numerals is in fact more complicated, as we will briefly discuss below):

(12) {certain, {probable/likely}, possible}, {. . . , 6, 5, 4, 3, 2, 1}, {boiling, hot, warm}, {adore, love, like}, {excellent, good, okay}

On alternatives

A crucial component of the generation of scalar implicature is the appropriate definition of scalar alternatives; let us pause to discuss some issues one might raise. (The role of informativity might seem trivial enough, but as we will see in Section 22.2.2 this is not so: recent accounts posit that not only stronger alternatives but also more generally non-weaker ones can give rise to implicatures.)

Why lexical alternatives? In the neo-Gricean tradition (see Horn, 1972), the alternatives of a sentence φ are computed by making all the possible replacements of scalar items in φ with their lexical alternatives, as was summarized in (9a). This raises two questions: (i) Do we really need to specify a set of alternatives in some way – couldn't a *pure* Gricean approach do the job? (ii) If a set of alternatives needs to be specified, does this have to be done by way of lexical stipulations?

Ad (i): the answer to the first question seems to be a clear 'yes'. If we did not specify a set of alternatives in some way, we would simply have too many more informative sentences to negate, as is shown in (13) on the example of *some*:

(13) The 'symmetry problem'
Someone passed the exam.
Literal meaning: at least one person passed the exam
a. Plausible hypothesis: *Everyone passed the exam* is an alternative; hence, the inference: not[Everyone passed the exam]. Strengthened meaning: someone but not everyone passed the exam.
b. Incorrect hypothesis: *Exactly one person passed the exam* is an alternative; hence, the inference: not[Exactly one person passed the exam]. Strengthened meaning: at least two people passed the exam.

If there are no constraints whatsoever on the set of alternatives, we can even derive a more absurd result: any sentence φ could have as alternatives *φ and φ'*, *φ and not φ'* (for some φ'). Both are more informative than φ – and triggering a secondary implicature for both yields the strengthened meaning *φ and not (φ and φ') and not (φ and not φ')*, and hence *φ and not φ' and φ'*, which is a contradiction.

Are lexical replacements sufficient to derive all the necessary alternatives? Once it is established that alternatives must be specified in some way, we should ask whether lexical replacements are the way to go. They turn out to be insufficient to derive all the necessary alternatives. Consider again the case of a simple disjunction:

(14) a. John will invite Ann or Mary.
b. Observed primary implicatures
not-*B*(John will invite Ann)
not-*B*(John will invite Mary)
c. Predicted primary implicatures with a scalar set {or, and}
not *B*(John will invite Ann and Mary)

Intuitively, primary implicatures are obtained to the effect that the speaker is not in a position to assert either disjunct. However, with the scalar set {or, and}, a theory based on lexical replacements alone only derives the inference that the speaker is not in a position to assert the corresponding conjunction; importantly, this is not sufficient to exclude the possibility that the speaker asserted (14a) because he believed with certainty that John will invite Ann (as long as the speaker did not *also* believe that John will invite Mary).

The correct result is derived if (14a) has as alternatives *John will invite Ann, John will invite Mary, John will invite Ann and Mary*.[5] The standard procedure to compute alternatives on the basis of lexical replacements cannot derive this result without serious complications (see Sauerland, 2004, for such a procedure; see also Levinson, 1983). We could posit that, in addition to lexical replacements, we allow for alternatives that are obtained by deleting part of a target sentence; in this way, p as well as q could both be alternatives to p or q. However, this solution might pose a dilemma:

- If we stick to the assumption that the relation 'is an alternative of' is symmetric, we obtain absurd results: since p has (p or q) as one of its alternatives, we predict that not p should have an alternative of the form not(p or q) – one which is more informative than not p. Hence, an utterance of not p should yield a secondary implicature that not(p or q) is false and therefore that (p or q) is true; with the assumption that not p, we thus infer that q. This is rather absurd: not p should not in general yield the inference that q (furthermore, note that a similar reasoning with the alternative (p or not q) yields an inference that not q!).
- Of course we could deny that the relation 'is an alternative of' is symmetric. Intuitively, we are willing to say that p is an alternative to (p or p') because it is syntactically simpler; but p should not have as an alternative (p or p'), which is more complex. Still, if we just abandon the symmetry requirement in all cases, our theory will lose some of its predictive force: the implicatures we predicted for conjunctive statements in negative environments, as in (10), were correctly derived on the basis of an analysis of the implicatures triggered by *or*, together with the assumption that if *and* is a lexical alternative of *or*, *or* is also a lexical alternative of *and*. This was a positive result that we would prefer not to lose.

Katzir's procedure I: alternatives for scalar implicatures Katzir (2007) (followed by Katzir and Fox, 2011) provides an elegant way out of the dilemma: his procedure to compute alternatives of a sentence φ allows for all lexical replacements permitted by the standard neo-Gricean procedure; but in addition, it allows sub-constituents of φ to be replaced with other sub-constituents (as well as certain other 'salient' constituents – a point we

[5] One could ask whether it is necessary to have (p and q) as an alternative to (p or q) once p, q are themselves alternatives. Given standard procedures to derive secondary implicatures (see Section 22.2.2), (p and q) turns out to be necessary in order to derive the 'not both' inference. This is not so in all theories, however (cf., e.g., Spector, 2003, 2007b).

disregard in our simplified discussion). Katzir and Fox's version is defined in (15) and (16):

(15) Computation of alternatives
φ' is an alternative of φ if φ' can be derived from φ by successive replacements of sub-constituents of φ with elements of the substitution source for φ in $\mathcal{C}$, $\mathsf{SS}(\varphi, \mathcal{C})$.

(16) Substitution source
$\mathsf{SS}(X, \mathcal{C})$, the substitution source for X in context $\mathcal{C}$, is the union of the following sets:
a. the lexicon
b. the sub-constituents of X
c. the set of salient constituents in $\mathcal{C}$

Since *and, or* are part of the lexicon, alternatives can always be generated by replacing one with the other in a sentence φ – hence, we preserve the alternatives we had in the neo-Gricean analysis. Since p is a sub-constituent of (p or q), it is a member of the substitution source of the latter. Since (p or q) is a sub-constituent of itself, by (16) we can replace it with p and obtain a new alternative, which is just p; and by similar reasoning, q is also an alternative of (p or q). Thus, we obtain the desirable result that each disjunct counts as an alternative to the entire disjunction. Still, we do *not* obtain the undesirable result that (p or q) counts as an alternative to the disjuncts: certainly (p or q) cannot be obtained from p by any substitution operation (unless (p or q) is itself salient in the discourse). In effect, we have preserved the symmetry of the relation 'is an alternative of' for those alternatives obtained by lexical replacements; for those obtained by non-lexical replacements, symmetry is not preserved, which appears to be a good thing.

Once this more sophisticated way of computing alternatives is introduced, we can provide a further truth-conditional argument in favor of scalar implicatures over ambiguity-based treatments of *or*. The observation is that (17) yields an inference that *it's not the case that each of us will invite Ann, and it's not the case that each of us will invite Mary*. This inference is not predicted by the exclusive reading of *or*: (17a-ii) is perfectly compatible with a situation in which each of us is to invite Ann and only her. By contrast, the desired inference is adequately predicted once alternatives are computed *à la* Katzir: *Each of us* (*P* or *Q*) has as alternatives *Each of us P*, *Each of us Q*; hence the result.

(17) Each of us will invite Ann or Mary.
a. Readings predicted by the ambiguity view
(i) Inclusive: Each of us will invite *Ann or Mary or both*.
(ii) Exclusive: Each of us will invite *Ann or Mary but not both*.
b. Readings predicted by the scalar implicature view (with Katzir's procedure)

(i) Literal reading: Each of us will invite *Ann or Mary or both*.
(ii) Strengthened reading:
  i. (b-i), with the primary implicature: not-B (Each of us will invite *Ann*), not-B (Each of us will invite *Mary*), not-B (Each of us will invite *Ann and Mary*)
  ii. (b-i), with the secondary implicature: B not- (Each of us will invite *Ann*), B not- (Each of us will invite *Mary*).

Katzir's procedure II: manner implicatures Katzir's theory has an unexpected benefit: although it was motivated on the basis of scalar implicatures, it predicts some cases of manner implicatures, specifically in cases in which a sentence φ is ruled out because there is an *equally informative* but *syntactically simpler* alternative that should be preferred to it.

To see how this case follows from Katzir's procedure, let us start with the following intuitive principle:

(18) *Conversational principle*: Do not assert φ if there is a better ψ which could have been asserted instead.

Within Katzir's framework, ψ counts as *at least as good as* φ (when the latter is considered) in case ψ is an alternative to φ and ψ is at least as informative as φ:

(19) ψ is *at least as good as* φ when φ is considered, $\varphi \leq \psi$, if (i) ψ is an alternative of φ, and (ii) ψ entails φ.

Naturally, ψ is strictly better than φ ($\varphi < \psi$) just in case $\varphi \leq \psi$ and not: $\psi \leq \varphi$. Given the conjunctive nature of (19), $\psi \leq \varphi$ can fail to hold because either φ is not an alternative of ψ, or it is one but it doesn't entail ψ:

(20) ψ is *better than* φ, $\varphi < \psi$, iff $\varphi \leq \psi$ but not: $\psi \leq \varphi$, iff $\varphi \leq \psi$ and (i) φ is not an alternative of ψ, **or** (ii) φ doesn't entail ψ.

Case (20-i) corresponds to the standard neo-Gricean case: an alternative ψ to φ is better than φ just in case ψ is strictly more informative than φ. Now case (20-ii) is satisfied in a situation in which ψ is equally informative as φ but is syntactically simpler than it, with the effect that ψ is an alternative to φ, but φ is *not* an alternative to ψ; this is the key to account for some violations of Manner. Consider (21): if one utters *The President from Chicago gave a good speech* in a context in which only the President of the United States could be intended, we obtain an odd sentence. Within Katzir's system, the reason is not hard to find: even though in the context at hand both sentences are equally informative, the one with *from Chicago* is strictly more complex and hence worse than its alternative.

(21) a. ?The President from Chicago gave a good speech.
b. The President gave a good speech.

Example (21b) is an alternative to (21a) [replace *President from Chicago* with *President*] but (21a) is not an alternative to (21b). Hence, (21b) is better than (21a) because it is simpler; even though relative to common knowledge, it is not more informative.

How pragmatic is the derivation of alternatives? Even if one adopts Katzir's procedure, context must play a role in the derivation of alternatives; in fact, Katzir explicitly proposes that some constituents must be considered as possible replacements because they are 'salient'. In principle, one could also add further constraints to prevent some replacements to be considered because they are somehow unnatural. This measure might well be necessary: Geurts (2011) observes that (22a) naturally leads to the inference that the speaker was not in a position to assert that he saw a dog – *animal* evokes *dog* as a possible alternative. However, the same reasoning fails in (22b): *dog* does not seem to evoke *poodle* as an alternative (or if it does, no implicature is derived from it). Furthermore, it would be gratuitous to posit a syntactic difference between the two cases.

(22) a. I saw an animal on the lawn this morning.
$\Longrightarrow$ not B I saw a dog on the lawn this morning.
b. I saw a dog on the lawn this morning.
$\not\Longrightarrow$ not B I saw a poodle on the lawn this morning.

Geurts concludes that the difference between the two cases is pragmatic in nature: "if an individual x is introduced as an 'animal', the hearer is likely to wonder what species of animal x is, but if x is introduced as a 'dog', the same question doesn't arise with equal force". The question, of course, is whether in the end a pragmatic procedure that explains *this* fact could not also derive the observations that Katzir's procedure was supposed to handle. For lack of an explicit pragmatic procedure with the required properties, this is a question we are not currently in a position to answer.

22.2.2 Localism vs. globalism

The neo-Gricean view offers (with some amendments) an appealing picture of implicatures, which are derived from the interaction of a theory of linguistic alternatives and a theory of rationality. The latter component is crucially based on the assumption that utterances are acts, and that all other things being equal a more informative utterance is a more cooperative act than a less informative one. But interest in implicatures was revived in the late 1990s when precisely this picture was called into question by Landman (2000), Schwarz (2011b), and most notably Chierchia (2004), who all proposed that (some) implicatures should be integrated to a recursive semantic procedure, and for this reason cannot (easily) be computed with respect to communicative acts. The debate has had numerous twists, and it has led to empirical generalizations and formal theories of great subtlety, making this one of the most dynamic fields in contemporary semantics. We will provide a brief sketch of the main developments.

Initial truth-conditional arguments for localist solutions

Two problems Chierchia (2004) initially produced two kinds of arguments against standard neo-Gricean treatments.

Predictions that are too strong: In some cases, a mechanical application of neo-Gricean recipes yields secondary implicatures that are too strong. Consider, for instance, (23a). It has, among others, the alternative in (23b) – which yields the secondary implicature in (23c). This is clearly absurd: from (23a) we derive the implicature that John is not a musician, and by symmetry we infer just as well that he is not a philosopher or a poet! Furthermore, the problem is entirely general and occurs whenever one of the disjuncts contains a weak scalar term, as is illustrated in (23d).

(23) a. (p or q) or r
(John is a philosopher or he is a poet) or he is a musician
b. (p and q) or r
(John is a philosopher and he is a poet) or he is a musician
c. not (p and q) and not r
d. Asserted: . . . *weak scalar term* . . . or r
Alternative: . . . *stronger scalar term* . . . or r
Implicature: not (. . . *stronger scalar term* . . .) not r

Clearly, a mechanical application of a simple-minded version of the neo- Gricean procedure goes wrong in this case.

Predictions that are too weak: In other cases, standard neo-Gricean predictions are arguably too weak. Chierchia (2004) considers (24a) and (24b), which according to him carry the implicatures in (24a-ii) and (24b-ii), where it seems that the meaning of the minimal clause containing *some* is strengthened (to *some but not all) before* it is composed with the next higher operator.

(24) a. All my students have read some book by Chomsky.
(i) *Predicted implicature*: It's not the case that all my students have read all books by Chomsky.
(ii) *Actual implicature according to Chierchia*: None of my students has read all books by Chomsky.
b. John believes that some students are waiting for him.
(i) *Predicted implicature*: It's not the case that John believes that all students are waiting for him.
(ii) *Actual implicature according to Chierchia*: John believes that not all students are waiting for him.
c. John knows that some students are waiting for him.
Actual presupposition according to Chierchia: some but not all students are waiting for John.

The example in (24c) yields an additional argument, based on presuppositions: according to Chierchia, the sentence presupposes that some but not all students are waiting for John; he suggests that this is expected if the meaning of *some* is strengthened *before* the embedded clause is composed with *know* (a *presupposition trigger*) but that these judgments are unexpected if a standard procedure is adopted. Importantly, some of the judgments given in this section are controversial. However, they have given rise to sophisticated developments in the experimental literature, with the result that the debate is now on a much stronger methodological footing (see Geurts and Pouscoulous, 2009; Chemla and Spector, 2011, for highly relevant experimental discussion, which we do not survey for reasons of space).

A localist treatment A simplified version of the localist treatment offered by Chierchia (2004) is summarized in (25) (Landman, 2000; Schwarz, 2011b, sketch related proposals):

(25) Computation of strengthened meanings with local implicatures
  a. When a non-negative operator is encountered: a 'strong meaning' is obtained by applying
    - the meaning of the operator to the strong meaning of its argument;
    - and possibly adding implicatures triggered by the operator.
  b. When a negative operator is encountered: a 'strong meaning' is obtained by applying
    - the meaning of the operator to the literal meaning of its argument (otherwise the supposedly 'strong' meaning would be weaker than the literal meaning!);
    - and possibly adding implicatures triggered by the operator.

The 'local strengthening' at work in this analysis bears a family resemblance to some ideas of dynamic semantics, where some pragmatic conditions are thought to apply at the level of 'local contexts' (see Section 22.3.2 for discussion). The special treatment of negative operators is motivated by the fact that the 'strong meaning' should never be weaker than the literal meaning – hence, when a negative operator is applied, its argument should never be given a strengthened meaning.

To illustrate (25a) in greater detail, we will consider how it addresses an early challenge, which is to derive the appropriate secondary implicature for *A or B or C*. As shown in (26), we would like to obtain a strong meaning to the effect that *exactly one of A, B, C is true*.

(26) a. Rick is a philosopher or he is a poet or he is a musician.
  b. *Observed implicature*: Rick has at most one of these occupations.

How is the observed implicature to be derived? Doing so with lexical ambiguity is not trivial; for instance, it can be checked that two instances of an exclusive disjunction or^{excl} will not do the trick: $((A\ \mathrm{or}^{excl} B)\ \mathrm{or}^{excl} C)$ turns out to be true, in particular when each of A, B, C is true, because in this case the disjunct (A or^{excl}B) is false while C is true. Furthermore, as we argued at the outset, there are good arguments against positing an exclusive disjunction in the first place. So let us see how the localist view can solve the problem. In this special case, the necessary rules are given in (27), and illustrated in the case at hand in (28) (for notational simplicity, we write φ for the literal meaning of a clause φ, and $\boldsymbol{\varphi^S}$ for its strengthened meaning; note that in the following we use or^{excl} to abbreviate certain truth conditions, not as a primitive element of the vocabulary of English):

(27) Definition of the strong meaning $\boldsymbol{\varphi^S}$ of a clause φ

a. If φ is an elementary clause, its strong meaning $\boldsymbol{\varphi^S}$ is the conjunction of the meaning of φ together with the implicature predicted by the neo-Gricean analysis. In particular:

b. If $\varphi = (A \text{ or } B)$, $\boldsymbol{\varphi^S} = (\mathbf{A^S \text{ or } B^S})$ **and not** $(\mathbf{A \text{ and } B})$

(28) $\psi = A$ or (B or C)

a. *Step 1*: Compute the strong meaning of (B or C)
By (27b), $(\mathbf{B \text{ or } C})^{\mathbf{S}} = (\mathbf{B\ or^{excl}\ C})$

b. *Step 2*: Compute the strong meaning of A or (B or C)
By (27b), $(\mathbf{A \text{ or } (B \text{ or } C)})^{\mathbf{S}} = (\mathbf{A^S \text{ or } (B \text{ or } C)^S})$ **and not** $(\mathbf{A \text{ and } (B \text{ or } C)})$

c. Hence
$\boldsymbol{\psi^S} = (\mathbf{A \text{ or } B(\ or^{excl}\ C)})$ **and not** $(\mathbf{A \text{ and } B\ (\text{ or } C)})$

Readers can check for themselves that the strong meaning obtained in (28b) is equivalent to: exactly one of A, B, C is *true*. But it is essential that the strengthened meaning in (27b) must be obtained by negating the normal rather than the strengthened meaning of (A and B). The alternative, stated in (29), would predict incorrect results: in the case of ((A or B) or C), the strengthened meaning would just be ((A or^{excl} B) or^{excl} C), that is, the incorrect meaning we got in the first place with exclusive disjunction.

(29) a. *Incorrect rule*: If $\varphi = (A \text{ or } B)$,
$\boldsymbol{F^S} = (\mathbf{A^S \text{ or } B^S})$ **and not** $(\mathbf{A^S \text{ and } B^S})$

b. *Incorrect strengthened meaning predicted for*
$\psi = ((A \text{ or } B) \text{ or } C)$: $\boldsymbol{\psi^S} = ((\mathbf{A\ or^{excl}\ B})\ \mathbf{or^{excl}\ C})$

In this case, then, we avoid the first problem noted by Chierchia, namely that sometimes the secondary implicatures predicted by a mechanical neo-Gricean procedure are too strong. Let us now see how we solve the second problem, that of implicatures that were too weak. Since *all of my students, believe* and *know* are all positive operators, we obtain a strengthened meaning for the examples in (24) by composing these operators with the strengthened meaning of their argument (following the rule in (25a)). Writing $\mathbf{some^S}$ for the strong meaning of *some* (= *some but not all*, or even: *some but not most*), we obtain the following strengthened meanings for the relevant sentences; it is clear that they are stronger than the meanings with global implicatures (in addition, (30c) immediately explains why a presupposition of the form *some but not all students are waiting for John* is generated).

(30) a. **All my students have read some^{S} book by Chomsky.**
b. **John believes that some^{S} student is waiting for him.**
c. **John knows that some^{S} student is waiting for him.**

Globalist responses The globalist response to these problems is different. It consists in three main measures (see Spector, 2003, 2006, 2007b; Sauerland, 2004; van Rooij and Schulz, 2004; Sevi, 2005; Russell, 2006).

First, it expands the set of alternatives – for instance using Katzir's procedure, which yields for (p or q) not just (p and q), but also p, q as alternatives. The result is to predict primary implicatures that are at least as strong and sometimes stronger than those predicted by a standard neo-Gricean treatment; this will solve the problem of implicatures that were too weak.

Second, we need an explicit method to explain which primary implicatures become secondary implicatures. It will not do to propose that *all* do. In the case of p or q, a strengthening of not-Bp, not-Bq to B not-p, B not-q respectively would be absurd, as the speaker could not assert that p or q while believing that not-p and also that not-q. Following Sauerland (2004), one can propose a theory in which primary implicatures are strengthened into secondary implicatures just in case this strengthening does not contradict the literal meaning combined with all primary implicatures. In some cases, this measure combined with the first step ('more alternatives') will have the effect of *weakening* the secondary implicatures that are derived in a naive neo-Gricean procedure: with more alternatives, we generate more primary implicatures; however, this also means that more potential strengthenings into secondary implicature will be ruled out for fear that they contradict these primary implicatures. This might solve the problem of secondary implicatures that were too strong.

The spirit of Sauerland's procedure is simple: we start by generating all the primary implicatures of a sentence φ; then we strengthen a primary implicature of the form not-$B\varphi'$ into B not-φ' just in case this strengthening does not contradict the literal meaning (more precisely: the epistemic statement $B\varphi$), combined with the primary implicatures, of the form not-$B\varphi'_1$, not-$B\varphi'_2$, etc. We illustrate this procedure for p or q:

(31) Primary and secondary implicatures of p or q
a. Asserted: p or q
hence by Quality: $B(p$ or $q)$
b. Primary implicatures: not-Bp, not-Bq, not-$B(p$ and $q)$
c. Secondary implicatures:
If compatible with (31a) and (31b), strengthen not-$B\varphi$ to B not-φ

- Can we get B not (p and q)? Yes: this is coherent, and it is the secondary implicature we in fact want.
- Can we get B not-p? No: if $B(p$ or $q)$ and B not-p, it must be that Bq, which contradicts (31b).
- Can we get B not-q? No: Same reason.

For p or q, we get exactly the results we want. It can be shown that in the case of the multiple disjunction ((p or q) or r), this procedure derives the correct primary implicatures, and also the correct secondary implicature, namely that at most one of p, q, r is true. Briefly, the reason is that Katzir's procedure in (15) yields, among others, the following alternatives:

- (p and r): in ((p or q) or r), replace (p or q) with p, and replace the remaining *or* with *and*;
- (q and r): same reasoning;
- (p and q): replace (p or q) with p and r with q; then replace *or* with *and*. It turns out that each of these alternatives can be negated without contradicting any of the primary implicatures, in particular that not Bp, not Bq, not Br. When all three alternatives are negated in this way, we get a strengthened reading to the effect that exactly one of p, q, r is true – as desired (though showing this rigorously would require a longer discussion).

Importantly, this derivation was offered on the basis of mechanisms that are independently motivated: (a) we enriched the set of alternatives of φ or ψ to include φ, ψ in order to get the primary implicatures of disjunction; (b) once this move was made, the mechanism to derive secondary implicatures *had* to be made more sophisticated: negating φ, ψ in a secondary implicature would have led to a contradiction. So it seems that the globalists can justifiably claim that, in this case at least, they have a good way to solve the problem of implicatures that were too strong.

There is also a third component to the globalist response, which is essential to address the problem of some overly weak implicatures (Spector, 2006). The main idea is that implicatures are obtained by negating not just more informative alternatives, but more generally non-weaker ones, that is, ones not entailed by the literal meaning and which, for this reason, can be negated coherently. To see this procedure at work, consider (32a), with the strengthened reading predicted by localist accounts in (32b). For simplicity, we restrict attention to the set of alternatives generated on the basis of the lexical alternatives *some*, *each*.

(32) a. Each of my students has read some book by Chomsky.
b. Each of my students has read some^{S} book by Chomsky.
c. Alternatives of (b)
(i) Each of my students has read each book by Chomsky.
(ii) Some of my students have read some book by Chomsky.
(iii) Some of my students have read each book by Chomsky.

Consider the alternatives in (32c-i)–(32c-iii). (32c-ii) is entailed by (32a), and hence it cannot yield a primary implicature. (32c-i) yields an uncontroversial primary and secondary implicature – the latter to the effect that *not every student has read every book by Chomsky*; however, this is not enough to emulate the strong localist reading represented in (32b). By negating (32c-iii) (i.e., by deriving from it a primary and then a secondary implicature), however, we do obtain the desired result: each of my students has read some book by Chomsky, and none of them has read all books by Chomsky; in other words, each of my students has read some but not all books by Chomsky, which is precisely the localist reading represented in (32b).[6]

Importantly, this result can only be achieved if non-weaker alternatives can be negated in addition to stronger ones, since it is immediate that (32c-iii) does not entail (32a). But how can we make sense of this assumption within a Gricean framework? The question is rather open: it is unclear why one could take an alternative that is not stronger than the original sentence to count as 'better' than it. Still, there is a way out, albeit of a somewhat stipulative nature (but see Spector, 2003, 2007b). Let us assume that, in addition to the alternatives φ' to a sentence φ, obtained by Katzir's procedure, we generate the *conjunction* of *φ and φ'* of the original sentence with each of these alternatives. Applying this procedure, we would in particular obtain for (32a) an alternative of the form *Each of my students has read some book by Chomsky, and some have read each.* It is immediate that *this* alternative asymmetrically entails (32a) ((φ and φ') clearly entails φ!); thus, we can remain faithful to the Gricean idea that only stronger alternatives are considered as better than the original sentence. On the down side, however, this analysis forces us to consider alternatives that are considerably more complex than the sentence uttered, which goes against the common intuition that only alternatives that are 'not too complex' are considered.

Going back to the issue of overly weak implicatures, we still have not given a procedure to emulate the strong localist reading of (30b), repeated in (33).

(33) John believes that some$^{\mathrm{S}}$ student is waiting for him.

The problem is that there is no reasonable alternative to *believe* that could play the role of the *some* alternative in (32c-iii). So a different line is sometimes taken here (Spector, 2006, followed by Geurts, 2011; see also Russell, 2006): the rough idea is that attitude verbs have a quotational component, and that the use of an embedded clause with *some* suggests that this roughly corresponds to the sentence that the agent had in mind. Note that when the attitude verb is *say* this line of thought has clear plausibility, but when the verb is *believe*, this line is not trivial to develop (e.g., we would need to say that the speaker asserts (33) because John asserted the embedded clause, which in turn triggers a *not all* implicature); we leave this point open.

6 For simplicity, we just worked with the scale {some, each}, but we could have emulated a local implicature just as well with the scale {some, most, each}.

So far we have emphasized cases in which the same predictions can be achieved by localist and by sophisticated globalist treatments. However, in the general case the two approaches make very different truth-conditional predictions, and thus the debate can and should be decided on empirical grounds (it would also be desirable to have *general* results of equivalence in subclasses of cases). To see a clear situation where the predictions differ, consider (34), investigated with experimental means in Chemla and Spector (2011).

(34) Exactly one student solved some of the problems.

Chierchia's version (2004) of the localist theory predicts that (34) has a strong reading with a local implicature, as in (35a), paraphrased in (35b) (here we apply (25a), using the fact that *exactly one student* is a non-monotonic operator and is for this reason non-negative).

(35) a. Exactly one student solved some^{S} of the problems.
b. Exactly one student solved some but not all of the problems.

Importantly, this strengthened reading does *not* entail the literal reading of (34) (precisely because *exactly one student* is not upward-monotonic). Furthermore, in the globalist approach, strengthened readings are *always* obtained by adding some implicatures to the literal meaning; hence, they always entail the latter. In other words, in this case a localist approach makes a prediction that could not be matched by a globalist approach.

Conversely, sophisticated globalist approaches predict for (34) a strong reading that cannot be emulated by unsophisticated localist approaches:

(36) a. *Alternative of (34)*: Exactly one student solved each of the problems.
b. *Strengthened reading (globalist view, with negation of non-weaker alternatives)*: Exactly one student solved at least one of the problems, and it's not the case that exactly one student solved each of the problems; *or in other words*: exactly one student solved at least one of the problems, and that student didn't solve each of the problems.

To obtain this reading, non-weaker alternatives must be negated. A localist analysis without such a mechanism could not derive this reading; notice in particular that (35b) does not entail (36b), since (35b) does not entail the literal reading which is strengthened in (36b).

Indirect arguments

As we just saw, it is in principle possible to tease apart the truth- conditional predictions of localist and of recent globalist accounts, but this is by no means trivial. Two further arguments, of an indirect nature, were adduced in the literature (one of them turns out to have subtle truth-conditional reflexes as well). For simplicity, we will henceforth represent the strong meaning of a clause by inserting an exhaustivity operator *Exh* at the beginning of the relevant constituent; the semantics of the exhaustivity operator is further explored in the next subsection. (*Exh* has a semantics similar to the word *only*, with some differences that we will discuss later.)

An argument from intervention effects One can reconstruct from Chierchia 2004 an argument in favor of locally computed implicatures on the basis of intervention on the licensing of negative polarity items (NPIs).

The first observation is that, as a first approximation, an NPI is licensed as soon as it is in an environment which is semantically negative (downward-monotonic) with respect to at least one constituent – and this environment may but need not be the entire sentence.[7] The basic effect is seen in (37c), where the NPI *any wine* is licensed despite the fact that the whole sentence is positive (the two negations cancel each other out); still, with respect to the embedded clause the environment is negative, and this suffices to license the NPI.

(37) a. #There is any wine left.
b. There isn't any wine left.
c. It's not true that there isn't any wine left.

The second observation is that implicatures count when one determines whether an environment is semantically negative or not. This explains, for instance, the following contrast:

(38) a. I doubt that Theo drank the leftover wine or any coffee.
b. *I doubt that Theo drank the leftover wine and any coffee.

Example (38b) is deviant because *I doubt that p and q* triggers the implicature that *I don't doubt that p or q*. When the strengthened meaning is computed, *any* does not appear in a negative environment any more: the standard test for downward-monotonicity (truth preservation from the superset *coffee* to the subset *decaf coffee*) fails in (39b) (which contrasts with (39a), which only takes into account the literal meaning).

(39) a. I doubt that Theo drank the leftover wine and coffee.
$\Longrightarrow$ I doubt that Theo drank the leftover wine and decaf coffee.
b. I doubt that Theo drank the leftover wine and coffee, but I don't doubt that Theo drank the leftover wine or coffee.
$\not\Longrightarrow$ I doubt that Theo drank the leftover wine and decaf coffee, but I don't doubt that Theo drank the leftover wine or decaf coffee.

Importantly, while the existence of implicatures yields a natural explanation of the contrast, it is entirely unclear why the implicatures in question cannot be canceled in order to 'save' these constructions; we leave this

[7] Our description is a simplification; see Homer (forthcoming) for a far more detailed analysis (see also Israel, 2004).

question aside in what follows (a related problem is briefly discussed in Section 22.3).

The third observation, which is implicit in Chierchia's work, is that the same intervention effect can be found with respect to embedded constituents:

(40) a. John thinks that [<u>I doubt that Theo drank the leftover wine or any coffee</u>].
b. #John thinks that [I doubt that Theo drank the leftover wine and any coffee].
c. [John thinks that Exh[I doubt that Theo drank the leftover wine and any coffee]].
d. Exh[John thinks that <u>I doubt that Theo drank the leftover wine and any coffee</u>].

In (40a), the NPI must be licensed with respect to the underlined clause. The licensing fails in (40b). This follows if a local implicature is computed, as in (40c). By contrast, the facts are surprising if no implicature is computed, or only a global one, as in (40d): not being targeted by a local implicature, the underlined clause should license the NPI. (Here too, what is *not* explained is why the presence of the embedded exhaustivity operator is somehow obligatory.)

An argument from Hurford's constraint Chierchia et al. (2011) make another indirect argument in favor of local implicatures (see Sauerland, 2012, for important extensions). It has the following structure: A disjunction (φ or ψ) is deviant if ψ entails φ (*Hurford's constraint*). This is represented schematically in (41):

(41) # . . . φ or ψ . . . if ψ entails φ

Nevertheless, there are cases in which φ contains a scalar item and the effect *fails* to arise. This can be explained if a local implicature strengthens φ to Exh φ, which fails to be entailed by ψ – as is represented in (42):

(42) . . . [Exh φ] or ψ . . . , where ψ entails φ but ψ does not entail Exh φ.

Basic instances of Hurford's constraint are illustrated in (43); its obviation is illustrated in (44):

(43) a. #John lives in France or in Paris.
b. #Mary saw a dog or an animal.

(44) a. Mary solved [the first problem or the second problem] or both problems.
b. Mary read some of or she read all the books.
c. Either the first year students came or all of the students came.

Chierchia et al.'s analysis appeals to local implicatures, as shown in (45):

(45) a. Exh[Mary solved the first problem or the second problem] or both problems.
b. Exh[Mary read some of the books] or she read all the books.
c. Either Exh[the first year students came] or all of the students came.

Consider, for instance, (44b), of the form φ or ψ with $\varphi =$ *Mary read some books* and $\psi =$ Mary read all the books. It is clear that ψ entails φ, and hence if we restricted attention to the literal meanings of the disjuncts, we would be in violation of Hurford's constraint in (41). However, with a local implicature added to the first disjunct, the problem disappears: with the scalar set {some, all}, the first disjunct becomes equivalent to *Mary read some but not all of the books*, and this is clearly not entailed by the second disjunct.

Chierchia et al. adduce a truth-conditional argument to further buttress their conclusion. Consider (44c), which they claim must have the representation in (45c) in order to circumvent a violation of Hurford's constraint. Without the embedded exhaustivity operator, the sentence would be equivalent to its first (i.e., weakest) disjunct, i.e., to: *(at least) the first year students came*. On the assumption that alternatives to the first disjunct include *the second year students came, the third year students came*, the exhaustivity operator (which negates non-weaker alternatives) will yield for the first disjunct a meaning akin to *only the first year students came*, with the effect that the entire disjunction entails that one of the following incompatible states of affairs holds:

- The first year students and no others students came.
- All the students came.

Chierchia et al. argue that the latter truth conditions are in fact found, which supports their analysis.[8]

In addition, Chierchia et al. argue that an embedded exhaustivity operator can have an effect on the implicatures triggered by the sentence it finds itself in. This is an important point because it suggests that the exhaustivity operator, which up to this point was just a notational convenience to encode the presence of locally computed implicatures, might have syntactic reality, at least if the alternatives are themselves computed by modifying the form of the target sentence. Consider the contrast in (46):

(46) a. Every student [is a syntactician or a semanticist].
does not *implicate*: at least one student is both a syntactician and a semanticist

[8] To detect this truth-conditional effect, it is essential that the exhaustivity operator present in the first disjunct should exclude more alternatives than just the second disjunct; for this reason, a similar truth-conditional effect will not be found in (44a); it will be found in (43b) with the scalar set {some, most, all}, but not with the scalar set {some, all}.

b. Every student is [[a syntactician or a semanticist] or both].
implicates: at least one student is both a syntactician and a semanticist

The explanation of the contrast can be found once we take into account the embedded exhaustivity operator needed to circumvent Hurford's constraint:

(47) a. Every student is [Exh[a syntactician or a semanticist] or both].
b. *Alternative 1*: Every student is Exh[a syntactician or a semanticist].
c. *Alternative 2*: Every student is both a syntactician and a semanticist.

On the assumption that it is syntactically real, Exh will be found in the alternatives to (47a), which include (by Katzir's procedure in (15)) (47b) and (47c). Negating (47b) yields (with (47a)) the inference that at least one student is both a syntactician and a semanticist.

Constraints on embedded implicatures Proponents of embedded implicatures must somehow constrain the mechanism by which they are generated; if local implicatures are cashed out in terms of the embedded insertion of Exh, its distribution must be limited. In particular, it is usually thought that embedded implicatures are dispreferred if their effect is to weaken the literal meaning of a sentence; for this reason, they are thought not to appear easily in downward-monotonic environments. This is in fact essential to account for some of the examples we started out with: we argued in (8a) that an ambiguity theory of disjunction could not account for the *lack* of ambiguity of *or* in semantically negative environments; but if exhaustivity operators could be inserted at will, we would generate all the readings obtained on the ambiguity view. To avoid this undesirable consequence, we must somehow rule the representations in (48) as unacceptable or at least dispreferred.

(48) a. *I doubt that Exh[John will invite Ann or Mary].
b. *Whenever John invites Exh[Ann or Mary], his parties are a success.

Arguably, the facts are different when *or* is focused, in which case many more 'embedded' readings arise. This highlights the importance of the relation between scalar implicatures and theories of focus – a topic we cannot discuss in the present survey (see Spector and Fox, forthcoming, for discussion).

Variety of exhaustivity operators

When it has matrix scope, the exhaustivity operator can be seen as a convenient way to encode secondary implicatures, irrespective of the view (globalist or localist) that one has on how they are generated.[9] When it is embedded, Exh serves to represent local implicatures, and it is taken to

[9] This section is intended for readers interested in issues of technical implementation.

have syntactic reality by some analyses. But what is its precise semantics? A standard intuition is that Exh has the same semantics as the focus-sensitive particle *only*, with the difference that the latter has presuppositions that the former lacks, in particular a presupposition that at least one alternative is true (e.g., *Will John only invite Mary?* triggers the inference that John will invite someone).[10] This connection with *only* is important for two reasons: it has made it possible to borrow from theories of *only* lexical entries for the exhaustivity operator, and it highlights the connection between implicatures and focus – a connection which should not come as a surprise since both are based on the consideration of alternatives to a sentence uttered.

Three main lexical entries have been proposed in the literature for the exhaustivity operator. The first, which we call $\mathrm{Exh_S}$, is Fox's (2007) reconstruction of Sauerland's (2004) procedure to compute secondary implicatures. The second one, $\mathrm{Exh_{MM}}$, originates in van Rooij and Schulz (2006), who partly follow Spector (2003) and build on Groenendijk and Stokhof's (1984) analysis of *only*, as well as ideas developed in artificial intelligence by McCarthy (1980, 1986) (see also Sevi, 2005). The last one, $\mathrm{Exh_F}$, results from Fox's (2007) attempt to combine empirical advantages of both operators.

(49) If φ is a proposition and Alt is its set of alternative propositions:
   a. $\mathrm{Exh_S}(\varphi, \mathrm{Alt}) = \{w \mid \varphi$ is true in w
      and for every $\varphi' \in \mathrm{Alt}$, if φ does not entail φ', and
      $\neg\exists\varphi'' \in \mathrm{Alt}$ s.t. φ doesn't entail φ'' and (φ and not φ') entails φ'',
      then φ' is false in $w\}$.
   b. $\mathrm{Exh_{MM}}(\varphi, \mathrm{Alt}) = \{w \mid \varphi$ is true in w and $\neg\exists w'$ s.t.
      φ is true in w' and $w' <_{\mathrm{Alt}} w\}$, where for all worlds w', w:
      $w' <_{\mathrm{Alt}} w$ iff $\{\varphi' \mid \varphi' \in \mathrm{Alt}$ and φ' is true in $w'\} \subset \{\varphi' \mid \varphi' \in$
      Alt and φ' is true in $w\}$ (where $\subset$ is strict inclusion).
   c. $\mathrm{Exh_F}(\varphi, \mathrm{Alt}) = \{w \mid \varphi$ is true in w
      and for every $\varphi' \in \mathrm{IE}(\varphi, \mathrm{Alt})$, φ' is false in $w\}$,
      where $\mathrm{IE}(\varphi, \mathrm{Alt}) = \cap\{A \subseteq \mathrm{Alt} \mid A$ is a maximal subset
      of Alt such that $A \cup \{\varphi\}$ is consistent$\}$, where $A = \{\neg p \mid p \in A\}$.
      Terminology: $\mathrm{IE}(\varphi, \mathrm{Alt})$ is the set of 'innocently excludable
      alternatives'.

We will briefly discuss these operators in turn.

The definition in (49a) is in two steps, following Sauerland's procedure: (i) we consider each of the alternatives φ' to φ which is not entailed by φ – and thus can give rise to a primary implicature of ignorance; (ii) we negate φ' to obtain a secondary implicature, unless doing so contradicts the literal

[10] Another presupposition triggered by *only* is that the alternative which is asserted to be true is low on some salient scale. For instance, *Does John only earn $1 million a year?* makes the (non-standard) presupposition that $1 million a year is a small amount of money.

meaning φ together with some other primary implicature.[11] This operator encounters a problem, however: while it is checked that each secondary implicature *on its own* does not contradict any primary implicature combined with the literal meaning, there is no guarantee that the secondary implicatures *taken together* will not have such an undesirable consequence. Under certain assumptions, this problem does arise in (50), as analyzed in (51):

(50) –Who did Fred talk to? –Some GIRL. (Fox, 2007)

(51) Assume that there are three girls in the domain of discourse and that the alternatives we have are: {Fred talked to some girl, Fred talked to g_1, Fred talked to g_2, Fred talked to g_3}, abbreviated as: $\{p, g_1, g_2, g_3\}$.
a. Primary implicatures: not Bg_1, not Bg_2, not Bg_3
b. Secondary implicatures: B not g_1, B not g_2, B not g_3

In (51), each of g_1, g_2, g_3 can be coherently negated given the primary implicatures (this is so because there are more than two individuals that are quantified over: knowing that Fred did not talk to one does not imply that one knows who he in fact talked to). However, taken together, these negations imply that Fred talked to none of the three girls – which contradicts the literal meaning.

The minimal model operator in (49b) is designed to avoid this problem, among others. A world w' is taken to be 'smaller' or 'more minimal' than a world w (in symbols: $w' <_{\text{Alt}} w'$) relative to the set of alternatives Alt just in case w' makes fewer members of Alt true than w where *fewer* is construed, as is standard, in terms of proper subset-hood). With this definition, the minimal model operator applied to S only keeps from the worlds that satisfy S those that are minimal relative to Alt, i.e., that make false as many alternatives as possible. In simple cases, such as a disjunction p or q, this operator derives the results of the standard analysis: with the alternatives p, q, p and q, the minimal worlds satisfying the disjunction are those that make true exactly one of the disjuncts:

[11] To be more precise, we wish to avoid the case in which for some non-entailed alternative φ'' to φ,

(i) for every belief operator B, $B(\varphi$ and $\neg\varphi') \Longrightarrow B\varphi''$

(i) corresponds precisely to the case in which strengthening $\neg B\varphi'$ to $B\neg\varphi'$ has as a necessary consequence that some other primary implicature $\neg B\varphi''$ is contradicted (on the assumption the literal meaning of φ is believed). Assuming that belief operators are closed under logical consequence, we have the following equivalence:

(ii) i. iff
a. for every belief operator B, $B(\varphi$ and $\neg\varphi') \Longrightarrow \varphi'')$, iff
b. $\models (\varphi$ and $\neg\varphi') \Longrightarrow \varphi''$

(ii-b) immediately entails (ii-a). For the converse, notice that $\models$ (i.e., logical validity) counts as a belief operator, representing the epistemic state of an agent with no beliefs whatsoever, one who thus believes a proposition just in case it is *a priori* true.

(52) a. $\varphi = p$ or q
b. Alt $= \{p, q, p$ and $q\}$
c. $\text{Exh}_{\text{MM}}(\varphi, \text{Alt}) = \{w \mid \varphi$ is true in w and $\neg\exists w' \mid \varphi$ is true in w' and $w' <_{\text{Alt}} w\} = \{w \mid$ exactly one of p, q is true in $w\}$

However, in the case of (51) the minimal models operator avoids the problem encountered by Sauerland's operator: the minimal worlds that satisfy the literal meaning are those that make true exactly one of the alternatives g_1, g_2, g_3 – as is desired:

(53) a. $\varphi =$ Fred talked to some girl
b. Alt $= \{g_1, g_2, g_3,$ Fred talked to every girl$\}$
c. $\text{Exh}_{\text{MM}}(\varphi, \text{Alt}) = \{w \mid \varphi$ is true in w and $\neg\exists w'$: φ is true in w' and $w' <_{\text{Alt}} w\} = \{w \mid$ exactly one of g_1, g_2, g_3 is true in $w\}$

Still, this operator, as well as Sauerland's, encounters difficulties in another case which we have not discussed at all so far, that of *free choice permission*, illustrated in (54):

(54) a. You may have tea or coffee.
Inference: You may have tea and you may have coffee.
b. Some passengers got sick or had trouble breathing. (Klinedinst, 2007)
Inference: Some passengers got sick and some passengers had trouble breathing.

Space does not allow us to do justice to the important recent literature on this topic (Schulz, 2005; Aloni, 2007; Aloni and van Rooij, 2007; Barker, 2010; Franke, 2010). For present purposes, the important observation is that (54a), which is of the form *may (p or q)*, gives rise to an inference that *may p* and *may q* ((54b) has a similar structure, but with an existential quantifier replacing the existential modal). Now with Katzir's procedure to generate alternatives, *may p* and *may q* are alternatives to *may (p or q)*, and hence in Sauerland's system we obtain a primary implicature *not B may p*, as well as *not B may q*. Alas, this squarely contradicts the inference we intuitively derive. The minimal models approach does not do any better, as it implies that exactly one of *may p, may q* is true – which contradicts the inference we find, as shown in (55c).

(55) a. $\varphi =$ may (p or q)
b. Alt $= \{$may p, may q, may (p and q)$\}$
c. $\text{Exh}_{\text{MM}}(\varphi, \text{Alt}) = \{w \mid \varphi$ is true in w and $\neg\exists w'$: φ is true in w' and $w' <_{\text{Alt}} w\} = \{w \mid$ exactly one of *may p*, *may q* is true in $w\}$
d. $\text{Exh}_{\text{S}}(\varphi, \text{Alt}) = \{w \mid \varphi$ is true in w and *may*(p and q) is false in $w\}$

Interestingly, Sauerland's operator in (49a) does not lead to this problem. The reason is the following: *not B may p* and *not B may q* are generated as primary implicatures; however, *not may p* is *not* generated as a secondary implicature: if it were, we could infer from *may (p or q)* that *may q*, which would contradict the primary implicature *not may q*. By a symmetric argument, *not may q* is not generated as a secondary implicature. Now this suggests that if we take Sauerland's to have some reality independent from the pragmatic procedure that Sauerland sketches (so that we can have the secondary implicature without having the primary implicatures!), we might have a chance of solving the free choice puzzle. Fox (2007) takes one additional step: he notices that when Sauerland's is iterated, it gives rise to exactly the inference we want, as is seen in (56) (since we now need to put the operator in the object language, we write it as $\mathrm{Exh}_S^{Alt}\,\varphi$; for simplicity, we disregard the alternative generated by replacing *may* with *must*):

(56) a. $\varphi = \text{may}\ (p \text{ or } q)$
b. $\text{Alt} = \{\text{may } p, \text{may } q, \text{may } (p \text{ and } q)\}$
c. $\mathrm{Exh}_S(\varphi, \text{Alt}) = \{w \mid \varphi \text{ is true in } w \text{ and may } (p \text{ and } q) \text{ is false in } w\}$
d. $\varphi' = \mathrm{Exh}_S^{Alt}\ \text{may}\ (p \text{ or } q)$
e. $\text{Alt}' = \{\mathrm{Exh}_S^{Alt}\ \text{may } p, \mathrm{Exh}_S^{Alt}\ \text{may } q, \mathrm{Exh}_S^{Alt}\ \text{may } (p \text{ and } q)\}$
f. $\mathrm{Exh}_S(\varphi', \text{Alt}') = \{w \mid \varphi \text{ is true in } w \text{ and may } (p \text{ and } q) \text{ is false in } w \text{ and } \mathrm{Exh}_S^{Alt}\ \text{may } p \text{ is false in } w \text{ and } \mathrm{Exh}_S^{Alt}\ \text{may } q \text{ is false in } w\}$

The result is derived as follows: the alternatives to $\varphi' = \mathrm{Exh}_S^{Alt}$ may (p or q) are Exh_S^{Alt} may p, Exh_S^{Alt} may q, Exh_S^{Alt} may (p and q). The last one is equivalent to *may (p and q)*, which is already excluded by the literal meaning of φ'. The first and the second have the meaning *only may p, only may q* – and both can be denied coherently. We end up with a meaning akin to: (a) literal meaning of φ': *may (p or q)* but not *may (p and q)*; (b) contribution of exhaustification: it is not the case that *only may p*, it is not the case that *only may q* – hence, *both may p and may q*. This is precisely the result we want.

In Fox's final analysis, the exhaustivity operator is syntactically realized and can be iterated under certain circumstances. If one uses Sauerland's operator, the reduplicated exhaustivity operator derives the desired free choice inference. Fox also offers a solution to the problem he noted in (50)/(53) (*Who did Fred talk to? –Some GIRL*). The operator in (49c) is intended to retain the good properties of Sauerland's operator (when iterated) while addressing this initial problem. In a nutshell, Fox's operator works in two steps:

- We first determine what are the maximal subsets of Alt whose members can be coherently denied in the presence of S.
- Second, we end up denying those alternatives that are in each of these maximal subsets (intuitively, this is to avoid the case in which we are forced to make 'arbitrary choices' among the alternatives we choose to deny).

Readers can check this has the desired effect in (50)/(53): the maximal set of alternatives whose members we can coherently deny are $\{g_1, g_2\}$,$\{g_2, g_3\}$, $\{g_1, g_4\}$, but they have a null intersection; hence, we get no secondary implicature, and we do not run into the problem encountered with Sauerland's procedure. For (56d), we can – with some computations – derive the free choice inference *may p and may q* just as well with Fox's operator as with Sauerland's (but see Schulz, 2005 and Aloni and van Rooij, 2007 for an account of free choice based on minimal models).

To summarize, here are some of the main motivations for each operator:

(57) a. $\mathrm{Exh}_{\mathsf{S}}$
- derives Sauerland's secondary implicatures;
- encounters problems with *Fred talked to some girl* (all the strengthenings together might be contradictory);
- iterated, can account for free choice readings.

b. $\mathrm{Exh}_{\mathsf{MM}}$
- is based on 'mimimal models';
- has no problem with *Fred talked to some girl*;
- cannot account for free choice readings.

c. $\mathrm{Exh}_{\mathsf{F}}$
- is a refinement of $\mathrm{Exh}_{\mathsf{S}}$;
- has no problem with *Fred talked to some girl*;
- can account for free choice readings.

For readers who might want to delve into this topic in greater detail, we provide a preliminary description of the logical relations that hold among these exhaustivity operators (see Spector, forthcoming, for a detailed treatment):

(58) Logical relations among operators (further results can be obtained, for instance, when additional constraints are introduced on sets of alternatives). We write $F \geq G$ for: *F is at least as strong as G* and $F > G$ for: *F is at least as strong and sometimes stronger than G*.

a. $\mathrm{Exh}_{\mathsf{MM}}(\varphi, \mathrm{Alt}) > \mathrm{Exh}_{\mathsf{F}}(\varphi, \mathrm{Alt})$
Reason: It can be shown (Spector) that $\mathrm{Exh}_{\mathsf{F}}(\varphi, \mathrm{Alt}) = \{w \mid \varphi$ is true in w and for all $p \in \mathrm{Alt}$, (if $\mathrm{Exh}_{\mathsf{MM}}(\varphi, \mathrm{Alt})$ entails $\neg p$, p is false in w)$\}$.

b. $\mathrm{Exh}_{\mathsf{S}}(\varphi, \mathrm{Alt}) > \mathrm{Exh}_{\mathsf{F}}(\varphi, \mathrm{Alt})$
Reason: Suppose φ' is negated by $\mathrm{Exh}_{\mathsf{F}}(\varphi, \mathrm{Alt})$. Then $\{\varphi, \neg\varphi'\}$ is consistent; hence φ' isn't entailed by φ. Furthermore, there couldn't be an $\varphi'' \in \mathrm{Alt}$ s.t. (a) φ doesn't entail φ'' and (b) (φ and not φ') entails φ'', for if so $\{\varphi, \neg\varphi''\}$ would be consistent but $\neg\varphi'$ couldn't be contained in any maximal superset A of $\{\varphi''\}$ such that $A \cup \{\varphi\}$ is consistent. Therefore, φ' is negated by $\mathrm{Exh}_{\mathsf{S}}(\varphi, \mathrm{Alt})$ – and $\mathrm{Exh}_{\mathsf{S}}(\varphi, \mathrm{Alt}) \geq \mathrm{Exh}_{\mathsf{F}}(\varphi, \mathrm{Alt})$. In the case of (51), $\mathrm{Exh}_{\mathsf{S}}$ yields a

contradiction but Exh_F doesn't; hence, in the end $\text{Exh}_\text{S}(\varphi, \text{Alt}) > \text{Exh}_\text{F}(\varphi, \text{Alt})$.

c. It is not in general the case that $\text{Exh}_\text{MM}(\varphi, \text{Alt}) \geq \text{Exh}_\text{S}(\varphi, \text{Alt})$, nor that $\text{Exh}_\text{F}(\varphi, \text{Alt}) \geq \text{Exh}_\text{S}(\varphi, \text{Alt})$.
Reason: In (53), Exh_S yields a contradiction but the other two operators don't.

d. It is not in general the case that $\text{Exh}_\text{S}(\varphi, \text{Alt}) \geq \text{Exh}_\text{MM}(\varphi, \text{Alt})$.
Reason: Consider $\varphi = (p \text{ or } q)$, and take $\text{Alt} = \{(p \text{ or } q), p, q\}$ (without $(p \text{ and } q)$).

22.2.3 Further questions

We end this section with some important questions for current and future research.[12]

Grounding implicature theory

- From a globalist neo-Gricean perspective, there are important recent attempts to ground scalar reasoning in an explicit theory of rationality. An early proposal can be found in Spector (2003). More recent attempts use the tools of cooperative game theory; see Franke (2011) and Rothschild (2013) for discussion. The hope is that the choice among the various exhaustivity operators could be made on the basis of an independently motivated theory of rationality.
- From a localist perspective, several issues are open. (i) The distribution of the exhaustivity operator has yet to be constrained in a principled way. (ii) So far the literature is compatible with two interpretations of it: according to one, there is an operation of *semantic enrichment* that does *not* require the presence of an operator in the syntax; according to the other, the operator is really syntactically represented. The latter might be at an advantage to deal with (47), where the embedded exhaustivity operator has a consequence on the *alternatives* which are considered; however, the issue is still quite open. (iii) The very *existence* of the exhaustivity operator – or of the corresponding operation of semantic enrichment – is not very well motivated conceptually, though its proponents have provided quite a bit of empirical evidence for it. Unlike globalist theories, which might find some grounding in a theory of communicative rationality, localist theories are not currently derived from more primitive considerations; more foundational work might be helpful on this point.

[12] In addition to these, one would need to go back to examples such as (26) and explain how the exhaustivity-based approach can avoid generating a reading equivalent to $((A \text{ or}^{\text{excl}} B) \text{ or}^{\text{excl}} C)$. Couldn't one be obtained with the Logical Form $\text{Exh}_2(\text{Exh}_1(A\ or_1\ B)\ or_2\ C)$? As B. Spector (p.c.) notes, the answer depends in part on the alternatives each exhaustivity operator has access to. For instance, taking the minimal models operator discussed in (49b) ($\text{Exh}_{MM'}$), we will obtain the wrong results if Exh_1 operates on $\{A, B\}$ and their conjunction, while Exh_2 operates on $\{\text{Exh}_1(A\ or\ B), C\}$ and their conjunction, as this would yield a reading equivalent to $((A \text{ or}^{\text{excl}} B) \text{ or}^{\text{excl}} C)$. Things are different if Exh_1 operates on $\{A, B\}$ and their conjunction, while Exh_2 operates on $\{A, B, C\}$ and their conjunctions: the minimal worlds (according to Exh_2) satisfying $\text{Exh}_2(\text{Exh}_1(A\ or_1\ B)\ or_2\ C)$ would end up being those that satisfy exactly one of $\{A, B, C\}$, as is desired.

Proponents of *truth-conditional pragmatics* (see Recanati, 2010, for recent references) suggest an interesting connection with other cases of *pragmatic enrichment* that take place before the post-compositional level. One example is *predicate transfer* (Nunberg, 1995), which in Recanati's words (2010) takes us "from a certain property, conventionally expressed by some predicative expression, to a distinct property bearing a systematic relation to it", as is illustrated in (59).

(59) a. I am parked out back.
$\Longrightarrow$ parked out back undergoes transfer to denote a property of cars rather than of individuals.
b. The ham sandwich left without paying.
$\Longrightarrow$ ham sandwich undergoes transfer to refer to an individual who ordered a sandwich.
c. There is a lion in the courtyard.
$\Longrightarrow$ lion can undergo transfer to refer to a representation of a lion (e.g., a statue).

Proponents of truth-conditional pragmatics suggest that local implicatures should be seen in this broader class of pragmatic enrichments.

- As was mentioned in passing, the theory of scalar implicatures is intimately connected to the theory of focus and the theory of questions: all three make crucial use of 'alternative semantics', and the last two might give a clue to the nature of the alternatives.

Further topics

Numerals When standard tests for implicatures are applied, numerals show a dual behavior: they do give rise to implicatures, but at the same time these appear to be preserved in the scope of negative operators. A survey and possible explanation of their special behavior is offered in Spector (2013).

Blind implicatures Magri (2009, 2011, 2012) discusses the deviance of examples such as (60):

(60) #Some Italians come from a warm country.

Intuitively, one would like to say that (60) is deviant because it triggers an implicature that *not all Italians come from a warm country*. The problem is that such reasoning cannot be made if the comparison between *some Italians come from a warm country* and its alternative *all Italians come from a warm country* is effected relative to the context set. This is because relative to any reasonable context, the two sentences are equivalent: *some* Italians come from a warm country is true just in case *all* Italians do. As a result, there is no reason one should infer from the first sentence the negation of the second. Magri proposes that implicatures are not computed relative to the context set after all; rather, they are computed 'blindly', that is, without access to the context set, and oddness ensues if the resulting inference contradicts information which is in fact taken for granted in the context. This has lead to empirically rich developments, which we do not survey here.

Psycholinguistic evidence

Finally, and very importantly, it should be added that there is currently a very active debate about the reality of the various strengthened readings we have discussed. Sophisticated experimental techniques have been used to decide this question, but for reasons of space we cannot discuss the results here (see Chemla and Singh, 2014a,b, for recent references).

22.3 Presuppositions

In our discussion of scalar implicature, we saw that part of the field moved from neo-Gricean pragmatic analysis to a semantic or even a syntactic one – though the debate is by no means closed. In part, the opposite historical movement occurred in presupposition theory: semantic approaches that dominated the field in the 1980s and 1990s have recently found renewed competition from more pragmatic corners.[13]

22.3.1 Introducing presuppositions

As a *first approximation*, a sentence *S* has a presupposition *P* if *S* cannot be uttered felicitously unless the speech act participants take *P* for granted. Thus, *S* may be deemed neither true nor false unless it is common belief among the speech act participants that *P* is true. It is usually thought that presuppositions are triggered by some words (*presupposition triggers*) such as *the*, *know*, *regret*, *stop*, as is illustrated in (61).

(61) Some presupposition triggers

a. The king of Moldova is powerful.
Presupposition: Moldova has a king.

b. John knows that it is raining.
Presupposition: It is raining.

c. John regrets that he is incompetent.
Presupposition: John is incompetent.

d. John has stopped smoking.
Presupposition: John used to smoke.

This is only a preliminary definition, however. First, there are many other problems that can make a sentence less than felicitous (e.g., the speaker may say something irrelevant, or be overly familiar), and they need not

[13] This section shares material (both in substance and form) from Schlenker (2011b,c) to which the reader is referred for further technical details. For a recent survey from a different perspective, see Beaver and Geurts (2011); see also Dekker (2008) and Geurts and Maier (2013), as well as the historically important Gazdar (1979).

form a natural class. Second, there are many cases in which a sentence is felicitous despite the fact that its presupposition is not initially believed by the addressee. For instance, if I have never heard of Moldova and someone utters (61a), I will in many cases silently add to my initial beliefs the assumption that Moldova is a monarchy and has a king, thus ensuring that the sentence is felicitous after all. This process has been called *(global) accommodation* because the addressee somehow *accommodates* the speaker's presupposition to ensure that communication proceeds smoothly (Lewis, 1979c).

As a *second approximation*, then, presuppositions are better characterized by their 'projection' behavior. Clauses that include a presupposition trigger give rise to inferences such as those illustrated in (61). However, presuppositions differ from other inferences in how they are 'inherited' by complex sentences. If the presupposition of an elementary part is inherited by the sentence it occurs in, it is said to 'project'; more generally, the problem of computing the presuppositions of complex sentences from the meaning of their parts has been called the 'projection problem'. The presuppositions of elementary clauses typically project out of questions, negations, and the antecedents of indicative conditionals, as is illustrated in (62b)–(62d); and they give rise to universal inferences when they are embedded under the negative quantifier *none of* . . . , as is illustrated in (62e).

(62) a. Bill knows that he is incompetent.
$\Longrightarrow$ Bill is incompetent.
b. Does Bill know that he is incompetent?
$\Longrightarrow$ Bill is incompetent.
c. Bill doesn't know that he is incompetent.
$\Longrightarrow$ Bill is incompetent.
d. If Bill knows that he is incompetent, he will resign.
$\Longrightarrow$ Bill is incompetent.
e. None of my students knows that he is incompetent.
$\Longrightarrow$ Each of my students is incompetent.

Although presuppositions yield inferences that could be mistaken for entailments in unembedded environments such as (62a), with respect to the embeddings illustrated in (62) they systematically differ from entailments. Thus, *Bill is in Paris* entails (given standard world knowledge) that *Bill is in France*, but as shown in (63) all our other tests show that this inference is not presuppositional.

(63) a. Bill is in Paris.
$\Longrightarrow$ Bill is in France.
b. Is Bill in Paris?
$\not\Longrightarrow$ Bill is in France.
c. Bill isn't in Paris.
$\not\Longrightarrow$ Bill is in France.

d. If Bill is in Paris, he is staying near the Louvre.
$\not\Longrightarrow$ Bill is in France.
e. None of my students is in Paris.
$\not\Longrightarrow$ Each of my students is in France.

In effect, projection tests are based on global accommodation: in the absence of sufficient information about the context, subjects will assume that it is one in which the presupposition holds. Importantly, there are cases in which even these tests fail because the presupposition is somehow turned into a part of the assertive component. Take the verb *stop*. In many contexts, *Has John stopped smoking*? gives rise to an inference that John used to smoke, and the other tests in (62) would also suggest that this inference is a presupposition. However, in some contexts the expected projection behavior fails: Simons (2001), citing Geurts (1995), observes that one may without special presupposition ask a nervous stranger: *Have you recently stopped smoking?* In this case, the presupposition seems to become part of the assertive component. In technical terminology, it is *locally accommodated*; we will come back to this phenomenon below.

We used the examples in (62) as tests for determining whether an inference is presuppositional or not, but they also illustrate results that should be derived from a general theory of presupposition projection. Before we turn to the major contenders, we should first ask whether these inferences could conceivably be treated as implicatures. Most of the literature assumes that they cannot be, in part because of the impression that sometimes a presupposition which is not satisfied yields a genuine failure – unlike implicatures, which are thought to be cancelable.[14] Still, one could attempt to develop such a theory. How would one go about it? Suppose first that (62a) = *Bill knows that he is incompetent* has the meaning *Bill is incompetent and he believes that he is*; this immediately accounts for the inference in (62a). Suppose further that (62a) forms a scale with *Bill is incompetent*, which is clearly weaker. Because negation 'reverses' logical strength, the negation (62c) competes with the stronger scalar alternative *Bill isn't incompetent*. An implicature that the latter is false gives rise to the inference that *Bill is incompetent*. In other words, we have just sketched a way to explain why presuppositions are preserved under negation – and this was done entirely in terms of scalar implicatures.

Turning this welcome result into a full-fledged theory turns out to be difficult, however. Consider in particular (62e). Owing to the presence of the negative quantifier, the purported scalar alternative *None of my students is incompetent* is logically stronger than (62e). As was the case with (62c), a scalar implicature yields the inference that this alternative is false – and hence that *some of my students are incompetent*. However, this is still a far cry from the universal inference obtained in (62e), namely that *each of my*

[14] In Magri's analysis, however, *blind implicatures* can yield a deviance, as was illustrated in (60).

students is incompetent. In this case, an analysis of presuppositions as scalar implicatures delivers predictions that are too weak (but see Chemla, 2009, for relevant experimental results, and Chemla, 2007, for a theory that does handle scalar implicatures and presuppositions within a unified framework; see also Boër and Lycan, 1976; Thomason, 1990; Romoli, 2014; Stone et al., forthcoming, for relevant discussion.)

22.3.2 Dynamic semantics

The Basic Account

From the start, a very simple account presented itself to account for the data in (62a)–(62d); we will call it the *Basic Account*. Let us a say that a possibly complex sentence φ containing a clause φ' that triggers the presupposition P results in a semantic failure – and thus is neither true nor false – unless P is taken for granted by the speech act participants. In effect, we take P to be a condition that must be satisfied for φ' to be meaningful; and the entire sentence φ cannot be meaningful unless each of its components – including φ' – is meaningful. So a simple sentence like *Bill knows that he is incompetent* is neither true nor false unless it is taken for granted that Bill is incompetent; this is thus a very different analysis from the bivalent account ('presuppositions as implicatures') which was sketched in the previous paragraph. This analysis immediately explains why in simple examples the presuppositions of elementary clauses are 'inherited' by the complex sentences they appear in (technically, the requirement that each subcomponent of a sentence be satisfied can be formalized with the 'Weak Kleene' trivalent logic).

Unfortunately, the Basic Account fails in more complex examples (and this is so irrespective of whether one considers facts about *felicity* or about *projection*). On its own, the clause *John knows that he is incompetent* presupposes that (and yields an infelicity unless) John is incompetent. Hence the Basic Account predicts that all three sentences in (64) should presuppose this as well. However, this is not so: (64a) asserts rather than presupposes that John is incompetent; and (64b)–(64c) neither assert nor presuppose it.

(64) a. John is incompetent and he knows that he is.
b. If John is incompetent, he knows that he is.
c. John is not incompetent, or else he knows that he is.

In the case of (64a), there might be a way out. We could posit that the second conjunct is not evaluated in the initial (or 'global') context, but rather in that context as modified by the assertion of the first conjunct. The relevant notion of context is what Stalnaker calls the *context set*, which represents what the speech act participants take for granted at a certain point in a conversation.[15] If the addressee is willing to grant the first conjunct after he has

[15] In the literature on indexicals, the term *context* refers to an object that determines the speaker, time, and world of the utterance; the indexical notion should be clearly distinguished from the presuppositional one. A context set can sometimes be equated to a set of contexts in the indexical sense.

heard it, the relevant context for the evaluation of *he knows that he is (incompetent)* will be the initial context updated with the assumption that John is incompetent. We will call this the *local context* of the second conjunct. By construction, it does entail its presupposition. So if we ask what the entire sentence imposes on the initial (global) context for this presupposition to be (locally) entailed, the answer is: nothing – no matter what the initial context is, the local context of the second conjunct will always satisfy its presupposition. By developing an account of context change, we have been able to save the Basic Account – at least in this case. In addition, we have obtained an elegant account of an unexpected asymmetry:

(65) a. John is incompetent, and he knows that he is.
b. #John knows that he is incompetent, and he is.
c. John used to smoke, and he has stopped smoking.
d. #John has stopped smoking, and he used to smoke.

In each case, one much prefers the canonical order in which what justifies the presupposition comes first, and the presupposition trigger comes second, as in (65a) and (65c). The inverse order is degraded, as in (65b) and (65d). For Stalnaker, the reason is simple: context update follows the order in which the words are pronounced, and the local context of an expression incorporates information that comes before but not after it.

This, in a nutshell, is the justification for the strategy based on context change developed by Stalnaker (1974) and Karttunen (1974). Stalnaker's analysis was pragmatic: he assumed that general considerations of communicative rationality were enough to develop rules of context update. We have already discussed the case of conjunction. Stalnaker further thought that (64b) could be analyzed by observing that a conditional involves the hypothetical addition of the antecedent to the original context set; it then contributes the claim that the consequent follows from this modified context. Here too, the local context of the second clause is one which, by construction, entails that John is incompetent; so no matter what the initial context is, the presupposition of the consequent will be satisfied – which means that the sentence as a whole presupposes nothing. (A similar analysis could be extended to (64c) by taking *else* to mean something like *if not*, and reducing this case to (64b).)[16] Karttunen's analysis, by contrast, was semantic: he stated lexical rules that determined how each connective transmitted the presuppositions of its arguments; this presuppositional component had to be stipulated in addition to the truth-conditional behavior of the connectives (we will see shortly that in Heim's system, by contrast, the two are handled together).

The difficulty is that in its current form, based on the speech act participants' beliefs, the logic of context change does not easily extend to quantified cases. Consider the presuppositional predicate *stopped smoking* in *None*

[16] This suggestion is explicitly made in Stalnaker (2010).

of my students has stopped smoking. We would like the prediction to be that its local context entails *used to smoke*. There is no formal difficulty in defining a generalized notion of entailment among predicates – and the correct result can be obtained if the local context of *stopped smoking* is the property of *being a student* (relative to the initial context $\mathcal{C}$). However, a property is not the right kind of object to be believed, which makes a pragmatic analysis difficult to pursue in this case (further difficulties are discussed in Schlenker, 2009; see also Cooper, 1983; Heim, 1983b; Beaver, 2001; George, 2008a,b; Fox, 2008, 2012; Sudo, 2012, among others, for a discussion of presupposition projection in quantified sentences).

Heim's dynamic semantics

Heim (1983b) extended Stalnaker's theory by taking the very meaning of words to be instructions to update the context set (or Context Change Potentials); the *context set* became a technical notion, with no claim that the speech act participants literally believe local contexts (i.e., local context sets). In simple cases, Heim followed Stalnaker in taking the context to be a set of possible worlds; in particular, the global context is supposed to be the set of worlds compatible with what the speech act participants take for granted. In the final version of her system, which we will not review here, Heim took contexts to be sets of *pairs* of the form ⟨world, assignment function⟩; the addition of assignment functions proved crucial to handle quantificational statements.

In simple cases, we obtain a semanticized version of Stalnaker's pragmatic analysis. Let us assume for the moment that the context is a set of possible worlds. Now consider the clause *John stopped smoking*, which we will represent as $\underline{p}p'$, with the convention that the underlined part is the presupposition and the non-underlined part is the assertive component (here: $p =$ John used to smoke, and $p' =$ John doesn't smoke). When $\underline{p}p'$ is uttered in a context set $\mathcal{C}$, two things may happen:

1. If $\mathcal{C}$ does not entail p, the update fails, which we will encode as: $\mathcal{C}[\underline{p}p'] =$ # ('$\mathcal{C}$ updated with $\underline{p}p'$ yields a failure').
2. If $\mathcal{C}$ does entail p, the update proceeds by keeping only those worlds of $\mathcal{C}$ (or those '$\mathcal{C}$-worlds', as we will say) which satisfy p': $\mathcal{C}[\underline{p}p'] = \{w \in \mathcal{C} \mid p'$ is true in $w\}$.

These results are summarized in (66).

(66) $\mathcal{C}[\underline{p}p'] =$ # unless $\mathcal{C} \neq$ # and for each $w \in \mathcal{C}$, p is true in w. If $\mathcal{C}[\underline{p}p'] \neq$ #, $\mathcal{C}[\underline{p}p'] = \{w \in \mathcal{C} \mid p'$ is true in $w\}$.

The key step is to provide rules of context update for connectives and quantifiers. For the first case, Heim posits the rules in (67) for any clauses F, G.

(67) a. $\mathcal{C}[F \text{ and } G] = \#$ unless $\mathcal{C}[F] \neq \#$ and $\mathcal{C}[F][G] \neq \#$.
If $\mathcal{C}[F \text{ and } G] \neq \#$, $\mathcal{C}[F \text{ and } G] = \mathcal{C}[F][G]$.[17]
b. $\mathcal{C}[\text{not } F] = \#$ unless $\mathcal{C}[F] \neq \#$. If $\mathcal{C}[\text{not } F] \neq \#$, $\mathcal{C}[\text{not } F] = \mathcal{C} - \mathcal{C}[F]$.
c. $\mathcal{C}[\text{if } F, G] = \#$ unless $\mathcal{C}[F][G] \neq \#$.
If $\mathcal{C}[\text{if } F, G] \neq \#$, $\mathcal{C}[\text{if } F, G] = \mathcal{C} - \mathcal{C}[F][\text{not } G]$.

These rules can be justified as follows.

Example (67a) simply captures the intuition, inherited from Stalnaker, that the update of $\mathcal{C}$ with F and G is the successive update of $\mathcal{C}$ with F, and then with G (note that $\mathcal{C}[F][G]$ is the same thing as $(\mathcal{C}[F])[G]$: first we update $\mathcal{C}$ with F, and then with G); a failure arises if any step of the update process yields one.

Example (67b) tells us that we obtain the update of $\mathcal{C}$ with not F by 'throwing out' of $\mathcal{C}$ those worlds that survive the update of $\mathcal{C}$ with F ($\mathcal{C} - \mathcal{C}[F]$ is $\mathcal{C}$ minus the update of $\mathcal{C}$ with F). However, for this operation to be defined, $\mathcal{C}[F]$ should be defined in the first place. So we derive in this way the result that not F has the same presupposition as F: in both cases, the condition on $\mathcal{C}$ is that $\mathcal{C}[F] \neq \#$.

Example (67c) defines a dynamic version of conditionals viewed as material implications. Recall that in classical logic a conditional *if* F, G is false just in case F is true and not G is true; in all other cases, the conditional is true. The rule in (67c) says that we obtain the update of $\mathcal{C}$ with *if* F, G by throwing out of $\mathcal{C}$ those worlds that survive the update of $\mathcal{C}$ with F and then with not G. Intuitively, we throw out those worlds that make the material implication false. However, for this operation to be defined, $\mathcal{C}[F][\text{not } G]$ should be defined in the first place. Moreover, by the rule in (67b), this holds just in case $\mathcal{C}[F][G]$ is well defined (since $(\mathcal{C}[F])[\text{not } F]$ is defined just in case $(\mathcal{C}[F])[G]$ is).

We can see in this way that F and G and *if* F, G are predicted to give rise to the same presupposition: in both cases the requirement is that $\mathcal{C}[F][G]$ should be defined. Of course conjunctions and conditionals have different dynamic effects: they update $\mathcal{C}$ in different ways. An example is given in (68), where we write p for *John is 64 years old*, q for *John can't be hired*, and q' for *John believes he can't be hired*; we derive from (p and $\underline{q}q'$) a presupposition that if p, q. Application of (67c) to (if $p, \underline{q}q'$) would also derive the presupposition that (if p, q).

(68) a. John is 64 years old and he knows that he can't be hired.
a′. (p and $\underline{q}q'$)
b. $\mathcal{C}[(a')] = \#$ unless $\mathcal{C}[p][\underline{q}q'] \neq \#$, i.e., unless each world w in $\mathcal{C}[p]$ is such that q is true in w; this holds just in case each world w in $\mathcal{C}$ which makes p true also makes q true. In the case of (a), this means: each world in $\mathcal{C}$ in which John is 64 years old is one in which he can't be hired.

[17] We could write this rule in (67a) more succinctly as: $\mathcal{C}[F \text{ and } G] = \mathcal{C}[F][G]$ (the right failure conditions automatically follow from the definition of basic updates).

If $\mathcal{C}[(a')] \neq \#$, $\mathcal{C}[(a')] = \mathcal{C}[p][\underline{q}q'] = (\{w \in \mathcal{C} \mid p \text{ is true in } w\})[\underline{q}q']$
$= \{w(\mathcal{C} : p \text{ is true in } w \text{ and } q' \text{ is true in } w\}$.
In the case of (a), the result of the update is the set of $\mathcal{C}$-worlds in which John is 64 years old and he believes/knows he can't be hired.

In dynamic semantics, presupposition and truth are handled in tandem, whereas they were treated by different rules in Karttunen's system. Nevertheless, we can still recover from Heim's system a definition of presuppositional acceptability and of truth. A sentence φ will be presuppositionally acceptable relative to a context set $\mathcal{C}$ just in case the update of $\mathcal{C}$ with φ does not yield a failure; moreover, the compositional system is set up in such a way that this happens just in case any presupposition triggered by an expression is entailed by its local context. As for truth, the definition is simply that a sentence φ is true in a world w of $\mathcal{C}$ just in case w 'survives' the update with φ. Both definitions are given in (69)

(69) Let a sentence φ be uttered relative to a context set $\mathcal{C}$.
a. *Presuppositional acceptability*
φ is *presuppositionally acceptable relative to* $\mathcal{C}$ if and only if $\mathcal{C}[\varphi] \neq \#$.
b. *Truth*
If $w \in \mathcal{C}$ and if φ is presuppositionally acceptable in $\mathcal{C}$, φ is *true in* w *relative to the context set* $\mathcal{C}$ if and only if $w \in \mathcal{C}[\varphi]$.

In the quantificational case, which we do not review here, Heim's system derives *universal presuppositions* when a trigger appears in the verbal argument of a generalized quantifier, as in *every student stopped smoking*, *no student stopped smoking*, *exactly four students stopped smoking*: each of those is taken to presuppose that *every student used to smoke*. Heim also predicts universal presuppositions when a trigger appears in the nominal argument of a quantifier: for example, *every student who stopped smoking is nervous*, and *no student who stopped smoking is nervous* are predicted to yield an inference that *every student used to smoke*. We come back to these predictions below. (One could easily tweak Heim's system to obtain different predictions; thus Beaver (1994, 2001) argues for existential presuppositions instead of universal ones. However, as we discuss below, the ease with which the predictions can be changed is a symptom of another problem.)

Assessment

Two main criticisms have been leveled at Heim's system: the first is that the theory is empirically inadequate; the second is that it is insufficiently explanatory.

The Proviso Problem Van der Sandt (1992) and Geurts (1999) argue that in many cases Heim's predictions are too weak (the following are modifications of examples discussed in Geurts, 1999, Chapter 3):

(70) a. The problem was easy/difficult and it is not John who solved it.
b. If the problem was easy/difficult, then it isn't John who solved it.
c. Peter knows that if the problem was easy/difficult, someone solved it.

In all three cases, Heim predicts a presupposition that *if the problem was easy/difficult, someone solved it*. However, Geurts convincingly argues that there is a clear empirical difference between (70a) and (70b), on the one hand, and (70c) on the other: the expected presupposition is found in the latter case, but in (70a)–(70b) one typically infers that someone did in fact solve the problem. Van der Sandt and Geurts argue that better predictions can be achieved if an alternative account of presupposition projection is given within the framework of Discourse Representation Theory (DRT), which unlike dynamic semantics is essentially representational; we come back to this theory below. Other researchers have tried to argue that pragmatic mechanisms can in some cases strengthen conditional presuppositions into unconditional ones (Beaver, 2001; Heim, 2006; Singh, 2007, 2009; van Rooij, 2007; Pérez Caballo, 2009; Schlenker, 2011d; Lassiter, 2012).

The Explanatory Problem Soames (1989) and Heim (1990b) noted that the dynamic account lacks explanatory depth. On the basis of simple sentences involving no presupposition triggers, we could certainly posit the lexical entry for *and* defined in (67a), and copied in (71a), but we could just as well posit one of the 'deviant' entries in (71b)–(71c):

(71) a. $\mathcal{C}[F \text{ and } G] = \mathcal{C}[F][G]$
b. $\mathcal{C}[F \text{ and}^* G] = \mathcal{C}[G][F]$ (i.e., $\mathcal{C}[F \text{ and}^* G] = \mathcal{C}[G \text{ and } F]$)
c. $\mathcal{C}[F \text{ and}^{**} G] = \#$ unless $\mathcal{C}[F] \neq \#$ and $\mathcal{C}[G] \neq \#$. If $\mathcal{C}[F\text{and}^{**} G] \neq \#$, $\mathcal{C}[F \text{ and}^{**} G] = \mathcal{C}[F] \cap \mathcal{C}[G]$

When F and G are non-presuppositional, all three lexical entries yield the same result: the update rule outputs the set of $\mathcal{C}$-worlds that satisfy both F and G. However, in presuppositional cases the three entries make entirely different predictions: *and** predicts that the presuppositions of the first conjunct can be satisfied by the second conjunct, but not the other way round, while *and*** predicts that the conjunction should inherit the presuppositions of each conjunct. It turns out that *and* is correct while *and** as well as *and*** are not. Moreover, most researchers' impression is that this conclusion holds in all known languages, but nothing in the theory explains why this is so. We come back to this point below.

22.3.3 Discourse Representation Theory

The analysis of presupposition projection offered by Discourse Representation Theory (DRT) seeks to offer a viable alternative to Heim's dynamic semantics, one that does not suffer from the Proviso Problem (van der Sandt, 1992; Geurts, 1999). The basic idea is that presuppositions are parts of a

Logical Form that want to 'percolate up' as far as possible in a Logical Form. Whenever possible, they are given matrix scope, though other – and less preferred – options are also open.

Basic DRT

To illustrate, we start from a sentence such as (72a), which is given the initial representation in (72b) (here too the presupposition is underlined). Following Kamp's analysis of anaphora (1981b), the formal representation contains two components, separated by a semi-column: a list of discourse referents (here: the variable x) and a list of conditions on these discourse referents. Van der Sandt's innovation is to underline certain conditions – the presuppositional ones – and to require that they be accommodated by being moved upwards.

(72) a. If John is realistic, he knows that he is incompetent.
b. $[_1\ x$: John x, $[_2$: realistic $x] \Longrightarrow [_3$: $\underline{x \text{ is incompetent}}$, x believes that x is incompetent$]]$

There are various 'projection sites' that the underlined material could land to. We obtain three possible readings depending on the landing site: in (73a) the presupposition appears at the matrix level, and we obtain an unconditional inference that John is incompetent – which is the preferred reading; in (73b), the presupposition lands in the antecedent of the *if*-clause (*intermediate accommodation*), while in (73c) it stays in its original position (*local accommodation*). In this case these readings are not plausible, but they have been claimed to be instantiated in other examples (this is not debated for local accommodation; intermediate accommodation is far more controversial, as is for instance discussed in Beaver, 2001).[18]

(73) a. **Reading 1 [preferred]: Global accommodation**
$[_1\ x$: John x, x **is incompetent** $[_2$: realistic $x] \Longrightarrow [_{3:}\ x$ believes that x is incompetent$]]$
b. **Reading 2: Intermediate accommodation**
$[1\ x$: John x $[_2$: realistic x, x **is incompetent**$] \Longrightarrow [_{3:}\ x$ believes that x is incompetent$]]$
c. **Reading 3: Local accommodation**
$[_1\ x$: John x $[_2$: realistic $x] \Longrightarrow [_{3:}\ x$ **is incompetent**, x believes that x is incompetent$]]$

Since DRT offers a variety of landing sites for presuppositions, it generates many more readings than satisfaction theories do. However, it cuts down on these readings by adding constraints on interpretation (see Geurts, 1999, p. 59, for a more detailed discussion). For instance, it posits a constraint

[18] The issue of intermediate accommodation is further discussed in Schlenker (2011a); dubious cases of intermediate accommodation (into the restrictor of an operator) are contrasted with more robust cases, due to Bart Geurts (they involve intermediate accommodation within the scope of attitude operators).

of 'informativeness' which prohibits a clause from being replaceable with a tautology or a contradiction in the environment in which it appears. This explains why, despite the general preference for matrix accommodation, the latter is not an option in (74a)– (74b):

(74) a. If John is incompetent, he knows that he is.
b. **Matrix accommodation** (*violates local informativity*)
$[_1\ x$: John x, x **is incompetent** $[_2$: incompetent $x] \Longrightarrow [_{3:}\ x$ believes that x is incompetent$]]$
c. **Local accommodation** (*does not violate local informativity*)
$[_1\ x$: John x $[_2$: incompetent $x] \Longrightarrow [_{3:}\ x$ **is incompetent**, x believes that x is incompetent$]]$

With matrix accommodation as in (74b), the antecedent of the conditional becomes replaceable with a tautology – it is, in other words, locally uninformative. Local accommodation can solve the problem: when it is applied, as in (74c), no other expression is made uninformative (though the presupposition is – but this is of course entirely in order).

DRT has great appeal, for at least two reasons. First, it offers a compelling solution to the Proviso Problem, which the satisfaction theories we considered earlier cannot handle without further additions. Second, it handles presupposition projection and anaphora resolution within a unified framework. Without discussing anaphora resolution proper, let us give an idea of the parallels that motivated the analysis (see Geurts, 1999, p. 46, for a more detailed discussion of some of the same examples). In each of the cases (75)–(77), the (a) example involves a pronoun (underlined) and its antecedent (in bold), while the (b) example displays a trigger (underlined) and what intuitively justifies the presupposition (in bold).[19]

(75) Conditionals
a. If Smith owns **a donkey**, he beats <u>it</u>. (Geach, 1962)
b. Maybe **Mary proved the theorem** and John proved it, <u>too</u>.

(76) Disjunction
a. Either Morrill Hall doesn't have **a bathroom** or <u>it</u> is in a funny place. (attributed to Partee)
b. Either Morrill Hall doesn't have **a bathroom** or <u>the bathroom</u> is in a funny place.

(77) Modal subordination
a. It is possible that John has **children** and it is possible that <u>they</u> are away.
b. It is possible that John has **children** and it is possible that <u>his children</u> are away. (Gazdar, 1979)

[19] We write "*intuitively* justifies the presupposition" because the actual implementation in DRT is more complex and does not just involve coindexation between a trigger and its antecedent.

It is quite easy to construct systematic examples displaying the parallel between anaphora resolution and presupposition projection: start from an anaphoric sentence such as (76) and (77), and replace the pronoun with a definite description that is appropriate for the antecedent. For proponents of DRT, the similarity between pronouns and presuppositions holds because presupposition projection is a species of anaphora resolution. For some proponents of satisfaction theories, the similarity may well hold, but for the opposite reason: pronouns are a species of presupposition triggers. This analysis has some plausibility because an entire class of theories of anaphora, called *E-type theories*, treat pronouns as concealed definite descriptions (see, for instance, Elbourne, 2005, for a detailed analysis and a survey); since definite descriptions are presupposition triggers, pronouns should be too – and they should behave like other triggers with respect to presupposition projection. Thus, the similarity between presupposition projection and anaphora resolution need not favor one camp over the other, at least not without much more detailed argumentation.

Problems

Conditional presuppositions One of DRT's advantages over satisfaction theories is that it can generate unconditional presuppositions. Still, it has been argued that in *some* cases *bona fide* conditional presuppositions do arise (e.g., Beaver, 2001). By *bona fide* conditional presuppositions, I mean conditional inferences that project like presuppositions and thus cannot be explained away as mere entailments. I believe the examples in (78) have this property:

(78) a. If you accept this job, will you let your family know that you're going to be working for a thug?
$\Longrightarrow$ If you accept this job, you're going to be working for a thug.
$\not\Longrightarrow$ You're going to be working for a thug.
b. If you accept this job and let your family know that you are going to work for a thug, they won't be happy.
$\Longrightarrow$ If you accept this job, you're going to be working for a thug.
$\not\Longrightarrow$ You're going to be working for a thug.

Example (78a) has the form *if* p, $\underline{q}q'$? with $p =$ *you accept this job* and $q =$ *you will work for a thug*. If the conditional did not appear in a question, the inference we obtain (= *If you accept this job, you are going to be working for a thug*) could be treated as a mere entailment. However, the fact that the conditional inference survives in a question suggests that we are dealing with a *bona fide* conditional presupposition. The same argument applies to (78b), which is of the form *if* p *and* $\underline{q}q'$, r. Here we obtain the conditional inference predicted by Heim (1983b): p and $\underline{q}q'$ presupposes *if* p, q, and this presupposition projects out of the antecedent of the conditional. Standard DRT does not account for these cases. Take, for instance, the case of (78b), with the simplified representation in (79). The various accommodation possibilities are represented in (80):

(79) $[_1$ x: you x, $[_2$: x accepts this job$]$ $\Longrightarrow$ $[_3$: $\underline{x \text{ will work for a thug}}$, x tells x's family that x is working for a thug$]]$

(80) a. **Matrix accommodation**
$[_1$ x: you x, x **will work for a thug**, $[_2$: x accepts this job$]$ $\Longrightarrow$ $[_3$: x tells x's family that x is working for a thug$]]$
b. **Intermediate accommodation**
$[_1$ x: you x, $[_2$: x **will work for a thug**, x accepts this job$]$ $\Longrightarrow$ $[_3$: x tells x's family that x is working for a thug$]]$
c. **Local accommodation**
$[_1$ x: you x, $[_2$: x accepts this job$]$ $\Longrightarrow$ $[_3$: x **will work for a thug**, x tells x's family that x is working for a thug$]]$

None of these representations gives rise to the conditional inference *If you accept this job, you're going to be working for a thug*; in particular, (80b) does not predict this inference because the entire sentence is embedded under a question operator.

Quantified statements Owing to the architecture of DRT, a presupposition that contains a bound variable cannot be accommodated outside the scope of its binder, as this would 'unbind' the variable (this is sometimes called the *trapping constraint*). In simple cases, we can still obtain the correct results through local or intermediate accommodation. For instance, (81a) gives rise to an inference that *each of these ten students is incompetent*, and this inference is captured by the reading with local accommodation in (82).

(81) a. Each of these ten students knows that he is incompetent.
b. [[each x: student x] $\underline{x \textbf{ is incompetent}}$, x believes that x is incompetent]

(82) **Local accommodation**
[[each x: student x] x **is incompetent**, x believes that x is incompetent]

As soon as we consider non-assertive uses of (81a), however, the predictions are far more problematic.

(83) a. Does each of these ten students know that he is incompetent?
b. If each of these ten students knows that he is incompetent, they must be depressed.

In each case we find, as before, an inference that each of these ten students is incompetent, but this is not predicted by either local or intermediate accommodation; in particular, local accommodation fails to make the right predictions because in these cases the Logical Form in (82) appears in a non-assertive environment.

The problems get worse when the quantifier *no* is considered. As mentioned, Chemla (2009) shows with experimental means that French sentences of the form $[\text{No } \psi]\underline{Q}Q'$ yield the universal inference $[\text{Every } \psi]Q$ (here capital letters stand for predicative elements). For instance, (84a) triggers an inference that each of these ten students is incompetent. However, neither Logical Form in (85) derives the correct inference.

(84) a. None of these ten students knows that he is incompetent.
b. [[no *x*: student *x*] $\underline{x \textbf{ is incompetent}}$, *x* believes that *x* is incompetent]

(85) a. **Local accommodation**
[[no *x*: student *x*] *x* **is incompetent**, *x* believes that *x* is incompetent]
b. **Intermediate accommodation**
[[no *x*: student *x*, *x* **is incompetent**] *x* believes that *x* is incompetent]

(It should be added that when a trigger with a variable finds itself in the restrictor of the quantifier that binds it, only local accommodation is available, because accommodating the presupposition in a higher position would unbind that variable. This predicts extremely weak inferences, which might be a good thing – Chemla (2009) suggests that no universal inferences are obtained in this case.)

Proviso Redux Even when DRT predicts appropriate inferences in simple quantified statements, further embeddings can lead to the re-appearance of the Proviso Problem.

(86) If I grade their homeworks, each of my students will know that he is {a genius | incompetent}.
$\Longrightarrow$ Each of my students is {a genius | incompetent}.

Owing to the prohibition against unbinding, the presupposition triggered by *know* must be accommodated within the scope of *each of my students*. As a consequence, it must remain within the consequent of the conditional – and we just cannot obtain an unconditional presupposition in this case.

22.3.4 Further developments

We will briefly discuss two strands of recent research that address two main questions: (i) How can the Explanatory Problem be addressed? (ii) Can better predictions be obtained in the quantificational case?[20]

The first question has direct consequences for the precise localization of presupposition projection at the syntax–semantics interface. The heart of the problem is that dynamic semantics is strictly more powerful than classical semantics; this made it possible for Heim's system to handle

[20] This section only surveys developments prior to 2010–2011. In particular, it does not take into account the innovative ideas of Sudo (2012).

presuppositional data that classical semantics did not, but the very power of the framework also makes it possible to define all sorts of lexical entries which presumably do not exist in the world's languages. To solve the problem, several new approaches (a) start from a leaner semantics (which might be bivalent and classical), and (b) add to it a projection algorithm which *predicts* the projection behavior of any operator once its syntax and classical (bivalent) semantics have been specified. Part (b) is often viewed as belonging in part or wholly to the realm of pragmatics. As a result, several recent approaches return to a pragmatic view of presupposition projection, one closer to architectures of the 1970s than of the 1980s.

Transparency-based approaches

Several recent 'transparency-based theories' (Schlenker, 2008, 2009, 2010a) address the Explanatory Problem by turning a derived property of dynamic semantics into the centerpiece of a theory of presupposition projection. These theories have two components: *a substantial component*, which explains under what semantic conditions a presupposition is 'licit'; and an *incremental component*, which derives the left–right asymmetries we observed at the outset in (65). Since these theories are built on the basis of a classical semantics, $\underline{p}p'$ will henceforth represent a classical meaning, equivalent to the conjunction of p and p'. For instance, we treat *x stopped smoking* as roughly equivalent to *x used to smoke* and *x doesn't now smoke*, with the specification (encoded by underlining) that one entailment, namely *x used to smoke*, has a special status. So in this case we have $p =$ *x used to smoke* and $p' =$ *x doesn't now smoke*, and the notation $\underline{p}p'$ indicates that the sentence will be pragmatically deviant unless p is entailed by its local context. It is then incumbent on the theory of presupposition projection to explain why the distinguished entailment behaves in a special way.[21] Importantly, nothing prevents us from working with a classical semantics while still claiming that sentences are pragmatically deviant if a presupposition fails to be entailed by its local context; this just means that 'deviance' could be encoded in the pragmatics rather than in the semantics.

Let us turn to a description of the two components of transparency-based theories.

Substantial component: A consequence of Heim's system is that presuppositions are semantically inert, in the following sense: if a sentence is felicitous, one can 'erase' from it all the presuppositions without affecting the truth conditions. Let us consider three examples. We saw at the outset that $\underline{p}p'$ and (*not* $\underline{p}p'$) both presuppose that p, and that (p *and* $\underline{q}q'$) as well as (*if* p, $\underline{q}q'$) both presuppose that (*if* p, q). However, when these

[21] We could also ask a different question – namely, why some entailments become underlined. This is the *Triggering Problem*: the question is to determine how the presuppositions of elementary expressions are generated in the first place. We do not consider this problem here; see, for instance, Abrusán (2011) for a recent discussion.

conditions hold, (*not* $\underline{p}p'$) is equivalent to (*not* p'); similarly, (p *and* $\underline{q}q'$) and (*if* p, $\underline{q}q'$) are equivalent to (p *and* q') and (*if* p, q'): we can delete the underlined material without affecting the truth conditions. This is the sense in which presuppositions are 'transparent'. These simple results are summarized in (87), where $\mathcal{C} \models p$ means that p holds in each world of $\mathcal{C}$ (in other words, p follows from $\mathcal{C}$).

(87) Uttered in a context set $\mathcal{C}$:

a. $\underline{p}p'$ and (*not* $\underline{p}p'$) both presuppose that $\mathcal{C} \models p \ldots$ and when $\mathcal{C} \models p$, $\mathcal{C} \models \underline{p}p' \Leftrightarrow p'$, and $\mathcal{C} \models (\text{not } \underline{p}p') \Leftrightarrow (\text{not } p')$.

b. (p and $\underline{q}q'$) and (if p, $\underline{q}q'$) both presuppose that $\mathcal{C} \models p \Rightarrow q \ldots$ and when $\mathcal{C} \models p \Rightarrow q$, $\mathcal{C} \models (p \text{ and } \underline{q}q') \Leftrightarrow (p \text{ and } q')$, and $\mathcal{C} \models (\text{if } p, \underline{q}q') \Leftrightarrow (\text{if } p, q')$.

Transparency-based theories start from the requirement that presuppositions should be 'erasable', or 'transparent', which in turn imposes constraints on $\mathcal{C}$. For all these theories, it turns out to be essential that the equivalence should hold no matter what the assertive component is.[22] To take a very simple example, consider (*not* $\underline{p}p'$). How can we guarantee that $\mathcal{C} \models (\text{not } \underline{p}p') \Leftrightarrow (\text{not } p')$ no matter what p' turns out to be? The condition is equivalent to $\mathcal{C} \models \underline{p}p' \Leftrightarrow p'$, and it will certainly hold if $\mathcal{C} \models p$. Conversely, if $\mathcal{C} \models \underline{p}p' \Leftrightarrow p'$ holds for all p', the equivalence holds in particular when p' is a tautology – which implies that $\mathcal{C} \models p$ (recall that semantically $\underline{p}$ and p are the same thing). So in this very simple case, the condition that a presupposition should be transparent suffices to derive the desired result, namely that *not* $\underline{p}p'$ presupposes p.

Incremental component: The substantial component on its own does not distinguish between, say, (p and $\underline{q}q'$) vs. ($\underline{q}q'$ and p), which are equivalent in classical logic. In order to regain a difference, transparency-based theories require that the equivalence imposed by the substantial component should be guaranteed to hold as soon as one processes a presupposition trigger, no matter how the sentence ends. When the trigger is at the end of the sentence, this changes nothing – and thus the result we obtained for (not $\underline{p}p'$) still holds. However, we will derive different results for (p and $\underline{q}q'$) vs. ($\underline{q}q'$ and p): although the two sentences are equivalent, the second will yield a stronger presupposition because the trigger is at the beginning, and as a result one cannot 'use' information about p to satisfy the substantial condition.

Transparency-based theories come in several varieties. In each case, the main question is how the requirement that presuppositions are transparent should be derived.

[22] To see why this is crucial, consider the sentence *It is Obama who won the election*. The cleft triggers a presupposition that *exactly one person won the election*. The assertive component seems to be that *Obama won the election*. But in this case the presupposition is entailed by the assertive component, so in all standard contexts $\mathcal{C}$, $\mathcal{C} \models \ldots \underline{p}p' \cdots \Leftrightarrow \ldots p' \ldots$. This is an undesirable result, as it implies that *It is* X *who won the election* never presupposes anything.

A purely pragmatic theory was developed in Schlenker (2008). It may be seen as an attempt to formalize an insight due to Grice, who proposed to add a new maxim of manner to account for presuppositions: "if your assertions are complex and conjunctive, and you are asserting a number of things at the same time, then it would be natural, on the assumption that any one of them might be challengeable, to set them out separately and so make it easy for anyone who wanted to challenge them to do so" (Grice, 1981). This approach does not seek to *explain* what it means for an assertion to be 'complex and conjunctive'; rather, it takes for granted that certain components of an assertive meaning are somehow taken to be pre-conditions of the rest and are for this reason underlined in our formalization. Now a version of Grice's principle, called *Be Articulate* in Schlenker (2008), requires that *whenever possible* the distinguished status of a pre-condition should be made syntactically apparent and thus that the meaning of an expression $\underline{d}d'$ should be preferably expressed as (d and $\underline{d}d'$):

(88) Be Articulate
In any syntactic environment, express the meaning of an expression $\underline{d}d'$ as (d and $\underline{d}d'$) (. . . unless independent pragmatic principles rule out the full conjunction).

Be Articulate is controlled by another Gricean principle of manner, *Be Brief*, which prohibits unnecessary prolixity, and takes precedence over *Be Articulate*. Now the suggestion is that the theory of presupposition projection reduces to the interaction between these two principles. *Be Brief* can be stated in various ways, and the choice one makes has momentous consequences for the theory of presupposition. In the following version, we state the principle with a left-right bias (the incremental component we announced at the outset): a sentence of the form *blah (d and e) blah'* is ruled out if one can determine as soon as *blah* (d is uttered that no matter what the second conjunct d' will turn out to be, no matter what the end of the sentence is, (d and d') could be replaced with d' without modifying the truth conditions of the sentence relative to the context set.

(89) Be Brief – incremental version
Given a context set $\mathcal{C}$, a predicative or propositional occurrence of d is infelicitous in a sentence that begins with $\alpha(d$ and if for any expression γ of the same type as d and for any good final β, $\mathcal{C} \models \alpha(d \text{ and } \gamma)\beta \Leftrightarrow \alpha\gamma\beta$.

This principle is, for instance, justified by the deviance of *#If John is in Paris, he is in Paris and he is happy*, where the underlined expression is clearly redundant and is in violation of (89).

Equipped with *Be Articulate* and *Be Brief*, we can derive a principle of transparency – which we call *incremental* because it incorporates a left-right bias. Briefly, a predicative or propositional occurrence of . . . $\underline{d}d'$ . . . is acceptable on its own (i.e., without being preceded by the words *d and*) in a certain syntactic environment just in case ... (d and $\underline{d}d'$) ... is ruled out because d is incrementally transparent:

(90) Incremental Transparency
Given a context set $\mathcal{C}$, a predicative or propositional occurrence of $\underline{d}d'$ is acceptable in a sentence that begins with $\alpha\underline{d}d'$ if the 'articulated' competitor $\alpha(d$ and $d')$ is ruled out because d is transparent, if for any expression γ of the same type as d and for any good final β,
$\mathcal{C} \models \alpha(d \text{ and } \gamma)\beta \Leftrightarrow \alpha\gamma\beta$.

To see informally how this principle derives the result that (p and $\underline{q}q'$) presupposes that $p \Rightarrow q$, we argue in two steps.

First, if $\mathcal{C} \models p \Rightarrow q$ it is clear that the 'articulated' sentence (p and (q and $\underline{q}q'$)) is in violation of *Be Brief*: it can be determined as soon as (p and (q has been uttered that q is redundant because, relative to $\mathcal{C}$, it already follows from p. Hence, if $\mathcal{C} \models p \Rightarrow q$, the sentence ($p$ and $\underline{q}q'$) should be acceptable because of its 'articulated' competitor.

Second, we show that if the sentence (p and $\underline{q}q'$) satisfies the principle of Incremental Transparency in $\mathcal{C}, \mathcal{C} \models p \Rightarrow q$. Applied to ($p$ and $\underline{q}q'$), (90) implies in particular that $\mathcal{C} \models (p \text{ and } (q \text{ and } T)) \Leftrightarrow (p \text{ and } T)$, where T is a tautology; hence, $\mathcal{C} \models (p \text{ and } q) \Leftrightarrow p$, from which it follows in particular that $\mathcal{C} \models p \Rightarrow q$.

It was shown in Schlenker (2007, 2008) that the principle in (90) derives something very close to Heim's predictions, including in the quantificational case. The advantage, however, was that the theory was entirely general and could be applied to any number of new operators without first stipulating their Context Change Potential. Schlenker (2009, 2010a) further shows that related ideas can be used to reconstruct a notion of local context akin to that of dynamic semantics – but one which is computed in a post-semantic component, on the basis of a classical (bivalent) semantics. In its basic version, this theory makes predictions very close to Heim's. However, the concept of 'local context' is rather versatile; one can also use it to reconstruct a version of DRT, by allowing presupposition triggers to be indexed with contexts other than their local contexts – this view is developed in Zeevat (1992) and Schlenker (2011d).

Incremental Strong Kleene (= Middle Kleene)

In 1979, Peters wrote a response to Karttunen's work in which he argued that a dynamic analysis was not needed to account for presupposition projection. He showed that in simple cases a trivalent approach could be made to work. As we saw above, it will not do to posit that a sentence S has the third truth value # in case any of its constituents does, as this would wrongly predict that each of the sentences in (64) inherits the presupposition that John is incompetent – the Weak Kleene logic is not a good model of presupposition projection. However, Peters observed that an incrementalized version of the Strong Kleene logic could derive far more adequate results. This trivalent approach was further developed in Beaver and Krahmer (2001); it was further refined in a way that meets the Explanatory Problem we raised above in George (2008a,b); Fox (2008, 2012).

The basic idea of the Strong Kleene logic is to treat a semantic failure as an uncertainty about the value of an expression: if $\underline{q}q'$ is evaluated at w while q is false at w, we just do not know whether the clause is true or false (and the same holds if the presuppositional predicate $\underline{Q}Q'$ is evaluated with respect to a world w and an individual d which make Q false). The semantic module outputs the value # in case this uncertainty cannot be resolved – which systematically happens with unembedded atomic propositions whose presupposition is not met. However, in complex formulas it may happen that no matter how the value of $\underline{q}q'$ (or $\underline{Q}Q'$) is resolved at the point of evaluation, one can still unambiguously determine the value of the entire sentence. This is, for instance, the case if (p and $\underline{q}q'$) is evaluated in a world w in which p and q are both false: $\underline{q}q'$ receives the indeterminate value #, but no matter how the indeterminacy is resolved, the entire sentence will still be false due to the falsity of the first conjunct p. Thus, for any world w in the context set, the sentence will have a determinate truth value just in case either (i) p is false at w (so that it does not matter how one resolves the indeterminacy of the second conjunct); or (ii) q is true (so that the second conjunct has a determinate truth value). Since we are solely interested in worlds that are compatible with what the speech act participants take for granted, we derive the familiar prediction that the context set must entail that *if* p, q.

In this case, the Strong Kleene logic suffices to derive the desired results. However, in its original form, this logic would also make the same predictions for ($\underline{q}q'$ and p); in other words, it yields a 'symmetric' account of presupposition projection. Peters, Beaver and Krahmer, George, and Fox propose to make the system asymmetric. There are several ways to do so. Peters stipulated appropriate truth tables; the resulting system is known as the Middle Kleene logic because it treats propositional arguments that come early as in the Weak Kleene logic, and arguments that come late as in the Strong Kleene logic; this can be seen in the truth tables in Figure 22.1. George defines an algorithm that takes as input the syntax and bivalent semantics of various operators and yields a compositional trivalent logic which is sensitive to the linear order of its arguments.[23] By contrast, Fox proposes to make Strong Kleene incremental by adopting the (non-compositional) device of quantification over good finals (= possible sentence completions), as was the case in the bivalent theories we presented above.

In the propositional case, the Middle Kleene logic makes exactly the same predictions as Karttunen's or Heim's theories (and also *Be Articulate*). So the empirical debate revolves around the quantificational case. Three cases are particularly interesting.

[23] One could try instead to make the operators sensitive to the order given by constituency relations, but this would arguably yield incorrect results. [q[and pp']] is often assumed in syntax to have a binary- and right-branching structure, which would mean that the second conjunct would have to be evaluated 'before' the first one – an undesirable result.

not p	
1	0
0	1
#	#

p and q	1	0	#
1	1	0	#
0	0	0	0
#	#	#	#

p or q	1	0	#
1	1	1	1
0	1	0	#
#	#	#	#

if p, q	1	0	#
1	1	0	#
0	1	1	0
#	#	#	#

Figure 22.1 *Middle Kleene truth tables (propositional case)*

For sentences of the form [Some P]$\underline{Q}Q'$, Heim's approach and *Be Articulate* predict a universal presupposition: [Every P]Q. However, Middle Kleene (or Strong Kleene, for that matter) does not: even if some P-individual fails to satisfy Q, yielding an uncertainty for the corresponding value for $\underline{Q}Q'$, this need not affect the value of the entire sentence as long as there is some other P-individual that satisfies both Q and Q'. This lack of a universal inference might be an excellent thing, since it was observed early on that universal inferences are undesirable for existential statements (e.g., *A fat man was pushing this bicycle* does not presuppose that every fat man has a bicyle: Heim, 1983b; see also Chemla, 2009).

The flip side of this positive result is that, by the rule of negation in Figure 22.1, not [Some P]$\underline{Q}Q'$, or [No P]$\underline{Q}Q'$, has the very same presupposition as [Some P]$\underline{Q}Q'$. Experimental results suggest that for [No P]$\underline{Q}Q'$, a universal inference is in fact derived. By itself this need not be a problem, since the experimental results do not tell us whether this inference is a presupposition or an entailment. Moreover, in Middle or Strong Kleene, if [No P]$\underline{Q}Q'$ is true, then so is [Every P]Q: if any P-individual d failed to satisfy Q, then the value of $\underline{Q}Q'$ at d would be uncertain and we could not state with certainty that no P-individual satisfies $\underline{Q}Q'$. The difficulty, however, is that the question *Does none of your students know that he is incompetent?* does seem to carry the same universal inference that *each of your students is incompetent*. Treating this inference as an entailment does not appear to be feasible in this case. Further refinements are needed to derive the desired result (Fox, 2012).

Finally, for [Exactly two P]$\underline{Q}Q'$ the trivalent theory derives results that appear to be too strong: here too, we get an entailment that [Every P]Q (if any P-individual d failed to satisfy Q, then the value of $\underline{Q}Q'$ at d would be uncertain and we could not determine with certainty the number of P-individuals that satisfy $\underline{Q}Q'$). Experimental results suggest that this is too strong (Chemla, 2009).

While dynamic semantics and DRT remain important points of reference, it is clear that a combination of methodological and empirical considerations has led to renewed debate and to new frameworks. Presuppositions seemed to have been safely anchored to the semantic side of the semantics/pragmatics divide after the successes of dynamic semantics in the 1980s. However, in view of recent developments, it seems plausible again that presuppositions might be a post-semantic and possibly even a Gricean phenomenon.

22.4 Conventional implicatures

In addition to the notion of *conversational implicatures*, Grice (1975) introduced that of *conventional implicatures*, which he illustrated on the example of *therefore* and *but*; for instance, the latter was taken to have a conjunctive literal meaning, but to carry a conventional implicature that distinguishes it from *and*. However, as Potts (2005) points out, the notion was 'born into neglect': Grice's primary interest was in conversational implicatures, and his goal in defining conventional implicatures was just to distinguish them from the former.

In the 1970s, Karttunen and Peters (1979) had argued that some presuppositions should be handled in terms a multidimensional semantics in which presuppositions are computed in a separate semantic dimension from assertions. Their framework was superseded by dynamic semantics (in part because it did not make correct predictions about the interaction between presuppositions and quantification). Interestingly, however, Potts (2005) used multidimensional ideas to revisit a different empirical terrain: he argued that two phenomena, supplements (e.g., appositive modifiers) and expressives (e.g., the derogatory term *honky*), trigger inferences that are neither conversational implicatures nor presuppositions and should be handled within a multidimensional framework. He proposed to call these phenomena *conventional implicatures*.[24]

22.4.1 Supplements

Potts' analysis

Let us start with supplements (examples minimally modified from Potts, 2005):

(91) Uttered in 1998:
a. Lance Armstrong, <u>a cancer survivor</u> / <u>who survived cancer</u>, will win the Tour de France.
(i) –No– he certainly won't.
Inference: Armstrong survived cancer.
(ii) –#?No, he didn't survive cancer; it was a different disease.

[24] Karttunen and Peters (1979) used the same term to refer to certain classes of presuppositions. See Potts (2012) for a survey of work on conventional implicatures.

b. I doubt that Lance Armonstrong, a cancer survivor / who survived cancer will win the Tour de France.
Inference: Armstrong suvived cancer.

We immediately note two properties of the inference triggered by the underlined nominal appositive:

(i) *Non-deniability:* As shown by the contrast between (91a-i) and (91a-ii), it is very difficult for the negative response *no* to target the inference that Armstrong survived cancer; *no* is taken to target the main point of the assertion, namely that Armstrong will win the Tour de France.

(iia) *Scopelessness – negation:* Relatedly, despite the fact that the nominal appositive is in the scope of doubt in (91b), the inference that Armstrong survived cancer is inherited by the entire sentence.

In these two respects, the inference behaves very much like a presupposition – and it clearly differs from a scalar implicature. However, Potts convincingly argues that in other respects his 'conventional implicatures' sharply differ from presuppositions.

(iib) *Scopelessness – quantifiers:* Presupposition triggers that are in the scope of the negative quantifier *none* are acceptable, as in (92c), and they typically trigger universal inferences, as was noted above (see also Chemla, 2009). However, appositive modifiers appear to be unacceptable in similar environments, as shown in (92d).

(92) a. John knows that he is incompetent.
b. John, an incompetent semanticist / who is incompetent, will fail the test.
c. None of my students knows that he is incompetent.
d. #?None of my students, an incompetent semanticist / who is incompetent, is able to pass the test.

(iii) *Non-triviality:* Even though they often allow for accommodation, presuppositions are certainly allowed to be trivial – in fact, the transparency-based theories which we discussed above take this fact to be at the very core of theories of presupposition projection. However, the facts are entirely different with appositives, which must be *non*-trivial:

(93) Lance Armstrong survived cancer.
a. #When reporters interview Lance, a cancer survivor / who survived cancer, he often talks about the disease.
b. And most riders know that Lance Armstrong is a cancer survivor. (after Potts, 2005)

By virtue of the beginning of the discourse, the information that Armstrong survived cancer is redundant in both (93a) and (93b). In the presuppositional case, this is as it should be; in the case of supplements, the result is markedly deviant.

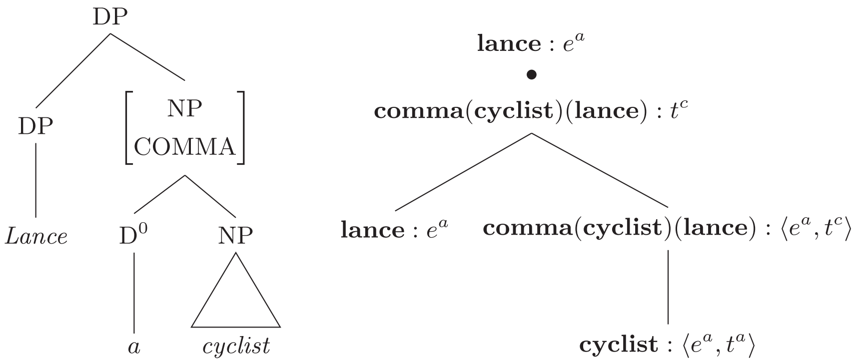

Figure 22.2 *Potts' analysis of* Lance, the cyclist

Potts (2005) proposes that supplements belong to a new dimension of meaning, the conventional implicature (or CI) dimension. He develops a multidimensional analysis by duplicating logical types, as shown in (94) (refinements of the type system are offered in McCready, 2010b).

(94) Potts' type system for conventional implicatures
a. e^a, t^a and s^a are basic at-issue types.
b. e^c, t^c and s^c are basic CI types.
c. If τ and σ are at-issue types, then $\langle \tau, \sigma\rangle$ is an at-issue type.
d. If τ is an at-issue type and σ is a CI type, then $\langle \tau, \sigma\rangle$ is a CI type.
e. The full set of types is the union of the at-issue and CI types.

It is noteworthy that type duplication is not complete: while each of the basic types exists both in an 'at-issue' and in a conventional implicature, this is not the case of all complex types; specifically, (94) (especially (d)) guarantees that no expression will ever take an expression with a CI type as one of its arguments. At this point, we can already see what the strategy will be:

(i) *Non-deniability:* By assumption, we will take the new dimension not to be the 'main' one, which will presumably explain why it cannot be targeted by denials in discourse.
(ii) *Scopelessness:* By construction of the type system, no expression can ever be sensitive to the supplementary component of its argument, and for this reason the supplementary component of an expression will never interact scopally with negations and quantifiers.
(iii) *Non-triviality:* Since supplements have nothing to do with presuppositions, there is no reason to assume that they should have the trivial character of the latter.

On a technical level, an example of Potts' analysis is given in Figure 22.2 for the expression *Lance, the cyclist*. Without going into full details, let us explain the ideas informally:

- The comma before *a cyclist* is taken to have a meaning, which transforms the at-issue expression *a cyclist*, of type $\langle e^a, t^a \rangle$, into the CI expression '*, a cyclist*', which has the complex type $\langle e^a, t^c \rangle$, where t^c is crucially a CI type.
- New composition rules guarantee that:
  (a) the supplement '*, a cyclist*', of type $\langle e^a, t^c \rangle$, can compose with its argument *Lance*, of type e^a, to yield a CI meaning of type t^c.
  (b) at the same time, the at-issue meaning of *Lance* is entirely preserved in a separate (at-issue) dimension.

In Figure 22.2, the two dimensions are separated vertically by the bullet sign •. An additional rule (called *parsetree interpretation*) will then collect all the meanings of propositional type that appear in a semantic parsetree (of which the right-hand side of 22.2 would only be a part) to yield a pair of the form below:

⟨at-issue meaning, {CI meaning #1, CI meaning #2, . . . , CI meaning #*n*}⟩

The second coordinate of the pair is an unordered set that simply collects all the propositional CI meanings that appear in the semantic parsetree.

Questions

Several questions can be raised, both within a multidimensional framework and outside of it. Here we only aim to give a few examples of a very lively contemporary debate.

Compositional interaction From the start, Potts (2005) noticed that the claim that supplements are never semantically embedded might be too strong. Thus in (95a), the appositive clause is interpreted exactly as if it were in the scope of the speech act; furthermore, it appears in the 'Konjunktiv I', a mood which is characteristic of reported speech in German.

(95) a. Juan behauptet, dass Maria, die sehr schwach sei, krank
Juan maintains that Maria who very weak be.konj sick
sei.
be.konj
'Juan maintains that Maria, who is supposed to be really weak, is sick.' (Potts, 2005)
b. Juan behauptet, dass Maria krank sei. Sie sei sehr
Juan maintains that Maria sick be.konj She be.konj very
schwach.
weak
'Juan maintains that Maria is sick. According to him, she is very weak.' (Potts, 2005)

However, as Potts (2005) is quick to point out, this is by no means a counterexample to his analysis: as (95b) shows, independent clauses in the Konjunktiv I can be understood as if they were semantically embedded – presumably by a mechanism of *modal subordination* or *perspective shifting*. Harris and Potts (2009) argue with experimental means that the latter mechanism is also available in English. Thus, their subjects accepted to attribute to the agent (= Sid, rather than the speaker) the content of the supplement *a complete waste of time* both in (96a) and in (96b).

(96) My brother Sid hates school.
  a. He says that he puts off his homework, a complete waste of time, to the last minute.
  b. He puts off his homework, a complete waste of time, to the last minute.

The fact that the nominal appositive in (96a) appears to be semantically embedded does not speak against Potts' multidimensional approach: as (96b) shows, it is independently possible to interpret such a nominal appositive as *if* it were embedded under an attitude operator – even when none is present (*put off* is certainly not an attitude verb!). Harris and Potts (2009) conclude that both examples in (96) should be analyzed by positing a pragmatic operation of perspectival shift – one that crucially does *not* require that the nominal appositive be semantically embedded under the verb *say*.

The logic that Potts applied to the German example in (95) leads to the opposite conclusion in other languages. For instance, it was argued in Schlenker (2010b, 2013) that the availability of appositive relative clauses in the subjunctive in French argues against Potts' proposal. In brief, the argument is that unlike the German Konjunktiv the French subjunctive cannot appear in an independent clause; furthermore, when an appositive relative clause does appear in the subjunctive, it is in some cases interpreted with unambiguously narrow scope with respect to the operator that licenses it.

If correct, these facts suggest that under ill-understood conditions, appositives can be interpreted with narrow scope relative to other operators – which would seem to speak against Potts' multidimensional system. Schlenker (2010b, 2013) sketches a 'unidimensional' analysis of these data (but see AnderBois et al., 2013, for a more sophisticated analysis within dynamic semantics). It has three main tenets:

(i) Appositives can be syntactically attached with matrix scope, despite their appearance in embedded positions; this is to account for *some* of the cases that motivated Potts' multidimensional analysis.
(ii) Appositives (a) are preferably attached with maximal scope (with the possible exception of attitude reports), but (b) they can in some cases be syntactically attached within the scope of other operators (whether attitudinal or not), in which case they semantically interact with them (this is intended to account for limited cases of semantic embedding discussed in the literature).

(iii) Appositives are semantically conjoined with the rest of the sentence, but they are subject to a pragmatic rule that requires that their content be relatively easy to accommodate ('Translucency') – hence, some non-trivial projection facts for appositives that do not have matrix scope.

While (ii) is motivated by the data we saw above, independent arguments are needed for (i) and (iii). (iii) is too complex to go into here. As for (i), the argument crucially has to be based on syntactic tests, since the fact that appositives are semantically unembedded are a given for Potts' approach. Finding clearly syntactic arguments is not trivial; one line of argument goes back to McCawley (1988), who discussed (97).

(97) John sold a violin, which had once belonged to Nathan Milstein, to Itzhak Perlman, and Mary did too.

McCawley observed that the second sentence does not imply that the violin that Mary sold to Perlman had once belonged to Nathan Milstein. On the (non-trivial) assumption that ellipsis targets a constituent, this suggests that the appositive can be attached outside the constituent which is the antecedent of the elided VP. An alternative, however, would be to posit that ellipsis resolution is at bottom a *semantic* operation, and hence that McCawley's facts do not speak against Potts' 'in situ' analysis of appositive clauses but rather argue *for* Potts' multidimensional semantics. Empirical developments will no doubt shed new light on this debate.

Varieties of appositives: nominal appositives vs. appositive relative clauses Wang et al. (2005) and Nouwen (2014) noted a contrast between some nominal appositives and some appositive relative clauses:

(98) a. If a professor, a famous one, publishes a book, he will make a lot of money.
b. If a professor, who is famous, publishes a book, he will make a lot of money.
c. It is not the case that a boxer, a famous one, lives in this street.
d. It is not the case that a boxer, who is famous, lives in this street.

As Nouwen notes, in (98a) and (98c) the nominal appositive is understood to further restrict the existential quantifier (*a professor*, *a boxer*); such a reading is unavailable or difficult in (98b) and (98d) (the remarks of the preceding paragraphs would lead one to expect that such a reading is available but dispreferred; Nouwen suggests in a note that in (98b) "*a professor* is read with wide scope with respect to the conditional" – which in turn allows the appositive relative clause to take maximal scope).

Still, Nouwen notes that it will not do to just posit that nominal appositives are more liberal in their attachment possibilities than appositive relative clauses; for when the modified NP is referential, the data change and a wide scope interpretation of the nominal appositive is once again preferred:

(99) a. If Jake, a famous boxer, writes a book, he will make a lot of money.
b. If Jake, who is a famous boxer, writes a book, he will make a lot of money.

Nouwen concludes that high attachment is preferred whenever it is available:

(100) A logical form in which nominal appositive is attached in a high position blocks competing logical forms in which the nominal appositive is attached in a lower position.

As Nouwen explicitly states, this generalization does not currently follow from anything (see AnderBois et al., 2013, for an alternative analysis in terms of corrections).

22.4.2 Expressives

Initial characterization

Potts (2005, 2007) provided another argument in favor of a multidimensional analysis, based on *expressives* such as *honky* or the antiquated term *Boche*, which refer to white people and Germans respectively, while conveying that the speaker has a negative attitude toward them (see Potts, 2007, and the commentaries in the same volume of *Theoretical Linguistics* for a glimpse of the lively debates on this topic). According to Potts (2007), expressives are characterized, among others, by the following properties (see also Kaplan, 2001):

(i) *Independence*: "Expressive content contributes a dimension of meaning that is separate from the regular descriptive content."

(101) I enjoy working with honkies.
a. Descriptive meaning: I enjoy working with white people.
b. Expressive meaning: I have a derogatory attitude toward white people.

(ii) *Nondisplaceability*: "Expressives predicate something of the utterance situation." In particular, expressive meaning leaps out of the scope of logical operators, as is illustrated in (102), where the inference that the speaker has a derogatory attitude toward white people is preserved under negation.

(102) I will never hire a honky.
a. Descriptive meaning: I will never hire a white person.
b. Expressive meaning: I have a derogatory attitude toward white people.

(iii) *Perspective dependence*: "Expressive content is evaluated from a particular perspective. In general, the perspective is the speaker's, but there can be deviation if conditions are right." Usually, the agent whose attitude is expressed is the actual speaker, but sometimes this is not so. Importantly, however, *some* perspective is needed.

(103) a. #I am not prejudiced against Caucasians. But if I were, you would be the worst honky I know.
b. I am not prejudiced against Caucasians. But John, who is, thinks/claims that you are the worst honky he knows. (Schlenker, 2003; Potts, 2007)

Multidimensional account and refinements

Potts (2005, 2007) offers a multidimensional account, following the general spirit of his analysis of supplements. In particular, he develops a type system similar to (94), but with expressive types replacing the CI types.

(104) Potts' original type system for expressives
a. e and t are descriptive types.
b. ϵ is an expressive type.
c. If σ and τ are descriptive types, then $\langle \sigma, \tau \rangle$ is a descriptive type.
d. If σ is a descriptive type, then $\langle \sigma, \epsilon \rangle$ is an expressive type.
e. The set of types is the union of the descriptive and expressive types.

As was the case in our discussion of types for supplements, the strict separation between expressive and descriptive types might be too radical. In particular, McCready (2010b) shows that in some very simple cases the system fails:

(105) John is a honky.

The problem is that in Potts' original system, an expression has either a descriptive or an expressive type. However, in (105) we both want *honky* to be predicated of John (which would require a type $\langle e, t \rangle$) and to yield an expressive meaning that the speaker has a derogatory attitude toward white people (which would require a type $\langle e, \epsilon \rangle$, where ϵ is the expressive type). McCready argues for an enriched type system that addresses this problem.

As was the case with supplements, Potts granted from the start that there are cases in which an expressive can be evaluated from a different perspective from the speaker's. However, does this show that Potts' type system is incorrect? No, if it can be shown that the same interpretations are available in unembedded sentences. As was the case for supplements, Harris and Potts (2009) argue with experimental means that an operation of perspectival shift is available in discourse given the right discourse conditions:

(106) Context: My classmate Sheila said that her history professor gave her a low grade.
Target: The jerk always favors long papers.
Experimental question: Whose view is it that the professor is a jerk?

An important proportion of the subjects have for *the jerk* a subject-oriented reading, whereby it is implied that *Sheila* takes the professor to be a jerk.

Still, it is unclear whether these measures are sufficient to account for cases such as (103b), where it seems crucial that *honky* be genuinely interpreted in the scope of *claim/believe*. This can be seen by embedding the attitude verb under further operators:

(107) I am not prejudiced against Caucasians.
  a. And if John, who is, claimed that you are the worst honky he knows/a honky, I would punch him in the face.
  b. And even John, who is, will never say that you are a honky.

If we were to posit an operation of perspectival shift to account for these examples, it could not be a discourse operation that only operates at the unembedded level, since in these cases it is crucial that the perspectival element should be interpreted within the scope of logical operators. For instance, (107b) cannot be interpreted as: *John will never say that you are a white person, and John has a derogatory attitude toward white people*. Furthermore, even allowing perspectival shift to be somehow negated as part of a separate operation will not work. This might provide an inference of the form: *John will never say that you are a white person, and John doesn't have a derogatory attitude toward white people*. However, the first part of the entailment is still too strong: there is nothing in (107b) that entails that John will never express the content of the embedded clause *devoid* of its expressive component; rather, what is denied is that John will express something that conjoins the descriptive and the expressive component of the term *honky*.

Presuppositional account

Several authors have explored a presuppositional account of expressives (e.g., Macià, 2002, 2006; Schlenker, 2003, 2007; Sauerland, 2007).[25] In one version, the hypothesis is that expressives are lexical items that carry a presupposition of a particular sort, namely one which is *indexical* (it is evaluated with respect to a context), *attitudinal* (it predicates something of the mental state of the agent of that context), and sometimes *shiftable* (the context of evaluation need not be the context of the actual utterance). To make the discussion concrete, we provide in (108) lexical entries for two prototypical expressives, the ethnic slur *honky* (Kaplan, 2001), and the French familiar pronoun *tu*. Our framework is two-dimensional, and thus we evaluate each lexical entry with respect to a context c and a world w. As usual, # indicates presupposition failure:

(108) a. $[\![\text{ honky }]\!](c)(w) \neq \#$ iff the agent of c believes in the world of c that white people are despicable. If $\neq \#$,
  $[\![\text{ honky }]\!](c)(w) = [\![\text{ white }]\!](c)(w)$
  b. $[\![\text{ tu }]\!](c)(w) \neq \#$ iff the agent of c believes in the world of c that he stands in a familiar relation to the addressee of c. If $\neq \#$, $[\![\text{ tu }]\!](c)(w) =$ the addressee of c

[25] This section shares some material with Schlenker (2007).

Let us now see how a presuppositional analysis might derive the main properties that expressives have according to Potts' analysis (see, for instance, Schlenker, 2007, for a more detailed discussion):

(i) *Independence*: "Expressive content contributes a dimension of meaning that is separate from the regular descriptive content." This result is immediate: the lexical entries in (108) are presuppositional, and on any account, presuppositions are a dimension of meaning that is separate from the 'regular' content of an utterance.

(ii) *Nondisplaceability*: "Expressives predicate something of the utterance situation." This result follows from the indexical character of expressives. It is not entirely common to define presuppositions that are indexical, but nothing prohibits their existence. Furthermore, there might be independent reasons for treating some expressions as triggering an indexical presupposition. Thus, the pronoun *you* is sometimes analyzed as a variable that carries the presupposition that it denotes the addressee:[26]

(109) $[\![\text{you}_i]\!]^s(c)(w) \neq \#$ iff $s(i) =$ the addressee of c. If $\neq \#$, $[\![\text{you}_i]\!]^s(c)(w) = s(i)$

The entry we posited in (108) has the same general form.[27]

(iii) *Perspective dependence*: "Expressive content is evaluated from a particular perspective. In general, the perspective is the speaker's, but there can be deviation if conditions are right." We account for this fact by suggesting that some expressives are *shiftable indexicals* (Schlenker, 2003; Sauerland, 2007). Standard indexicals are expressions that must be evaluated with respect to the context of the actual speech act. Shiftable indexicals are more promiscuous and may be evaluated with respect to any context (e.g., the context of a reported speech act). For the sake of concreteness, we adopt the assumptions of Schlenker (2003): context variables are explicitly represented in the object language, with the convention that a distinguished variable c^* represents the context of the actual speech act. A shiftable indexical may take as argument any context variable; a standard indexical may only take the variable c^*. As far as we can tell, *honky* is shiftable (it may be represented as *honky*-c_i or *honky*-c^*), while *tu* is unshiftable (it may only be represented as *tu*-c^*).

Importantly, this account must be supplemented with a pragmatic analysis to explain how expressive presuppositions differ from other

[26] The motivation for this approach lies in demonstrative uses of second person pronouns: *You* [pointing] *should stop talking to you* [pointing] (Schlenker, 2003).

[27] It is easy to combine the analysis in (108) with that in (109): $[\![\text{tu}_i]\!] s(c)(w) \neq \#$ iff $s(i)$ is the addressee of c and the agent of c believes in the world of c that he stands in a familiar relation to the addressee of c. If $\neq \#$, $[\![\text{tu}_i]\!] s(c)(w) = s(i)$.

presuppositions, in particular in that they appear never to give rise to cases of presupposition failure. The strategy adopted in Schlenker (2007) is to treat expressive presuppositions as *informative presuppositions*, as in (110):

(110) a. The stupid president will cause a disaster.
b. The fantastic president will take us out of this quagmire.

Stupid and *fantastic* need not be expressive: when I say that *John isn't stupid* or *John isn't fantastic*, no negative or laudative inference is preserved – unlike what happens when I say that *John isn't a honky* (the inference that I have a derogatory attitude toward white people is preserved). Still, the examples in (110) produce very much the effect of sentences containing expressives. The difference is that in (110) we can tell that the inferences are triggered by a presupposition trigger, *the*. Furthermore, these are cases in which the presupposition triggered – namely that the president is stupid or fantastic – must usually be taken to be *informative*. For the sake of this discussion, suppose it is clear in the context that there is only one president. Then *the stupid president* has the very same denotation as *the president*, and hence *stupid* must have some other contribution, or else it would run afoul of Grice's principle of manner (discussed above when we introduced Katzir's derivation of it, see (21)). So a reasonable guess is that these inferences belong to a class of *informative presuppositions*, which have been discussed from an empirical as well as formal perspective in the literature (e.g., Stalnaker, 2002; von Fintel, 2008; Schlenker, 2012).

From a formal perspective, Schlenker (2007) adopts an analysis based on Stalnaker (2002); it shows that under reasonable assumptions about the epistemic logic of presuppositions (namely that presuppositions must be common belief), it is sometimes enough to present oneself as presupposing that p to guarantee that p is indeed common belief. The key observation in Stalnaker (2002) is that, if it is common belief that the speaker believes that it is common belief that F, and if in addition the addressee believes that F, then it is common belief that F. Now the idea in Schlenker (2007) was that because expressives are *attitudinal presuppositions*, if the speaker shows that he or she presupposes that he or she has a derogatory attitude toward white people, the addressee would have every reason to *grant* that the speaker indeed does have such an attitude, and thus to come to believe that he or she does; with $F =$ *the speaker has a derogatory attitude toward white people*, we would be in precisely the kind of situation in which we can apply Stalnaker's result. If correct, this might provide a derivation of the fact that expressive presuppositions differ from standard presuppositions in being systematically informative.

Still, there are problems with this analysis because there are differences between presuppositions and expressives (see Richard, 2008, for further discussion).

First, the pragmatic effects of expressives and of presuppositions are rather different.

(111) a. Everybody knows that I hate Caucasians. Are you one?
b. Are you a honky?

Example (111a) explicitly introduces a presupposition that the speaker has a negative attitude toward Caucasians – and yet (111b) appears to be far more offensive. This might suggest that (i) or (ii) are correct: (i) the inference triggered by expressives is not just subjective ('the speaker has a negative attitude toward Caucasians') but objective ('Causians are despicable'); or (ii) the inference in question is not a presupposition.

We could revise our view that expressives trigger attitudinal presuppositions, but then we would also lose the result that they are automatically informative presuppositions. Importantly, Potts (2007) devised a dynamic account in which expressives have a semantic effect which is *sui generis* and could in principle be distinguished from any other component of meaning that has been posited so far.

Second, the projection behavior of expressives is not identical to that of presuppositions.

(112) a. Nobody stole my car, or it was John who did.
b. I am not prejudiced against Caucasians, or you are the worst honky I know.

In (112a), the presupposition that someone stole my car is not inherited by the entire sentence, because no matter what the initial context is this presupposition is satisfied ('in its local context') by the negation of the first disjunct. However, it is hard to see how the presupposition that I have a negative attitude toward white people can be 'filtered out' in (112b). One would have to say that the difference between the two cases stems from the fact that disjunctions introduce primary implicatures of ignorance that are never satisfied when one is talking about one's own attitudes – as is the case here:

(113) I am not prejudiced against Caucasians, or my colleagues know that I am.

However, at this point it is not quite clear how the presuppositional theory can account for these differences.

22.5 Conclusions

While we have not surveyed the important results that have recently come from psycholinguistics, we hope to have shown that the study of the semantics/pragmatics interface is one of the most fertile grounds in contemporary research on meaning: it offers a rather exceptional interplay between important foundational questions (the modular decomposition of meaning and the division of labor between language and reasoning) and rich arrays of new data which are analyzed with very sophisticated formal – and now also experimental – techniques. The debate on scalar implicatures, presuppositions, and conventional implicatures is probably more lively than ever – and this is a testament to the vitality of this field.

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23

Information structure

Enric Vallduví

23.1 Introduction

The term *information structure* is often used as a convenient cover expression for a bundle of phenomena – referred to by *(back)ground*, *comment*, *contrast*, *focus*, *given*, *new*, *rheme*, *theme*, *topic* and associated terms – that exhibit pragmatic, semantic, morphosyntactic and phonological features. It is clear that information structure affects content, and in particular that it concerns context-sensitive aspects of content, but it is not universally agreed whether information structure forms a distinct dimension within the interpretative component of language.

In this chapter, for expository purposes and as in Kruijff-Korbayová and Steedman (2003), the term *information structure* is used broadly as encompassing utterance-level features of both a semantic and a structural nature. The discussion will be centred around the following information-structural notions: the *theme–rheme* distinction (Section 23.3), *givenness* and *topic* (Section 23.4), and *contrast* (Section 23.5). These descriptive notions allow linguists to go a long way in analysing phenomena that have generally been thought of as concerning information structure. The facts concerning *focus*, one of the most (ab)used labels in information structure research, will be discussed in connection with the notions *contrast* and *theme–rheme*.

As a first approximation to information structure, consider (1) (small caps identify the lexical item associated with nuclear prominence):

(1) a. We like HOKEY-POKEY.
b. Hokey-pokey we LIKE.
c. Hokey-pokey we HATE.
d. We LIKE hokey-pokey.

Examples (1a) and (1b) have identical truth conditions but still differ interpretatively; there is something in the content, understood broadly, of (1a) which sets it apart from the synonymous (1b); this interpretative difference correlates with the difference in word order. Interestingly, (1b) and (1c) display a certain interpretative equivalence which is obviously not connected to their truth-conditional meaning; this interpretative equivalence correlates with the structural 'sameness' that they display. Both the interpretative difference between (1a) and (1b) and the partial interpretative equivalence between (1b) and (1c) are taken to be information structural in nature. There is also a difference in (non-truth-conditional) content between (1a) and (1d), which is of a nature similar to the difference between (1a) and (1b); here, however, the structural contrast associated with the interpretative difference is not in the word order but rather in the intonation. In English and many other languages, if not all, intonation is an important correlate of information-structural content.

The examples in (2) illustrate that the interpretative import associated with these structural differences is context dependent:

(2) a. A: What are we having for dinner?
b. B: We are having MUTTONBIRD for dinner.
c. B′: # We are having muttonbird for DINNER.
d. B″: MUTTONBIRD.

Query–answer pairs are used in the literature to illustrate the connection between information structure and discourse congruence. The query in (2a) evokes a context against which uttering (2b) is felicitous whereas (2c) is not. This contrast in felicity is due to the (lack of) compatibility between the context, as evoked by the query, and the different information-structural imports of (2b) and (2c) (the difference between them is manifested, as in the pair (1a)–(1d), via intonation). Moreover, notice that the declarative fragment in (2d), a 'short-answer' counterpart of the full-fledged answer in (2b), is also felicitous in the context evoked by (2a). In fact, *ceteris paribus*, (2d) is a less marked answer than (2b). It is evident that context is of the essence in determining the content of (2d).

That information-structural phenomena concern in one way or another the relation of utterances to the previous context appears to be now the general consensus. Thus, following Krifka and Musan (2012), information structure will be seen as referring to 'those aspects of natural language that help speakers to take into consideration the addressee's current information state, and hence to facilitate the current flow of information' (Krifka and Musan, 2012, p. 1). This process of 'facilitation' is effected with respect to a number of resources in the addressee's information state. It is therefore necessary to adopt a particular conception of what information states are like and describe the relevant contextual resources before we actually start discussing any information-structural notions.

23.2 Contextual resources

The view that context is of the essence for information structure gained wide acceptance due to the generalisation of dynamic accounts where the semantic contribution of sentences is seen as lying in their potential to change the context (see Isard, 1975). One of the main goals of the early approaches (e.g. Kamp, 1981b; Heim, 1983a; Seuren, 1985; Veltman, 1990; Groenendijk and Stokhof, 1991; Dekker, 1993) was to extend the analysis of a number of phenomena, like the interpretation of bound pronouns, beyond the limits of the sentence proper and into discourse. The influence of earlier views on context as a set of propositions held to be true by both speaker and hearer or as a *common ground* of shared beliefs (e.g. Karttunen, 1974; Stalnaker, 1974) was central to these approaches, but in the drive to account for the discourse data, two important theoretical adjustments were made. On the one hand, it became clear that context had to be understood not as an interlocutor-neutral common ground, but rather as (the public area of) the addressee's information state at the time of utterance (t_u), since speaker/addressee asymmetries exist which can only be accounted for if each conversationalist has a distinct 'dialogue gameboard' (Ginzburg, 2012). On the other hand, a subset of these early dynamic approaches felt that a view of the common ground as an unstructured construct was empirically insufficient and went on to introduce a certain degree of representational richness, which structured contexts into subdomains or broadened the spectrum of contextual resources available for the computation of content.

The idea that the relevant notion of context is a structured information state anchored in the addressee brought formal dynamic approaches to converge with research in other traditions, such as discourse analysis, (formal) pragmatics, functionalism, psycholinguistics and computational linguistics, as represented, for instance, by Halliday (1967), Chafe (1976), Clark and Haviland (1977), Webber (1978b), Prince (1981c), Gundel (1985), Grosz and Sidner (1986), Sgall et al. (1986) and Ariel (1988). These works already elaborated in one way or another on the idea that speakers structure utterances in accordance with their assumptions about their addressee's information state at t_u, which is the idea that inspired representative work on information structure in the 1990s (e.g. Vallduví, 1992; Lambrecht, 1995;

Erteschik-Shir, 1997), which has survived to this day, and is reflected in the quote above by Krifka and Musan (2012).[1]

The erstwhile conception of context as a Stalnakerian set of commonly agreed propositions, assumptions or facts was soon enriched with an additional resource type, namely 'open propositions' (Prince, 1986), 'quaestio' (Klein and von Stutterheim, 1987) or 'questions under discussion' (*quds*) (Carlson, 1983; Ginzburg, 1994; Kuppevelt, 1995; Roberts, 1996; Beaver and Clark, 2008), which play a central role in the dynamics of dialogue and the rhetorical organisation of discourse. Quds are semantic questions (issues) which are introduced into context (at least) through uttered assertions and queries – asserting p introduces *whether* p ($?p$) and posing q introduces q – and which (potentially) constitute the subject matter of discussion and, thus, drive the progression of conversation. Interlocutors must keep score of the quds that arise in conversation and also of their degree of salience: the quds in the context are partially ordered and the most salient qud is ranked highest – it is qud-maximal – at t_u (Ginzburg, 2012). A qud is naturally taken to be a propositional abstract, a function from meanings of different kinds – those of the qud's potential short answers – to propositional meanings (those of the potential full-fledged answers) (Tichý, 1978; von Stechow and Zimmermann, 1984; Ginzburg, 1995a; Krifka, 2001a).[2] Quds play an essential role in accounting for the *theme–rheme* distinction in utterances.

A different enrichment to contexts was the addition of a class of objects susceptible of acting as antecedents for standard pronominal anaphora and of entering into other referential links: what Karttunen (1976) called *discourse referents*. Discourse referents are entities of different kinds, including, at least, individual tokens, individual types, event tokens and event types. Uttered referential expressions may add discourse referents into a context or may establish an anaphoric link to a contextually available referent. Anaphora requires a successful pairing of contextual configuration and utterance form and, therefore, interlocutors must also keep track of the availability of discourse referents and their degree of salience or accessibility, as discussed in the functional, psycholinguistic

[1] The origin of the terms *information structure* (Halliday, 1967) and *information packaging* (Chafe, 1976) is to be found precisely in a subset of those early works. Also essential were the ideas of the Prague School of linguistics (e.g. Sgall et al., 1986; Hajičová et al., 1998 and references therein). Newmeyer (2001) is an informative survey of the parallelism and mutual influence between US research on information structure and the Prague School.

[2] An alternative approach to quds (and to questions in general) defines the meaning of a qud as the set of (all) its possible (for some, correct) answers; see Roberts (1996) for quds and Hamblin (1973), Karttunen (1977), Groenendijk and Stokhof (1984) in general. Evidence involving information structure has been used to argue for the superiority of one or other approach (Krifka, 2001a). The *Presup* in Jackendoff (1972) can be classed also as a qud, as it is an unsaturated propositional abstract. As for Prince's (1986) open propositions, although not formally defined as semantic questions, they are described as unsaturated abstracts and are explicitly argued to be, as a contextual resource, different from propositional assumptions or facts.

and computational approaches cited above (see also Hawkins, 1978; Garrod and Sanford, 1982; Givón, 1992; Gundel et al., 1993; Grosz et al., 1995; Poesio et al., 2004). Discourse referents, as a contextual resource, can be seen as constituting a level which is distinct from the 'propositional' level, which includes agreed propositions and quds (propositional abstracts). Contextual congruence, therefore, involves both entity-level congruence (e.g. referential specification) and propositional-level congruence (e.g. qud-related congruence). Here the term *(referential) givenness* will be used to refer to the felicity requirements associated with entity-level congruence and its theoretical extensions.[3] Discourse referents are central not only to the concept of givenness but also to the information-structural notion of *topic*, as, for instance, in Reinhart (1981), where the definition of topic is construed at the level of discourse referents.

A third contextual enrichment, which is relevant for information structure, as shown below, concerns the notion of *contrast* (see Dretske, 1972; Chafe, 1976). The context of a (sub)utterance may make available potential alternatives to that (sub)utterance. Alternatives become available (or are made salient) in context through explicit introduction of the class or set they belong to or via accommodation. The idea that (sets of) alternatives are (salient) contextual resources that play a role in the determination of content appears in, for instance, Jackendoff (1972), Ladd (1980), Rooth (1985, 1992), Büring (1997), Umbach (2003) and also in Hirschberg and Ward (1984), Ward (1988), Pierrehumbert and Hirschberg (1990), where it is claimed that, in order to account for some phenomena, the contextually available sets must be partially ordered sets (or scales). Also, alternatives as a contextual resource are at the basis of the notions of *parallel element* in higher-order unification approaches (Pulman, 1997) and of *focus establishing constituent* (FEC) in the dynamic framework of Ginzburg (2012).[4]

In sum, the relevant input context C_1 of an utterance U is viewed as the addressee's information state immediately prior to U. C_1 minimally contains propositional assumptions, quds, discourse referents and (sets of) elements that constitute potentially 'utterable' alternatives to the actual utterance or subutterances at t_u. These contextual resources are appealed to by information structural notions in effecting their role as facilitators of the flow of communication. The contextual congruence or felicity of U is partially determined by the fact that sentential information structure and the specific configuration of C_1 constrain each other.

[3] Gundel and Fretheim (2004) link entity-level congruence to *referential* given/new and propositional-level congruence to *relational* given/new. In contrast, some other approaches to givenness (Schwarzschild, 1999; Bott, 2008) obliterate the distinction between entity-level and propositional-level congruence (see Section 23.4).

[4] The FEC was called SAL-UTT in Ginzburg and Sag (2000). While contextual in nature, parallel elements/FECS are objects of type 'utterance' in that they are not purely semantic but rather include structural information as well. The idea that the form of utterances also contributes information which persists in context is convincingly argued for in Ginzburg (2012) and elsewhere.

23.3 Theme and rheme

The *theme–rheme* distinction is discussed here in connection to quds as essential elements in context update. The highest-ranked or maximal qud (henceforth, max-qud) in the qud set of C_1 circumscribes discourse progression: U, uttered in a context C_1, must be specific to or an *elaboration* of max-qud$_{C_1}$ (see Ginzburg, 1994, 2012; Kuppevelt, 1995; Roberts, 1996; Asher and Lascarides, 2003b; Büring, 2003 for different formulations). In addition, U introduces a qud which becomes qud-maximal in the output context C_2 (max-qud$_{C_2}$). This can be illustrated with a query–answer exchange like (a–d) in (2), repeated here as (3):

(3) a. A: What are we having for dinner?
b. B: MUTTONBIRD.
c. max-qud$_{C_1}$: ?λx.**have-for-dinner**(**A**+**B**,x)
d. max-qud$_{C_2}$: ?**have-for-dinner**(**A**+**B**, **muttonbird**)

Max-qud$_{C_1}$, introduced by query (3a), is the propositional abstract (3c). The declarative fragment in (3b) spells out an elaboration – here, in particular, an answer – on max-qud$_{C_1}$ by instantiating the latter's λ-bound variable, thus resolving it. At the same time, (3b), due to its status as a propositional assertion, introduces a max-qud$_{C_2}$: the assertion of p = **have-for-dinner** (**A**+**B**,**muttonbird**) makes ?p, namely (3d), the max-qud for C_2. Following, for example, Ginzburg (1999, 2012), Ginzburg and Sag (2000) and Fernández (2006), declarative fragments belong to a syntactic type which constructionally absorbs part of its content from max-qud$_{C_1}$ (contra Merchant, 2005). This contextually sourced part of the content is not structurally expressed; rather, fragments spell out the only meaning component of p that elaborates on max-qud$_{C_1}$. In the case of (3) this is the value of the λ-bound variable: **muttonbird**.[5]

Muttonbird in (3b) is a *rheme*. Rhemes spell out the meaning components of U which elaborate on max-qud$_{C_1}$ (Engdahl et al., 2000; cf. the idea that the rheme is the expression of the actual update potential of an utterance: Vallduví, 1992, 1994; McNally, 1998b; Steedman, 2000, 2014), and it is thanks to this elaboration that max-qud$_{C_1}$ progresses to max-qud$_{C_2}$. In this sense, it can also be said that the rheme is the structural exponent of the progression from max-qud$_{C_1}$ to max-qud$_{C_2}$ (but see below). The idea that the rheme is the locus of progression in discourse can be traced back to early work within the Prague School (see references in Sgall et al., 1986; Hajičová et al., 1998; Newmeyer, 2001).

Fragments like (3b) will be referred to as *themeless utterances*. Other themeless utterances, namely, affirmatives (*yes*) and rejections (*no*), occur also as

[5] The emergence of (3d) as max-qud$_{C_2}$ need not imply that (3c) is previously downdated; (3c) could remain in the qud set of C_2, ranked right below (3d), awaiting evidence that A does not reject p. If this tack is taken, once p is grounded as an assumption, both (3d) and (3c) will be removed from the qud set.

answer elaborations but do so on polar max-quds. *Yes* and *no*, like the answer *muttonbird* in (3b), are propositional in nature (Krifka, 2001a). The content of *yes*, for instance, is p, where p results from elaborating on $?p$ (max-qud$_{C_1}$) by, in a sense, 'stripping' it of its interrogativeness (Gutzmann and Castroviejo, 2011; Ginzburg, 2012). As a themeless utterance, *yes* spells out only the meaning component of U which elaborates on max-qud$_{C_1}$: the 'stripping' operation that $?p$ is subjected to.

Yet another example of themeless utterance is to be found in direct sluices, which embody a type of elaboration on max-qud other than that of answers. Direct sluices like (4b) are felicitous as queries for additional information that is underspecified (quantified away) in a previous utterance; in other words, they require a polar max-qud$_{C_1}$ $?p$, where p is a quantified proposition (Fernández, 2006; Ginzburg, 2012):

(4) a. A: We're having something (special) for dinner.
 b. B: WHAT?
 c. max-qud$_{C_1}$: $?\exists x.$**have-for-dinner**(A+B,x)
 d. max-qud$_{C_2}$: $?\lambda x.$**have-for-dinner**(A+B,x)

Assertion (4a) provides the right type of polar max-qud$_{C_1}$ $?p$, shown in (4c), for the sluice to be felicitous. The *wh*-meaning of the direct sluice is constructionally applied to $?p$ by λ-abstracting over the quantified element of p, thus yielding $?\lambda x.$**have-for-dinner**(**A**+**B**,x), which by qud update becomes max-qud$_{C_2}$, as in (4d). The sluice, a themeless utterance, spells out the *wh*-meaning of q, the only part of its content that elaborates on max-qud$_{C_1}$.

As noted above, themeless utterances are common in query–answer exchanges, which is expected. However, as seen in (2), full-fledged sentential answers are obviously also possible, albeit more marked: they spell out not only the elaboration on max-qud$_{C_1}$ but also a *replica* of max-qud$_{C_1}$. Spelling out this replica of max-qud$_{C_1}$, minus the element substituted by the elaboration, is precisely the job of the *theme*. Examples (5) and (6) illustrate 'short' and full-fledged utterances for elaborations on q and $?p$, respectively. The (c) utterances convey the same content and effect the same elaboration on max-qud$_{C_1}$ as the (b) utterances, but in addition, they replicate max-qud$_{C_1}$. Utterances like (5c) and (6c) will be referred to as *theme-containing utterances*:

(5) a. max-qud$_{C_1}$: $?\lambda x.$**have-for-dinner**(A+**B**,x)
 b. B: [$_R$ MUTTONBIRD]$_.$
 c. B′: [$_T$ We are having] [$_R$ MUTTONBIRD] [$_T$ for dinner]$_.$

(6) a. max-qud$_{C_1}$: ?**have-for-dinner**(A+**B**, **muttonbird**)
 b. B: [$_R$ YES]$_.$
 c. B′: [$_T$ We] [$_R$ ARE] [$_T$ having muttonbird for dinner]$_.$

Given that themeless utterances can constructionally combine with max-qud$_{C_1}$ and in principle effectively carry out a context update, the question arises as to why speakers opt to replicate max-qud$_{C_1}$: why are there theme-containing utterances? The answer to this question is that qud update can actually be a complex two-step process. The theme, if present, triggers the first step: a preparatory update from C_1 to $C_{1'}$, which renders the input context suitable for the ensuing rheme-provisioned update from $C_{1'}$ to C_2. Krifka (1993), Steedman (2000) and Kruijff-Korbayová and Webber (2007), for instance, take this step to be a verification that C_1 supports or can accommodate the 'presuppositional' import of the theme (cast in terms of structured meanings or Roothian sets of alternatives meanings). For current purposes, this context-preprocessing role of themes can be taken to be qud-related: theme-containing utterances prepare the input context by promoting a given qud to qud-maximality prior to its being elaborated on. Themes provision a specific max-qud$_{C_{1'}}$ (obtained from the qud set, other sources in C_1, or accommodation), and then the rheme updates $C_{1'}$ by elaborating on this max-qud$_{C_{1'}}$.[6]

One common set of cases in which themes are obligatory corresponds to utterances that elaborate on quds that are already in the qud set, but which have lost maximality at t_u: the theme (re-)raises the qud to qud-maximality to enable its elaboration by the rheme. As an example, consider the exchange in (7), an excerpt from the play *Everything in the Garden* (Giles Cooper, 1962), focusing on the polar query (7c) (in italics):

(7) a. Jenny: Do you want an egg?
b. Bernard: Are you having one?
c. J: *Do you want one?*
d. B: If you're having one, I will, otherwise no.
J: You are a lazy devil.
B: No. It's just that I don't want an egg enough to start everything going towards cooking it, but if you were going to do one for yourself, well, I'd want it enough for that.
J: I don't think I'll have one.
B: I'll do you one if you like.
e. J: [$_T$ You] [$_R$ DO] [$_T$ want one].
f. B: No, I don't. I'll just do you one. You ought to eat.

Jenny's query (7c), which introduces $?p_c$ = ?**want**(**B**,**egg**) as max-qud, is (self-)answered by (7e). However, by the time (7e) is uttered $?p_c$ has lost its

[6] In English, grammar bans fragment realisations of transitive predicators, as in (i), where max-qud is elaborated on via instantiation of the predicator λ-variable:

(i) a. max-qud$_{C_1}$: $?\lambda P.P$(**mia**),(**muttonbird**)
b. B: *[R LOVES]. / She LOVES it.
c. B′: [$_T$ Mia] [$_R$ LOVES] [$_T$ muttonbird].

There are two possible accounts of the facts. One: *she* and *it* in *She* LOVES *it* in (b) are thematic, like *Mia* and *muttonbird* in (c), and thus express a redundant replica of max-qud$_{C_1}$ (a pronominal version of (c)); English grammar excludes here elaboration via a themeless utterance. The other: *She* LOVES *it* is, despite appearances, a themeless utterance; the presence of *she* and *it*, important for referent tracking, is inert with respect to the theme–rheme distinction.

qud-maximality, since the intervening conversational moves, gathered in (7d), keep on updating the qud set: at t_u the max-qud inherited from context (max-qud$_{C_1}$), supplied by the last move in (7d), is whether Bernard will do an egg for Jenny (if she likes).[7] The use in (7e) of a theme-containing utterance enables elaboration on non-maximal query $?p_c$, without resorting to an explicit reformulation (*A few turns back I asked whether you wanted an egg and now I know the answer is yes*): the theme updates C_1 to $C_{1'}$, by replacing the inherited max-qud$_{C_1}$ with a newly provisioned max-qud$_{C_{1'}}$, and the rheme elaborates on this max-qud$_{C_{1'}}$ by resolving $?p_c$ to p_c. Notice that an elaboration on $?p_c$ spelled out by means of a themeless utterance would be infelicitous: #*Yes* (or even #*You do*).[8]

Interestingly, it has been observed that themeless utterances are a local phenomenon in dialogue. Fernández (2006) reports on a corpus study where all declarative fragments in two-party dialogue elaborate on a qud introduced at most three moves away (*one* move away in 83% of these) and where all non-sentential affirmatives elaborate on a qud which is one or two moves away (over 95% are *one* move away). This confirms that themeless utterances elaborate on quds whose maximality is pre-established at t_u, which also indirectly supports the idea that theme-containing utterances are used in non-local elaborations. In this respect, Vallduví (2001a) argues that there is a parallelism between themeless utterances at the qud-elaboration level and pronouns at the discourse-entity level, in that pronouns must specify referents that are maximal, or salient, at t_u, that is, the context dependence of themeless utterances and pronouns is subject to the same locality constraints (only 8% of pronouns in the corpora analysed in Hitzeman and Poesio (1998) had their antecedent more than one move away). In contrast, theme-containing utterances, which tend to elaborate on quds that are non-maximal at t_u, appear to be parallel to definite descriptions in that the latter also tend to specify non-local antecedents. The parallelism extends to the fact that theme-containing utterances can be used (redundantly and possibly giving rise to particular rhetorical effects) whenever a themeless utterance is used, as in (5) and (6) above, but not vice versa, which is exactly the situation with definite descriptions and pronouns (Gundel et al., 1993).[9]

Theme-containing utterances are also used when max-qud$_{C_{1'}}$ is obtained by 'broadening' the inherited max-qud$_{C_1}$: if max-qud$_{C_1}$ is part of or is a sub-issue of a broader issue max-qud$_{C_{1'}}$ (i.e. max-qud$_{C_1}$ upwardly entails max-qud$_{C_{1'}}$), then a theme-containing utterance may promote max-qud$_{C_{1'}}$ to

[7] The term *(conversational) move*, used here and below, refers to an utterance qua basic discourse unit with particular intentional or illocutionary meaning and context update effects (Carletta et al., 1997; Cooper et al., 1999).

[8] It is unlikely Bernard's second turn in (7d) is a first (unsuccessful) answer to (7c). Even if it were, there are two additional ensuing moves, which keep on updating the qud set.

[9] In (5) and (6) intermediate structural alternatives are possible: in (5) *We are having MUTTONBIRD* and in (6) *(Yes,) we ARE* or *(Yes,) we ARE having muttonbird*. It remains to be seen whether the existence and distribution of these 'intermediate' alternatives sheds light on the distinction between themeless and theme-containing utterances with respect to qud accessibility.

qud-maximality (prior to elaboration on it). The idea is that elaboration on the broader max-qud$_{C_{1'}}$ will also bring about a provision of information that is relevant for max-qud$_{C_1}$. Consider (8):

(8) a. A: Will Anna marry Manny?
b. B: [$_T$ Anna] [$_R$ ADORES / HATES] [$_T$ Manny].

The max-qud$_{C_1}$ introduced by query (8a), ?**marry**(**anna**,**manny**), is part of the broader issue ?$\lambda P.P$(**anna**,**manny**), which is the max-qud$_{C_{1'}}$ introduced by (8b). If the issue of Anna marrying Manny is under discussion, then so is the issue of Anna's relationship to Manny, so max-qud$_{C_1}$ upwardly entails max-qud$_{C_{1'}}$. While the theme-containing utterance in (8b) does not actually resolve (8a), it certainly constitutes a legitimate follow-up, by provisioning a new max-qud and elaborating on it.[10]

A third scenario in which theme-containing utterances are required is the case of the implicit (thus, non-maximal) quds that provide the rhetorical backbone of coherent discourse in approaches like Carlson (1983), Klein and von Stutterheim (1987), Kuppevelt (1995), Roberts (1996), Büring (2003). In (9), inspired by an example in Büring (2003), B answers A's query about a concert by assessing different aspects of it:

(9) a. A: How was Lorde's concert?
b. B: [$_T$ The band][$_R$ played very WELL],
c. B: [$_T$ the audience][$_R$ danced NONSTOP],
d. B: but [$_T$ the sound][$_R$ was APPALLING].

Max-qud$_{C_1}$ after (9a) is ?$\lambda P.P$(**L's concert**). However, moves (b–d) are elaborations not on max-qud$_{C_1}$, but on implicit quds about the band, the audience and the sound. Elaboration on these implicit quds forms part of a rhetorical strategy which splits up a broader issue into smaller components: the implicit quds are subquds of the (super)qud ?$\lambda P.P$(**L's concert**) introduced by (9a) (Roberts, 1996) or as quds on which the content of (9a) is dependent (Carlson, 1983): though obviously not maximal, they are available from C_1 at t_u via an associative, subsectional or non-monotone link to max-qud$_{C_1}$ (Hawkins, 1978; van Deemter, 1994; Hendriks, 2002). Thus, a theme-containing utterance is required to render each of them maximal at t_u. Move (9b), for instance, raises qud ?$\lambda P.P$(**band**), non-maximal in C_1, to max-qud$_{C_{1'}}$ and then elaborates on it by instantiating the λ-variable, eventually yielding a polar max-qud$_{C_2}$?**played-very-well**(**band**).

Both (8) and (9) require a theme to spell out that the max-qud to be elaborated on is not the inherited max-qud$_{C_1}$. However, the relationship between the inherited max-qud$_{C_1}$ and the theme-provisioned max-qud$_{C_{1'}}$ is different.

[10] Steedman (2014), on which example (8) is inspired, uses a related set of examples (his (10) and (13)) to illustrate the fact that themes do not (always) reflect max-qud$_{C_1}$. This fact is taken to show that the 'presuppositional' import of themes is primarily speaker determined (see also, e.g., Reis, 1999) and only indirectly limited by qud congruence. Despite some differences in emphasis, the speaker-centred view in Steedman (2014) and the qud-centred view adopted here are largely compatible.

In (8) we have an upward-entailing broadening of the max-qud, while in (9) there is no broadening; rather, $?\lambda P.P(\mathbf{band})$ is a subqud that 'narrows' down the superqud $?\lambda P.P(\mathbf{L's\ concert})$ in a non-monotonic fashion. This difference between (8) and (9) is reflected structurally: in cases of qud 'narrowing', like (9), there is explicit flagging by means of *contrast* on (one element of) the theme (cf. Büring, 2003, on contrastive topics). This will be discussed further in Section 23.5.

The three cases of theme-containing utterances described here do not exhaust the list of situations in which speakers may choose to provision a non-maximal qud at t_u. Take, for instance, classic examples of English focus-movement like *(Now they are coming out with a new hydraulic crane.)* CHERRY PICKERS *they are called* (Prince, 1981b). Here the provisioning of max-qud$_{C_{1'}}$, $?\lambda x.\mathbf{have\text{-}name}(\mathbf{hydraulic\text{-}crane},x)$ by means of the theme would appear to be licensed by a conversational rule stating that it is always an option to discuss the name of a recently introduced discourse referent (by *a new hydraulic crane* here). Engdahl (2006) states that elaboration by U on non-maximal quds is, in fact, an extremely common phenomenon and uses the term *focal question accommodation* to refer to the hearer's acceptance as qud-maximal of non-inherited quds that are spelled out by means of a theme-containing utterance (the first step in a two-step complex update).[11]

The examples discussed so far are cases in which the elaboration effected by U on max-qud is spelled out by a simplex expression (an NP, a verb, a *wh*-word, affirmation). These are often referred to as *narrow rhemes* (which include here rhemes in both theme-containing utterances and themeless utterances). In contrast, so-called *wide/broad rhemes* obtain when the elaboration effected by U on a max-qud is spelled out by a complex expression (VP, sentence). In (10) (a–b) illustrate a narrow rheme and (c–d) and (e–f) illustrate cases of wide rheme:

(10) a. max-qud$_{C_{1'}}$: $?\lambda x.\mathbf{buy}(\mathbf{moana},x)$
b. [$_T$ Moana bought] [$_R$ WHITEBAIT].
c. max-qud$_{C_{1'}}$: $?\lambda P.P(\mathbf{moana})$
d. [$_T$ Moana] [$_R$ bought WHITEBAIT].
e. max-qud$_{C_1}$: $?\lambda Px.P(x)$
f. [$_R$ Moana bought WHITEBAIT].

The mechanics of qud elaboration are the same in (a–b) and (c–d): the theme-provisioned max-qud$_{C_{1'}}$ is elaborated on via answerhood, in that U provides an instantiation for the λ-variable. The difference is that in (10d) this instantiation is realised by a VP. The same applies to (e–f), with a clausal rheme, where max-qud$_{C_1}$ would be a general question $?\lambda Px.P(x)$ in an out-of-the-blue context, expressed by queries such as *What's up?*, *What's new?*

[11] Qud accommodation is a common phenomenon in dialogue, introduced by update rules linked to specific conversational plans or genres or even to clarification routines (Cooper et al., 2000; Larsson, 2002; Traum and Larsson, 2003; Ginzburg, 2012).

Tokens like (10f), referred to as all-rheme utterances (e.g. Steedman, 2014), are themeless utterances. This makes sense, since $?\lambda Px.P(x)$ is the inherited max-qud$_{C_1}$.[12] All-rheme utterances have also been analysed as instantiating a predication on a spatiotemporal 'stage' constant corresponding to the 'here and now' of the discourse (Erteschik-Shir, 1997), so max-qud$_{C_1}$ would not be (10e) but rather something like $?\lambda P.P(\mathbf{stage})$. It is conceivable also that (10f), in which the subject spells out a referent that is given, is actually identical to (10d), even if it occurs after a query like *What's new?*: the subject *Moana* could arguably be thematic; if so, (10f) would elaborate not on the max-qud$_{C_1}$ in (10e) but rather on a self-provisioned max-qud$_{C_1'}$ like (10c), which is in fact a subquestion of (10e). Of course, not all all-rheme utterances can be analysed in such a way: subject-accented utterances like *The* COMPUTER *crashed* (Bolinger, 1972a) can be all-rheme, and cases like *A policeman arrived* are also generally treated as all-rheme (Erteschik-Shir, 1997). Kuroda (2005) is representative of a line of work in which all-rheme utterances like these are seen as fundamentally different from theme-containing utterances (and 'short answers'). In this approach, all-rheme utterances express thetic/descriptive judgements – unitary descriptions of perceived or conceptually apprehended situations; in contrast, theme-containing utterances express categorical/predicational judgements – cognitive associations of an attribute with an entity (see Section 23.4 for pertinent discussion on the notion of topic).

There has been substantial debate on how to reflect the relationship or opposition between the two theme-containing utterances and the themeless all-rheme utterance in (10), or, in other words, how to account for the ambiguity of the string *Moana bought* WHITEBAIT: at first blush it appears that this string, with nuclear prominence on a particular word (*whitebait*) is compatible with two or three theme–rheme partitions. The concept of *focus projection* has extensively been appealed to in the literature (Selkirk, 1996): a set of rules on the syntax–phonology interface determines whether the nuclear accent on a particular word may or may not 'project' to the phrasal level. The rules would allow the nuclear accent on *whitebait* in (10) to associate with the object NP, the VP or the sentence, whereas in other cases – e.g. the answer in (8) above – the projection of the nuclear accent to a higher phrasal level would be blocked. However, more recent approaches tend to do away with specific projection rules and derive the ambiguity in (10) from intrinsic default properties of prosodic or metrical structure (Büring, 2006; Calhoun, 2010) or from contrasting syntactic derivations (Steedman, 2014).

As noted at the start of this section, qud-based approaches to context update see U, uttered in a context C_1, as an elaboration of max-qud$_{C_1}$. Themeless utterances, both declarative fragments and all-rheme structures, effect this elaboration *simpliciter*; from the perspective of the mechanics

[12] (10f) is also a felicitous elaboration on a max-qud$_{C_1}$ $?\lambda x.\mathbf{cause}(x,\mathbf{happy}(\mathbf{B}))$, as introduced by a why-question such as *Why are you so happy?*

of context update, themeless utterances have a default status. In contrast, theme-containing utterances are used precisely to enable complex updates that consist of an elaboration on a qud which is not maximal in C_1 at t_u. Indeed, the job of the theme, if present, is to spell out this non-maximal qud so as to render it maximal (max-qud$_{C_{1'}}$) prior to its being elaborated on. Thus, it is clear that themes and rhemes are fundamentally different: themes are not inherent to a contextual update, whereas rhemes, which actually *embody* the contextual update, are. In a sense, rheme is interpretatively a non-category, in that its function as an elaboration (of max-qud$_{C_1}$ or max-qud$_{C_{1'}}$) is already built in in the dynamics of context update. Elaboration should not be seen as a contextual resource itself; rather, it is a means to effect the transition between input and output contexts. The theme, in contrast, is indeed a direct linguistic expression of a contextual resource, since it provisions a max-qud$_{C_{1'}}$ to enable a non-default update; therefore, it makes sense to consider it an information-structural category which is linguistically encoded across languages. In fact, in a variety of languages, themes, if present, are explicitly marked either syntactically, by appearing in non-canonical slots, often outside the 'core' clausal domain (Vallduví and Engdahl, 1996) or by associating with intonational phrases headed by complex fall-rise tones like L+H* and L*+H (Steedman, 2014) and non-default metrical structures, such as metrical reversal (Calhoun, 2010).[13]

In contrast, if rheme is technically not an interpretative category, there should be no expectation that it be associated with a particular realisation. Actually, it has been observed that rheme is never 'linguistically marked in any interesting way' (McNally, 1998b, p. 176). In many languages it associates with 'neutral' realisation, be it a canonical syntactic position (Vallduví, 2001b) or absence of prosodic marking other than default intonation (see Downing and Pompino-Marschall, 2013, for a list of languages). In this view, the label *rheme* would be no more than a convenient way to refer to the non-theme part of theme-containing utterances. However, this view of rheme could be argued to be untenable given the received wisdom that the structural exponent of 'new information' or 'answerhood', which may intuitively correspond to what has been referred to as rheme here, is indeed marked with some variant of structural prominence: syntactic, morphological or, most typically, prosodic, as discussed in Molnár and Winkler (2006), Büring (2007, 2010), Zimmermann and Féry (2010) and Zimmermann and Onea (2011). Of course, this claim is made most often not about rheme directly but about an allegedly broader category called *focus*, which is the category referred to as *contrast* in Section 23.5 below, and is extrapolated to rhemes via the assumption that rheme is a subtype of focus/contrast, namely information or answer focus (É. Kiss, 1998a; Büring, 2010). Here the assumption that rheme is a subtype of focus/contrast is eschewed (for

[13] Steedman's 'unmarked themes' – themes with no contrast within them – could be an exception, if they co-occur with no perceivable marking of the theme-rheme boundary. A subset of these unmarked themes, however, are 'redundant' themes, as found, for instance, in cases of full answers which immediately follow explicit *wh*-queries (see discussion in fn. 6).

experimental evidence against this assumption, see Katz and Selkirk, 2011). Rather, what is assumed is that (a) rheme and focus/contrast are independent notions, (b) that focus/contrast is indeed an information-structural category which is (often) grammatically encoded by prominence and (c) that (the non-theme part of) an utterance always includes a focus/contrast (see Section 23.5 below). In view of this, the putative structural marking of the rheme can, in fact, be seen as a marking of the focus/contrast which is set within the non-theme part, i.e. the rheme, of the utterance (see Selkirk, 2008, for related arguments that rheme is not structurally spelled out while focus/contrast – her 'contrastive focus' – is). This point, admittedly subtle, comes in handy to explain cases where nuclear-accent assignment does not follow default metrical patterns (e.g. FROZEN *whitebait* as a follow-up to *So you bought fresh whitebait. What did Moana buy?*). This, as noted, will be discussed in Section 23.4 and in Section 23.5.[14]

23.4 Givenness and topic

The interpretation of the pronoun *it* in *The kea pecked it* crucially depends on the availability of an antecedent in context, afforded by linguistic means, as in *Last night Hamish left his backpack outside. The kea pecked it*, or through physical co-presence, as when Hamish utters *The kea pecked it* after he has shown his damaged backpack to his tramping mates. This contextual antecedent – the mental object of type 'backpack' that *it* links to – is what we refer to as discourse entity or *discourse referent*, since Karttunen (1976). Discourse referents are useful to account for the context dependency not only of pronouns but also of all referring nominal expressions (Poesio et al., 2010, adapted):[15]

(11) a. indefinites (*a P, some P*): a referent x_1 is added to the context and asserted to be of type $\mathbf{p}$ ($[x_1, |\mathbf{p}(x_1)]$).
b. definites (*the P, that P*): a referent x_1 is added to the context and asserted to be identical with the unique referent of type $\mathbf{p}$ (in the context) ($[x_1, |x_1 = \iota y.\mathbf{p}(y)]$).
c. pronouns: a referent x_1 is added to the context and noted as needing resolution via a condition $x_1 =?$ ($[x_1, |x_1 =?]$); resolution leads to this condition being replaced with an equality with a salient referent.

[14] The theme–rheme distinction has been defined in connection to the contextual dynamics of qud. Quds have also been argued to characterise at-issueness (Potts, 2005) by, e.g., Simons et al. (2011): very roughly, a proposition p is at-issue if $?p$ is relevant to a qud. (Classical) presuppositions and other phenomena which also display projective behaviour are not-at-issue content. The at-issue/not-at-issue distinction appears to be analogous to the distinction between foregrounded and backgrounded content (e.g. Cummins et al., 2013).

[15] Quantificational and predicative nominal expressions are assumed to be non-referring, although there is debate on the nature and independence of these nominal semantic functions. Also, referents are not just individual tokens but should include also at least individual types, event tokens and event types. Finally, there are non-nominal expressions that display anaphoric behaviour.

These interpretative rules, of course, do not exhaustively characterise the referring expressions listed. It is well known, for instance, that definites may enter into referential links that are not based in identity, but on an associative bridging relation (part-whole, set-member) (Clark, 1977; Asher and Lascarides, 1998a). However, they suffice to illustrate the sort of congruence effects addressed by accounts of entity-level context dependency (Chafe, 1976; Clark and Haviland, 1977; Hawkins, 1978; Webber, 1978b; Prince, 1981c; Garrod and Sanford, 1982; Grosz and Sidner, 1986; Ariel, 1988; Givón, 1992; Gundel et al., 1993; Grosz et al., 1995). These accounts, as noted in Section 23.2, are of a diverse nature and, not surprisingly, deploy a terminology which is equally diverse: (referential) accessibility, (discourse) anaphora, cognitive status, (assumed) familiarity, information status, topicality, or (referential) givenness.

Common to most approaches to referential givenness is the distinction between referring expressions that establish a link between the referent they introduce and an antecedent referent – (11b),(11c) – and those that simply state that the referent they introduce is of a particular type – (11a). The former are evoked, familiar, given, (uniquely) identifiable, old or unused expressions, whereas the latter are new, novel or type identifiable. In addition, referents present in context must be ranked (or categorised) according to their degree of salience. Pronouns, for instance, as reflected in (11c), must take up a referent that is salient or highly accessible ('in focus' in Gundel et al., 1993). In fact, the interpretation of pronouns is very much a local phenomenon (see Section 23.3), since a vast majority of pronouns find their antecedent in the immediately preceding move (e.g. 92% in Hitzeman and Poesio's corpus). Ginzburg (2012), for instance, argues that an antecedent for a pronoun is to be found in an *active* move and provides a definition of *active* which indeed includes adjacent moves but also other moves on the 'right frontier' of the discourse structure, incorporating the well-known insight of the discourse-configurational literature that non-adjacent contextual locality is constrained in such a way (Polanyi, 1988; Asher and Lascarides, 2003b).

The locality of pronominal anaphora ('local focus' in Grosz and Sidner, 1986) is at the basis of formal treatments like Centering theory (Grosz et al., 1995; Poesio et al., 2004), a popular framework in computational and corpus linguistics. In Centering, the referents afforded by the local context of U (referents realised in the active move U−1, the utterance immediately preceding U) are partially ranked and the maximal referent in U−1 (preferred center or C_p) is, by virtue of certain rules and constraints and given some provisos, a very likely candidate for pronominal realisation in U. This likely candidate for pronominal realisation is the backward-looking center of U (C_b). The definition of C_b of U as expressor of the referent that is most salient in U−1 (if referred to in U at all) is akin to the definition of *topic* in Givón (1992), where all referents are called "topics" and the topic par excellence is the most salient one. The identity of C_b and topic, though not universally agreed upon, is argued for in Ward (1988) and exploited in detail in Beaver (2004). The notion of topic will be returned to shortly.

Discourse referents, as the relevant contextual resource behind givenness, are independently motivated and distinct from other resources, such as the quds which underlie the theme–rheme partition. The need to keep these two types of context dependency – referential givenness and qud-related themehood – separate is emphasised by Reinhart (1981), Prince (1981c, 1986), Gundel and Fretheim (2004) among others, on conceptual and empirical grounds. Ginzburg (2012), as noted, argues that pronouns are contextually associated with (a subutterance of) an active move. Since moves are of type 'utterance' – they include structural information in addition to content – they are fundamentally different from quds, which are propositional abstracts of a purely semantic nature. As such, quds are not rich enough to act as antecedents for pronouns, since it is essential that antecedents carry information about, for example, grammatical gender (pronouns in grammatical-gender languages agree with their antecedents).

However, not all approaches to context dependency distinguish between referent-level givenness and qud-level themehood. One such approach is Schwarzschild (1999), empirically based not so much on the referring expressions in (11b)–(11c) (also covered) but on another structural correlate of givenness: deaccenting (van Deemter, 1994; Büring, 2006, 2007; Ladd, 2008; Calhoun, 2010). Deaccenting, understood as the absence of accent on an item that would otherwise receive a (nuclear) accent in a default prosodic/metrical structure, is connected to referential givenness (deaccented definites often behave, anaphorically, like a pronoun) but also the 'given' in the given–new partition of Halliday (1967) or the 'background' in the contrast–background partition in Steedman (2014) (see Section 23.5). Deaccenting is illustrated in (12b):

(12) a. A: So you bought fresh whitebait. What did Moana buy?
b. B: FROZEN whitebait.
c. B: Frozen/FROZEN TARAKIHI.

The deaccenting of *whitebait* in (12b) is due to the earlier mention in (12a), which affords, as discussed shortly, an 'antecedent' for it; in Schwarzschild's terms it is 'GIVEN'. *Whitebait* in (12b) contrasts with *tarakihi* in (12c), which, as expected, is accented (*frozen* is optionally accented). Schwarzschild's GIVENness, however, is not simply defined on discourse referents but also on the propositional notion of entailment. To extend entailment-defined GIVENness to subsentential expressions, it is posited that they be semantically raised to a propositional type and subsequently subjected to existential closure. So in (12b) the GIVENness content of *whitebait* is $\exists x.\mathbf{whitebait}(x)$, which is entailed by the GIVENness content of *fresh-whitebait*: $\exists x.\mathbf{fresh\text{-}whitebait}(x)$. This same mechanism can be used to bring themehood under the aegis of GIVENness if we enrich the procedure with the assumption (commonplace in a number of approaches to contrast/focus) that *wh*-words in questions and accented items in their answers are substituted by a variable (giving rise to open propositions) and then subjected to existential closure. The GIVENness content of the full-fledged answer *We are having* MUTTONBIRD *for dinner*, example (5) in Section 23.3, is entailed by the GIVENness content of the question *What are we having for dinner*, since the GIVENness content of both is, technicalities aside, $\exists x.\mathbf{have\text{-}for\text{-}dinner}(\mathbf{A}+\mathbf{B},x)$.

Siding in some respects with Schwarzschild (1999), Bott (2008) explicitly advocates for a merger of referent-level givenness and qud-level themehood, arguing that the latter can be subsumed under the former (see also Rochemont, 1986) if (a) referents are crucially seen as encompassing different semantic types (at least entities, kinds, properties), and (b) the theme is not seen as a monolithic category but rather as a composite of different primitives (links and tails; Vallduví, 1992), each establishing its own anaphoric dependency of a different nature and on different antecedents. However, Bott's account also crucially includes a rich notion of discourse configurationality – discourse segments, a notion of referential topic for each segment, and also quds that guide discourse segmentation – which plays an essential role in the definition of the anaphoric dependencies of the theme (or its parts) and draws a line between them and the dependencies of 'classical' referential anaphora.

Erteschik-Shir (1997) also bases the definition of information structure solely on the referent level. Context is viewed as a set of referents (file cards) categorised in terms of salience; information-structural notions like *topic* and *focus* express in U the salience status of these referents: topic expressions denote referents that are members of the salient subset in C_1 and can accordingly be subjects of predication, whereas focal expressions denote referents that are not salient in C_1, but which, by their mere encoding as focal in U, become members of the salient subset in C_2 and are therefore available as subjects of predication in U+1.

While Erteschik-Shir's view of focus as promoter of referents into salience (or topicality) is quite unorthodox, her take on the notion of topic is quite representative of the standard definition of 'aboutness' topic as found in Reinhart (1981) and Gundel (1985) (see earlier antecedents in Krifka and Musan, 2012, pp. 25–30): the *topic constituent* in U expresses a designated (set of) referent(s) about which something is predicated by means of the non-topic elements of U (the *comment*). Erteschik-Shir (1997, p. 10), for instance, illustrates this with (13):

(13) a. A: Tell me about John.
b. A′: Tell me about Mary.
c. B: John invited Mary to dance.

If utterance B is a follow-up to the request by A, then the topic constituent in B is *John*; if B is a follow-up to the request by A′, then the topic is *Mary*. This suggests that (13a) and (13b) set up different input contexts for (13c) that differ precisely in the identity of the referent that is distinguished as topic.

The claim is that in human communication information is (also) organised as being 'about' particular entities (with the possible exception of thetic judgements, as discussed in Section 23.3); the job of topics as a contextual resource is to represent the (set of) referent(s) with which the information conveyed by U has to be associated and topic constituents are the spell-out of this contextual resource, thus enabling interlocutors to keep track of each other's referential 'aboutness' structure. One can remain agnostic about whether the organisation of information as being 'about' a particular topic is basically a linguistic matter related to discourse coherence (e.g. Bott, 2008) or a reflex of the architecture of human memory (e.g. Givón, 1992).[16]

It may be inferred from examples like (13) that the topic constituent of U expresses the topic referent in C_1 (as set up by U−1). However, topic constituents as defined could also be taken to specify the choice of topic referent for U's output context C_2. Of course, this does not matter in cases of *topic continuity*, that is, when the topic referent in C_1 is identical to the one in C_2, but it becomes highly relevant in cases of *topic shift*. Consider the two possible follow-ups to A in (14). The formal difference between the first sentences in B and B′ determines the preferred pronoun resolutions in the respective second sentences:

(14) a. A: Hamish plays curling.
b. B: He plays against Tip on Saturdays. He often beats him.
c. B′: Tip plays against him on Saturdays. He often beats him.

In B Hamish often beats Tip, whereas in B′ Tip often beats Hamish. *Hamish* is arguably the topic constituent in (14a), so 'Hamish' is the expected topic referent in C_1 for both B and B′. If topic constituents express the topic in C_1, then the topic of the first sentences in both B and B′ is the constituent that refers to 'Hamish' (*he* in B and *him* in B′). If so, we must conclude that the preferred pronoun resolutions in the second sentences have nothing to do with topichood. Alternatively, one could argue that the topic of B′ is not *him* but rather *Tip*: this would mean that it does not express the inherited topic, but rather the choice of topic referent for C_2, which can be identical to the topic in C_1, as in (14b), or not, as in (14c). This ties in with the open issue of the givenness status of topic constituents (discussion in Endriss, 2009), since the latter view naturally lends itself to the possibility that topics are not strictly given (see Portner, 2007b, also for a 'forward-looking' view of topics). It is also related to the issue of whether there is one topic or more per utterance. In fact, if one pursues the connection between topic and centers in Centering theory, as sketched above, the two candidates for topichood in the first sentence of (14c) would correspond each to one type of center: *him*

[16] See Schlobinski and Schütze-Coburn (1992), McNally (1998a), Gómez-González (2001), Endriss (2009) and Roberts (2011b) for informative discussions on the notion of topic, van Bergen and de Hoop (2009) for sample approaches to the interface with syntax and intonation and Cook and Bildhauer (2013) for issues that arise in annotation of topics in corpora. Roberts (2011b) includes a review of different diagnostics for topic – like the one in (13) – and their sometimes divergent results.

spells out the backward-looking center C_b (a continued topic) and *Tip* the preferred center C_p (a shifted topic) (some languages grammatically distinguish continued from shifted topics; see Aissen, 1992).

In sum, there is evidence that topics, as a distinguished (set of) referent(s) that act as organisational pivots for information – or effect an organisational partition of information in context (Portner and Yabushita, 1998) – are a distinct contextual resource type which plays a role in entity-level congruence. As argued in Büring (2003), Bott (2008), Roberts (2011b) and Karagjosova (2013), topics at the entity level work in parallel to quds – as spelled out by themes – in the propositional domain. This complementarity should not be obscured by the terminological confusion that surrounds the terms *theme* and (*discourse*) *topic*.

23.5 Contrast

As noted in Section 23.1, the notion of *alternative* is central to the concept of *contrast* adopted here. Namely, contrast is viewed as the expression of a dependency between an actual (sub)utterance U_a and some contextual antecedent U^+ (this contextual antecedent is taken to be an object also of type 'utterance', with structural information in addition to content). U^+ affords one or more relevant alternative (sub)utterances (U_b, U_c, ...) which may have been potentially produced instead of U_a and which, if produced, would have displayed the same type of contextual dependency on U^+ as U_a. This is shown in (15), adapted from Umbach (2003):

(15) a. The-research-team$^+$ arrived at the base camp late at night.
b. Ben talked to the LEADER$_a$.

Subutterance *the leader* (U_a) in (15b) is a contrast. It is anaphorically dependent on a contextual object U^+ introduced by *the research team* in (15a). U^+ affords (perhaps as an implicature) other (sub)utterances like U_b = the geologist, U_c = the meteorologist, which could have been uttered in (15b) instead of U_a. There is general agreement that in English contrast is, with some exceptions, marked by prosodic prominence. There are claims that prominence may be a universal structural correlate of contrast (see discussion in Büring, 2010; Féry, 2013).

The notion of contrast, as used here, is analogous to the notion of focus in Alternative Semantics (Rooth, 1985), since the general function of focus in this framework is to evoke alternatives (*focus* is also used in Selkirk, 2008; Zimmermann and Onea, 2011; Krifka and Musan, 2012, among many others). However, given that *focus* is also commonly used to refer to 'rheme', independently of whether *rheme* and *contrast* are merged into one category, the term is avoided here (*pace* Vallduví and Vilkuna, 1998; Steedman, 2014). In Alternative Semantics a contrast has an additional semantic value that corresponds to the set of alternatives its ordinary denotation belongs to, which, in turn, generates alternative propositional values. For example, in (15b) *the leader* would have a secondary denotation $\{\text{leader}\}_{team}$, which, provided *geologist* and *meteorologist* are members of $\{\ \}_{team}$, generates alternative propositions *Ben talked to the {geologist/meteorologist} last night*. One may wonder how this secondary set denotation arises: it could be introduced by the contrastive phrase itself by virtue of it being marked as a contrast (see Vallduví and Vilkuna, 1998), or it could be posited that all expressions have a secondary set denotation and that contrast indicates that this secondary denotation is relevant for interpretation in the corresponding context (see Steedman, 2014, for a position along these lines). Umbach (2003) takes the tack, adopted here, that contrasts are anaphoric to a 'bridging' antecedent – via associative, subsectional or nonmonotone anaphora (Hawkins, 1978; van Deemter, 1994; Hendriks, 2002) – which affords the relevant set of alternatives.

Comparability between alternatives – dissimilarity and similarity – is essential in contrast. Umbach (2004) shows that dissimilarity arises from alternatives having to be mutually non-subsuming (in (15) the leader, the geologist and the meteorologist are referentially independent), while similarity is due to the fact that alternatives must have a common integrator (a concept that subsumes them all). U^{+}, the bridging antecedent (in (15), 'the research team'), provides this common integrator.

Contrast, as defined here, is conceptually independent of themehood. In theme-containing utterances, therefore, one would expect contrastive expressions to be compatible with both their being theme and their being rheme (see, e.g., Vallduví and Vilkuna, 1998; Steedman, 2000, 2014). In fact, in Section 23.3 it was noted that contrasts in the theme appear in cases of 'qud narrowing', whereby the theme-provisioned max-qud$_{C_1'}$ is a subqud of the inherited max-qud$_{C_1}$. It was also suggested there that utterances always include a contrast within the non-theme part of an utterance, that is, a rhematic contrast. In other words, (a) all utterances would have a (rhematic) contrast and (b) a subset of the theme-containing utterances would include an additional (thematic) contrast. In Steedman (1991, 2000, 2014) the independence of contrast and themehood is reflected in the recognition of two independent layered information-structure partitions, theme–rheme and contrast–background. The utterance is partitioned into theme and rheme (all-rheme utterances are contemplated, and, nonstandardly, also all-theme utterances), and then both the theme and the rheme may in turn be partitioned into a contrast and a background (unmarked themes include no contrast).

Thematic contrasts are illustrated by (16) (= (9) in Section 23.3). The expressions *the band*, *the audience* and *the sound* in (b–d) are in the theme part of a theme-containing utterance. These expressions are often referred to as *contrastive topics* (Roberts, 1996, 2011b; Büring, 2003; Wagner, 2012):

(16) a. A: How was Lorde's-concert$^+$?
b. B: [$_T$ The BAND$_a$][$_R$ played very WELL],
c. B: [$_T$ the AUDIENCE$_a$][$_R$ danced NONSTOP],
d. B: but [$_T$ the SOUND$_a$][$_R$ was APPALLING].

Contrastive topics, being contrasts, are marked in English by means of prosodic prominence (hence, the small caps). However, the particular accent that characterises them is a complex L+H* (fall-rise) tone, distinct from the nuclear accent within the non-theme part of the utterance, which is a simplex high tone H* (followed by a low boundary tone).[17]

In (16) U$^+$ (the common integrator) is *Lorde's concert* in (a) and each of the contrasts in (b–d) is linked to this antecedent by means of a subsectional or non-monotone relation. Interlocutor B chooses not to elaborate on max-qud$_{C_1}$, $?\lambda P.P(\textbf{L's concert})$, but rather to single out and assess different subaspects of it. In (b), for instance, the theme provisions the nonmaximal max-qud$_{C_{1'}}$ $?\lambda P.P(\textbf{band})$. The role of the contrast within the theme is to guarantee that the theme-provisioned max-qud$_{C_{1'}}$ is necessarily interpreted as a subqud of max-qud$_{C_1}$. This is imposed precisely by the subsectional nature of the anaphoric dependency that holds between *the band$_a$* and *Lorde's concert$^+$*.

Contrastive topics illustrate one type of interplay between two dimensions of contextual congruence: on the one hand, the fact that (b) is a theme-containing utterance specifies that it does not elaborate on the inherited max-qud$_{C_1}$, but rather on a self-provisioned max-qud$_{C_{1'}}$; on the other, the fact that the theme of (b) includes a contrast U$_a$ which relates to an element of max-qud$_{C_1}$ via a subsectional dependency forces max-qud$_{C_{1'}}$ to be a subqud of max-qud$_{C_1}$ (see Roberts, 2011b, p. 1915). As noted in Section 23.3, it seems deployment of this type of qud-splitting rhetorical strategy requires explicit presence of a contrast (Büring, 2003).

The idea that contrasts are related to a subsuming antecedent U$^+$ is attractive and covers many occurrences. In some cases, however, the apparent U$^+$ is not a subsuming expression but rather an identical earlier mention of U$_a$, as in (17) (*concert* in (17b) can be deaccented; see below):

(17) a. A: How was Lorde's-concert$^+$?
b. B: [$_T$ LORDE's concert/CONCERT$_a$][$_R$ was GOOD]

However, examples like (17) can be accounted for if one plausibly posits, following Bott (2008), that contrasts, by definition, *must* depend subsectionally on a contextual antecedent (adapting his notation, U$_a$ $<$ U$^+$, where $<$ is instantiated by relations like 'be-a-member-of', 'be-part-of' or

[17] The term *contrastive topic* would suggest that thematic contrasts must be, in addition, a subtype of topic, defined in Section 23.4 as distinguished referents that act as organisational pivots for information. Certainly, this is a possibility that is exploited, for instance in Bott (2008). Repp (2010), however, discusses some facts that would suggest otherwise. The issue will not be addressed here.

'be-an-instantiation-of').[18] The mere co-presence of contrast-marking on U_a in (b) and the earlier mention of *Lorde's concert* in (a) is enough to coerce the accommodation of a subsuming U^+ – something like 'recent concerts/events attended by B' – which implicates the existence of comparable alternatives to U_a. In both (16) and (17), the 'alternatives' interpretation is due to the existence of a bridging contextual antecedent U^+; the difference is that in (16) *Lorde's concert* is explicitly introduced, whereas in (17) 'recent concerts/events attended by B' is accommodated. As expected, the 'alternatives' reading disappears if *Lorde's concert* in (17b) is not structurally marked as a contrast (if it were an unmarked theme); only the identity-anaphora reading would be available.

Contrasts like *Lorde's concert* in (17b), which coerce accommodation of a subsuming antecedent, also trigger a complex effect in the qud-structure of context. The max-qud$_{C_{1'}}$ (redundantly) provisioned by the theme, ?$\lambda P.P$(**L's concert**), must be understood as a subqud of some superqud, since, as in (16), the theme that expresses it contains a contrast. However, this superqud, namely ?$\lambda P.P$(**recent events**), is not explicit but rather must be accommodated (probably a rhetorical effect of the redundant replication of the inherited max-qud$_{C_1}$). Once this superqud is accommodated, elaboration on ?$\lambda P.P$(**L's concert**) by (17b) can be seen as being part of a qud-splitting rhetorical strategy. As expected, a natural continuation by B of (17b) would be as in (18c), where 'the recital by Kiri Te Kanawa' instantiates a non-subsuming alternative to U_a and where the self-provisioned ?$\lambda P.P$(**recital by KTK**) is elaborated on as part of the same qud-splitting strategy:

(18) a. A: How was Lorde's-concert? →
(How were the-recent-events-B-attended$^+$?)
b. B: [$_T$ LORDE's concert/CONCERT$_a$][$_R$ was GOOD]$_,$ but
c. B: [$_T$ the-recital-by-Kiri-Te-KANAWA$_b$][$_R$ was SUPERB]$_.$

In sum, despite appearances, there is no contrast-mediated anaphoric dependency between the two mentions of 'Lorde's concert' in (17) or the two non-subsuming alternatives in (18); rather, contrasts U_a and U_b anaphorically depend on an accommodated U^+, 'recent events attended by B', which acts as common integrator. Also, the contrast-containing themes in (17b) and (18b,c) implement a superqud-splitting strategy, as expected; this superqud is accommodated into context via a 'broadening' of the inherited max-qud$_{C_1}$ (see details in Bott, 2008).

It was also noted in connection with subutterances like *Lorde's concert* in example (17) that more than one accentual pattern is possible. This is so because contrast is actually not the expression of (the denotation of) an alternative, but rather the expression of whatever distinguishes the

[18] There is a conceptual connection between Bott's subsectional $<$ relations and the partially ordered set relation of Hirschberg and Ward (1984), Ward (1988) and Pierrehumbert and Hirschberg (1990), which is argued to define the dependency between, e.g., topicalised phrases and their contextual antecedent.

expressed alternative from the other alternatives (see Steedman, 2014), that is, the element of particularisation with respect to the common integrator or of dissimilarity between the alternatives. Consider (19):

(19) a. $[_{T}$ LORDE's-concert$_{a}$ $][_{R}$ was GOOD $]$, and
b. $[_{T}$ KIMBRA's-concert$_{b}$ $][_{R}$ was OKAY $]$.

In (19) the non-subsuming alternatives are 'Lorde's concert' in (a) and 'Kimbra's concert' in (b). The contrasts, however, are *Lorde's* and *Kimbra's*, whose meanings suffice to express the element of particularisation with respect to a common integrator like 'recent concerts' or of dissimilarity between the two alternatives. *Concert*, on the other hand, contributes the element of generalisation with respect to the common integrator or of similarity between the two alternatives. As such, it is marked as being part of the background (in the contrast–background partition of the theme) by means of deaccenting. In (17) the two accentual patterns may be correlated with whether the accommodated U^{+} is 'recent events' (no deaccenting) or 'recent concerts' (deaccenting of *concert*). Of course, deaccenting of *concert* is a priori also compatible with 'recent events' as U^{+}: (19a–b) could be uttered in reaction to a query like *How were the concerts you've recently been to?* but also a query like *How were the different events you've recently been to?* In the latter case *concert* further restricts the common integrator from the inherited U^{+} 'recent events' to 'recent concerts'. This is probably also why *concert* may be deaccented in (18b), since a recital can also be (non-technically) classed as a concert.

The cases of contrast dealt with so far are cases of thematic contrast, but, as suggested above, all utterances (except for Steedman's all-theme utterances) must have a rhematic contrast. Given the view of contrast adopted here, this is a natural conclusion if all utterances are seen as an elaboration on a (sometimes implicit) max-qud. Let us illustrate this with an elaboration like (5) in Section 23.3, partially repeated here as (20):

(20) a. A: What^{+} are we having for dinner?
b. B: MUTTONBIRD$_{a}$.

Themeless utterance (20b) answers the qud spelled out by *wh*-query (20a). *Wh*-expressions denote classes (or sets) of objects and, therefore, are prime candidates to act as bridging antecedent U^{+} for things that belong to the class (or the set) they denote. *Muttonbird* in (20b) belongs to the class of things – e.g. dishes or foodstuff – that may be had for dinner and therefore stands in a subsectional relation to *what*. Contrast on *muttonbird* expresses the existence of this subsectional relation (the same would apply to a theme-containing utterance like *We are having* MUTTONBIRD *for dinner*). As with the case of thematic contrast, *what*, as subsuming antecedent, affords alternatives to U_{a} (e.g. *whitebait*, *tarakihi*), which are also dishes that may be had for dinner.

The type of dependency displayed by *what* and *muttonbird* in (20) exists in all question–answer pairs (including polar questions and their answers). If all utterances are seen as elaborations on a qud, this is tantamount to saying that (the non-theme part of) every utterance must include a contrast. As noted in Section 23.3, this is not an unwanted result, since it accounts for the prosodic prominence of subutterances like *muttonbird* in a way which is analogous to the case of contrastive topics and preempts the need to claim that this prosodic marking is directly associated with 'rhematicity', something to be avoided in light of the arguments in McNally (1998b), Vallduví (2001b) and Selkirk (2008) that *rheme* is a non-category. The claim that (the non-theme parts of) all utterances are in principle contrastive goes back to Bolinger (1972a) and is also reflected in the claim that all nuclear accents are (broadly) contrastive (see Ladd, 2008; Calhoun, 2010; Steedman, 2014).

One can also establish a link between the idea that *wh*-expressions in quds are bridging antecedents for subutterances like *muttonbird* in (20) and the notion of *focus establishing constituent* (FEC) in Ginzburg (2012) (aka. *salient utterance* in Ginzburg and Sag, 2000), posited to account for certain properties of nonsentential utterances. The FEC is defined as 'an antecedent subutterance which specifies semantic, syntactic and/or phonological parallelism conditions for the fragment utterance' (Ginzburg, 2012, p. 234), and it is explicitly argued that the *wh*-expression in a *wh*-interrogative utterance acts as FEC for the ensuing declarative fragment that elaborates on the qud it introduces. FEC and the associated qud form a compound contextual resource; this means that wherever and whenever a given max-qud (of the *wh*- variety) is elaborated on by an utterance U, there is an associated FEC that acts as bridging antecedent for a subutterance of U.

Some of the issues, discussed above, which arise with thematic contrast also arise with rhematic contrast. For instance, there are times when it would appear that the relevant antecedent for a rhematic contrast is not a subsuming expression but rather a nonsubsuming alternative, in analogy to (18) above. Consider 'corrections' like (21), where the apparent contrast-related antecedent of *whitebait* is *muttonbird*:

(21) a. A: Did you buy muttonbird^{+}?
b. B: I bought WHITEBAIT$_{a}$.

However, as in (18), it could be argued that subsectional anaphoric dependency is obligatory for a contrast like *whitebait* and that this, together with the co-presence of an alternative like *muttonbird*, is enough to coerce the accommodation of a subsuming U^{+} ('food from the fishmonger's', for instance) for both alternatives. Alternatively, and perhaps more naturally in (21), it could be argued that (b) is an elaboration not on the qud introduced by (a) but rather on a self-provisioned max-qud$_{C_{1'}}$ 'what did B buy?', which provides a suitable subsuming antecedent (the denotation of the *wh*-expression) for *whitebait*.

Also, in analogy to (19), backgrounding is used to further restrict the inherited common integrator U^{+}, provided by the subsuming antecedent *what*. This is illustrated by (22):

(22) a. A: What^{+} did Moana buy?
b. B: FROZEN whitebait$_{a}$.

What in (22a) establishes as common integrator, say, the class of foodstuff things that Moana could have bought. However, the deaccenting and backgrounding of *whitebait* in (22b) indicates that only the meaning of *frozen* contributes to the element of particularisation with respect to the common integrator and that therefore this common integrator is not the inherited U^{+} but rather the more restrictive class of whitebait things that Moana could have bought.[19]

We have based the discussion in this section on a broad definition of contrast as expressing a subsectional dependency between the contrastive expression U$_{a}$ and a subsuming antecedent U^{+} that, in turn, affords comparable alternatives for U$_{a}$ (Umbach, 2003, 2004). This seems sufficiently adequate to account for a wide variety of facts and relates back to Bolinger's early insight that there is a common contextual basis for all perceived varieties of contrast. It also explains the absence of clear-cut systematic differences in the prosodic marking of different types of contrast detected by Calhoun (2010). Calhoun concludes that perhaps a sounder approach to the expression of contrast is to conclude that gradient increase in prominence and gradient constraining of the common integrator by contextual factors are positively correlated and feed each other. Of course, this does not rule out the possibility that in certain languages different subtypes of contrast be conventionally associated with discrete structural configurations, be they syntactic, prosodic or morphological (see Molnár and Winkler, 2006; Repp, 2010).

This broad definition of contrast is also sufficient to allow for those semantic operators that are known to depend on contrast (*focus-sensitive operators*) to express their meaning, since what they need is basically a set of comparable alternatives: the bridging antecedent affords these alternatives and therefore provides the needed domain of quantification. *Only*, for instance, expresses that the content of the proposition in which it occurs cannot be truly asserted of any of the alternatives of the subutterance that contains the contrast, as determined by the common integrator, whereas *also* expresses that it can. Other instances of association with contrast ('semantic uses of focus' in Krifka and Musan, 2012) work in a similar fashion. Beaver and Clark (2008) provide an exhaustive analysis of contrast-sensitivity building on a definition of context that, like here, includes a notion of max-qud ('current question') and the requirement that (some element in) this max-qud affords a set of alternative propositions that are its potential elaborations (the 'focus principle'). On such a basis, Beaver and

[19] Interestingly, Vallduví and Zacharski (1993) and Ladd (2008) argue that this deaccenting strategy used to distinguish the element of particularisation/ dissimilarity from the element of generalisation/similarity in the subutterance that contains the contrast is not available in some languages.

Clark (2008) propose that there are three degrees of contrast-sensitivity: (a) operators like *only* which associate with contrast by convention (they actually associate with the set of alternative propositions afforded by [the relevant element in] max-qud), (b) quantifiers like *always* which may freely use the qud-afforded set of alternative propositions as the domain variable defined by its restrictor and (c) operators like negation, which only appear to associate with a contrast (their 'scope' being entirely determined once the correct max-qud is identified).[20]

Interestingly, Beaver and Clark's approach is compatible with the idea that rheme is not actually a category in information structure. What we need is inherited maximal quds, themes that provision non-maximal quds when necessary, and contrasts (and the contrast–background partition) to evoke the common integrator that affords the sets of alternatives that are relevant for interpretation and are exploited by contrast-sensitive operators. The idea that rheme is not a category entails, of course, that any information-structure marking (such as accent in English) that is found within a themeless utterance or within the non-theme part of a theme-containing utterance has nothing to do with theme–rheme, but rather with the subsectional dependency of a part of this utterance on a part of the max-qud it elaborates on. If this is correct, it turns out that congruence between questions and answers in discourse is determined by two different contextual resources: on the one hand, by the dynamics of max-qud elaboration – where themes play a role – and, on the other, by the anaphoric dependency that holds between an interrogative expression and the subutterance that denotes its specification – where contrast plays a role.

23.6 Summary

As is well known, the literature on information structure is vast. There are many excellent overviews and monographs which contain ample discussions of concepts and data. In addition to the works cited in the preceding sections, a great deal of ground is covered by the following (by no means an exhaustive list): de Swart and de Hoop (2000), Drubig (2003), Ward and Birner (2004), Marandin (2004), Wedgwood (2005), Traat (2006), Dipper et al. (2007), Ishihara et al. (2004), Lee et al. (2007), Krifka and Féry (2008), Breen et al. (2010), Eilam (2011), Hinterwimmer (2011), Truckenbrodt (2012), Arnold et al. (2013), Song (2014).

Information structure can be thought of as concerning those aspects of the structure of utterances that contribute to their relation with context,

[20] In principle, association with contrast should exist with both thematic and 'rhematic' contrasts, since the basic semantics of contrast are one and the same (see, e.g., Vallduví and Zacharski, 1993, for cases of association with contrastive topics).

understood here as an interlocutor's information state at the time of utterance. Theories of meaning that take context to be of the essence for linguistic interpretation have come to view context as a richly structured multidimensional object inhabited by a number of resources. Within this general perspective, the information-structural notions discussed in this chapter have been defined as correlating with particular contextual resources. These correlations are at the heart of contextual congruence.

Theme (Section 23.3) has been analysed as relating to questions under discussion (quds). Quds are propositional abstracts that inhabit the propositional domain of context and which guide discourse progression. The basic idea is that at every point of a linguistic interaction there is (at least) a qud that is maximal (max-qud) which is elaborated on by an explicit move. This move is effected, in principle, by a themeless utterance, since max-qud is locally salient. Theme-containing utterances become necessary whenever a move does not elaborate on the inherited max-qud. They effect a two-step context update: they specify a non-maximal qud, which is promoted to qud-maximality, and then elaborate on it.

Givenness and topic, in contrast, have been discussed in Section 23.4 as relating to discourse referents, subutterances which inhabit the referential domain of context. Again, the basic idea is that at every point in discourse there is a subset of discourse referents that are maximally salient and other referents that are nonsalient and that this distinction correlates with the form of referential expressions. In addition, some of these discourse entities are distinguished by an additional role in context as organisational pivots for information. These are the discourse referents that are marked as topics.

In Section 23.5 contrast has been defined in connection with the notion of alternatives. An expression which is marked as contrast stands in a subsectional dependency with a subsuming contextual antecedent. The fact that this anaphoric dependency is subsectional implies that there are mutually non-subsuming alternatives to the contrast that are also subsumed by the antecedent. These alternatives play a number of important roles in contextual congruence and in the interpretation of some semantic operators. The subsuming antecedent of a contrast must have semantic and structural properties, like a discourse referent, but its contextual dynamics are closely associated with qud-structure.

It is true that other notions, or perhaps finer-grained distinctions within the notions discussed, could have been included in the general picture presented in this chapter. It is also true that for each of the notions covered additional facts exist that exhibit complexities of their own. Despite these shortcomings, this chapter will hopefully have succeeded in convincing readers that the more we learn about the nature of context and its role in dynamic interpretation, the better we will be able to understand utterance-level information structure.

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24

Semantics and cognition

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24.1 Introduction

This chapter is addressed to semanticists who are interested in studying semantic phenomena using neuro-imaging techniques and who wonder what might be the role of (formal) semantic theorising in such an endeavour. We first look at a domain (discourse) which, due to its temporal component, lends itself particularly well to the technique known as *event-related potentials* (ERPs). In the second part, we present examples of this technique, and we highlight the importance of formal semantic theories in producing hypotheses testable by ERPs. The third part ends the chapter on a cautionary note and discusses several methodological pitfalls.

24.2 Discourse

Most formal theories of semantics have come around to the view that discourse, not the sentence, is the primary unit of semantic analysis. The reasons are well known: the interpretation of verb tense requires (verbal and non-verbal) context beyond the sentence boundaries, as does the interpretation of anaphora. Kamp's treatment of these phenomena introduced a level of representation mediating between syntax and the first order models standing in for the real world: the *discourse representation structure*, or discourse model. Although these structures were not deemed to have cognitive significance at the time, contemporaneous developments in psycholinguistics strongly suggested the following hypothesis: language comprehension consists in the construction of a discourse model. It is the purpose of this chapter to show how this view of semantics provides a bridge to cognitive neuroscience: it yields predictions about the shape of neural signals recorded during discourse comprehension, and electrophysiological data to some extent constrain formal theories of discourse representation. Assuming the reader knows these formal theories, we concentrate on cognitive aspects of discourse representation.

In understanding discourse, people construct the 'gist' of what is said from non-linguistic information available in context, from the language of the discourse, and from prior knowledge and belief. If they cannot construct a gist, they cannot understand the significance of the discourse, or remember it. Gist is a pre-theoretical term for whatever this structure/content is that is derived from a full understanding of a discourse. Several fields have addressed themselves to analysing gist. The psycholinguistics literature over the last half-century has attempted to construct more elaborated accounts of what gist is, how it is constructed and how information is retrieved from its representation in memory. The term *situation model* is a general term for these partially analysed concepts of gist. Specific attempts to elaborate situation models include Kintsch (1988), Graesser et al. (1994) and Zwaan and Radvansky (1998).

The process of gist construction involves scales from micro-processes, such as anaphor resolution essential to the integration of information from different sentences, to macro-processes, such as understanding the thematic motives of the participants, or the global communicative motives of the speaker. An adequate discourse-based semantics must take into account that linguistic regularities can only be understood in their full generality with reference to the global gist of the discourse, and that means that a theory couched only in terms of linguistic information necessarily is less general, and arguably more complex. The following brief discussion of situation models will make clear that these structures are indeed much richer than the discourse representation structures of formal semantics.

As a statement of the state of the art at the turn of the century, Zwaan and Radvansky (1998) present the *Event Indexing Model*, which is mainly a classification of the dimensions on which events are routinely encoded in constructing a situation model: space, time, causality, intentionality and 'protagonist related'. Evidently the first empirical claim of the model is that it is events that are the prime entities which are to be indexed. In this the model finds common cause with much in linguistics. Every clause has a tensed verb, and such verbs often refer to an event or events, especially in the kind of simple narrative texts which dominate the experimental literature. The model's main concerns are the dimensions of classification and what kinds of inferences are drawn in order to make them.

The experimental literature supports the view that indexing of temporal, causal and intentional information is more likely to be automatic than spatial information, and that more generally, predictive inferencing is less common than explanatory inferencing. This last point will be relevant when we discuss logical properties of situation models. It had long been observed in artificial intelligence (AI) that forward inferencing tended to be combinatorially explosive and that backward inferencing from a goal could solve many problems that were intractable by unguided forward inferencing. Perhaps the simplest example is theorem proving, where forwardly applying reasoning steps to the premises with the aim of seeing whether a step produces the goal theorem, is less efficient than assuming the goal state, and reasoning backwards about what earlier subgoals would have arrived at it. This uses the goal to focus reasoning.

24.3 Planning and causal inference

Graesser et al. (1994) was an early attempt to delimit the inferencing involved in human discourse processing. By and large, that paper's specification of what predictive reasoning comprehenders engage in accords well with the AI generalisation. It presented the empirical findings in the literature as showing that comprehenders do not reason predictively, though later this blanket generalisation was modified to allow reasoning about the future through agents' goals (Keefe and McDaniel, 1993; Murray et al., 1993; Whitney et al., 1992).

Psycholinguistic studies on situation models show that a remarkable range of causal information is represented in situation models. Compare, for example, the following two discourses:

(1) a. John's face brightened when he heard the doorbell ring.
A moment later his girlfriend came in.
b. John's face brightened when he heard the doorbell ring.
An hour later his girlfriend came in.

Reading times for the second type of discourse, in which a time shift occurs, are significantly longer than those for the first type (Zwaan, 1996). This can be explained by assuming that participants have a *default* expectation that the event described in the second sentence of the discourse follows close upon the heels of the event described by the first sentence. This default can be overridden, but at the cost of extra computation. Thus, causal information even when not verbally encoded plays a role in interpreting the discourse.

Further confirmation that causality and planning are important in setting up situation models comes from a cluster of results discussed in Trabasso and van den Broek (1985). When recalling a story, initiating events, goals and consequences are consistently better recalled than other types of events (such as failed attempts). Furthermore, events that can be ordered in a causal network (not necessarily linear) are better remembered than other events, where the connectivity of the event determines ease of recall. Hence, the mapping from discourse to situation model tends to produce outputs organised as plans; conversely, that part of a situation model that represents a plan is most easily converted into discourse.

Plans are also important at a meta-level. The speaker(s) of a discourse plan for the audience to construct the intended model of the discourse. In a narrative discourse, the participant(s) plan to achieve their goals. Both levels of planning are simultaneously involved in selecting the events which must be referred to in the discourse and the presumed knowledge/belief base of the audience. Each such event must be inserted in the ordered model of the discourse at its appropriate place, in the correct intentional relations generated by the plans. Temporal, causal and intentional information is always involved in this process. Spatial and protagonist-related information may or may not be obligatory for the model construction. For example, in processing the apartment description discourses of Levelt et al. (1981) spatial relations are the topic, but the structure of the discourse is still given by temporal/causal relations as observed by a moving narrator, whereas in many other narratives, spatial relations may be of minor significance.

The importance of planning in structuring situation models has repercussions for the way events and objects must be represented in these models. Formal semantics leads one to think of events and objects as atomic, that is, as lacking internal structure. However, plans are typically hierarchical, which means that events such as the execution of an action are simultaneously represented with different granularities.

We are watching a silent film in which a woman goes about making a cup of coffee. We see her put the kettle on, fetch the milk, put the coffee in the pot, pour in the water and replace the lid. Or we read a commentary on the same sequence of actions. Either film or discourse can be broken down into even smaller units. To fetch the milk she crosses the kitchen, opens the fridge, takes the milk and returns across the kitchen. To take the milk, as she reaches towards the carton her hand opens and closes in a grasp, while her arm retracts, and so on. Our mental processes of understanding the two very different input streams are not the same, but they share a great deal. In both cases, we represent the two streams hierarchically, segmenting them into smaller and smaller nested units. In both cases, our understanding is predicated on our ability to segment. In both cases, we represent what we see, in film and in text, as organised by motives and goals.

Furthermore, we now know that the brain processes underlying the two mental processes also overlap. Zacks et al. (2001) study the brain processes of segmenting film of task-oriented human action into hierarchical units. Both in passive viewing and under the instruction to mark the temporal segmentation of events, participants showed distinctive peaks of neural activity both in posterior visual areas and in anterior regions associated with shifting of attention. These peaks were stronger for coarse-grained event boundaries than for fine ones. Activity in these areas built up before the event boundaries, indicating that they were to some extent foreseeable.

Kurby and Zacks (2008) review evidence for a close relation between this 'parsing' of the visual perception of purposeful non-linguistic activity and the parsing of narrative discourse. Gernsbacher (1985) showed that superficial information about a meaningful sequence of pictures is lost from working memory very rapidly after moving onto the next, mirroring the loss of surface syntactic information from working memory as a reader crosses clause-boundaries. There is an overlap between the brain regions dominantly employed in event boundary processing in non-linguistic film of human action (Zacks et al., 2001) and narrative discourse (Speer and Zacks, 2005), though of course there are also disjoint regions involved in the specifics of perceptual processing in the two modalities. Time shifts in narrative lead to a decrease in salience of working memory information about the events preceding the shift-induced boundary (Speer et al., 2007) just as with film. Both observations, of film and of text, issue in working memory representations of the gist of what happened, and this gist may be transferred from working to long-term memory if it proves significant.

If we could not understand our observations of human actions, or commit them to memory in this way, it is unlikely we would have any use for natural languages of the kind that permit the discourses describing such action sequences. Making a cup of coffee or watching a cup of coffee made are not linguistic or communicative acts, but they may share with such acts much cognitive apparatus.

24.4 The logic of processing discourse

Discourse creates interpretations by a process of defeasible reasoning from linguistic and non-linguistic information – reasoning *to* interpretations – which are constituted by models of the discourse. The reasoning involved is necessarily defeasible because of (i) the incompleteness of linguistic communication and (ii) the 'greediness' of processing, the fact that it uses all information, however incomplete and in whatever modality, in its search for meaning. As an example of (i), consider the changes in the expected action in the following discourse: *I began the novel in November. The pupils listened attentively. However, some found dictation extremely boring*. From the first sentence, we may conclude that the action initiated is reading or writing a novel. The second sentence suggests reading is the most likely action, and the third turns the current interpretation around again.

As to (ii), the ingredients of the construction of a situation model have been argued here and elsewhere to be non-linguistic and linguistic information, as they occur in the context, the discourse and the knowledge base. Once one no longer privileges the case where the information is only linguistic and is only in the discourse, then the obvious question about processes becomes one of establishing when inferences based on the various kinds of information get made. The answer is, in general, as soon as possible, even if the premises of the inferences are of quite different types and sources. In contrast with traditional models that assume that the sentence is the unit of processing, a discourse-based model assumes that integrative constructive inferences with heterogeneous information occur as soon as they can. For example, the resolution of anaphoric relations between structures in the current input sentence, the existing constructed situation model and the knowledge base will begin as soon as the structures are available, and even sometimes before, at the expense of having to be retracted when subsequent input shows them to be mistaken.

The logic governing these inferences must therefore be non-monotonic. In the next section the required logic will be studied in greater detail, and we shall see how it can lead to electrophysiological predictions.

24.5 Processing discourse

Event-related potentials (ERPs) are signals produced by the brain in response to a stimulus such as a written or an auditory word. The N400 (Kutas and Hillyard, 1980) is an ERP whose amplitude varies as an inverse function of the degree of semantic affinity between the eliciting word and the context in which it occurs. In the fragment *He spread his warm bread with . . .* the expressions *spread* and *warm bread* may prime *butter* as a possible continuation, but much less so (say) *socks*. *Butter* may get some activation from the preceding context, whereas the meaning of *socks* can be activated only when the word is encountered. The amplitude of the N400 is proportional to the cost of activating a word's meaning discounting the pre-activation it receives from the context. In Kutas and Hillyard (1980), the N400 was indeed larger for *socks* than for *butter*.

The N400 provides evidence that discourse is the primary unit of semantic analysis. The brain does not integrate semantic information at the sentence level first but does so by immediately updating the current discourse model. In a series of experiments by van Berkum et al. (2003), participants listened to sentences like *Jane told her brother that he was exceptionally quick* in a discourse context implying the brother had in fact been slow. *Quick* elicited a larger N400 than *slow*, with identical characteristics as the N400 evoked by within-sentence manipulations. This also shows that the N400 does not necessarily reflect long-term connectivity among concepts, as the butter/socks example may suggest, but tracks dynamic associations between meanings as set up by discourse (for an example, see Nieuwland and Van Berkum, 2006).

The N400 exemplifies the 'greediness' of discourse processing: it takes a mere 400 ms (the peak latency to which the component owes its name) for the brain to use discourse information in the interpretation of a stimulus word. However, what kind of computation does the N400 reflect? The butter/socks and quick/slow examples above seem to point to something quite unlike the operations envisaged by formal semantics, and indeed recent studies indicate that at least some of the neural footprints of semantic processing may be found off the N400 path. Here we consider three examples: (i) the computation of enriched event structures in cases of complement coercion, and defeasible inferences in narrative or deductive discourses containing (ii) progressive clauses or (iii) conditionals.

24.5.1 Complement coercion

A hotly debated issue in psycholinguistics is whether semantic processing is carried out in a strictly compositional manner, with syntax being the only source of combinatoriality, or whether independent semantic operations exist that can enrich and elaborate on compositional meanings (Baggio et al., 2012). Discourse semantics provides reasons to suppose such operations must exist, and ERPs deliver the required empirical proof.

Consider the sentence *The journalist began the article before his coffee break*. A discourse model based on a compositional analysis would not specify what the journalist began doing, whether it was, for example, reading, writing, typing. Yet a theory of discourse processing should account for the possibility that the relevant activity is part of the gist. Neuroscience is only beginning to develop tools that may eventually reveal whether particular semantic contents are being represented or not (and where) in the cortex. ERPs can only provide (counter)evidence that certain linguistic constructions incur processing costs and hint as to what the nature of these costs may be.

Constructions like *the journalist began the article* are thought to involve the coercion of the complement noun (*article*) from an expression denoting an entity to one denoting an event. In typed semantic theories, coercion takes the form of type shifting (Pustejovsky, 1993): *the article* is of type e (an entity), whereas the verb *begin* requires a complement of type $\langle e, t\rangle$ (a function from entities to truth values, i.e. a predicate); shifting the type of the NP ensures the semantic representation is well-formed. Type shifting may leave traces on ERPs. A syntactic alternative involves the expansion of the subtree structure of the VP *began the book* with a phonologically silent V node, which may then be interpreted semantically. Another alternative to type shifting would see it as unnecessary to mobilise any syntactic machinery and would only require the binding of the variable a in the event substructure $initiates(start, a, t)$ – which captures the meaning of the VP 'to begin X' – with a suitable action concept retrieved via inference. That substructure

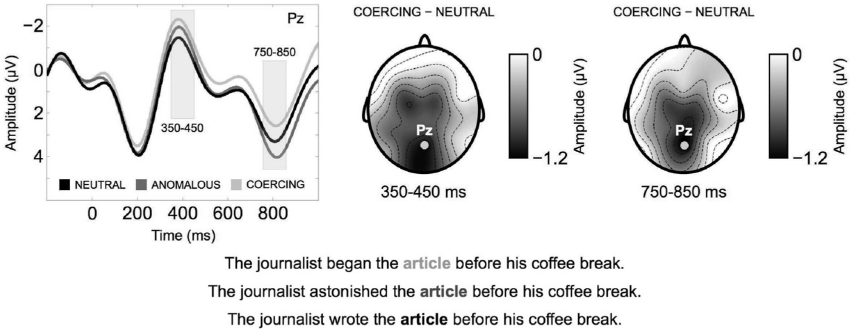

Figure 24.1 *ERPs elicited by the noun in neutral, anomalous and coercing sentences. Waveforms show average ERP signals in each condition across participants from a parietal midline channel (Pz), time-locked to the visual onset of the noun (0 ms). Negative values are plotted upward. Topographic maps show the mean difference between coercing and neutral conditions in the specified time windows. Modified from Baggio et al. (2010).*

would be part of a network of relations involving causal predicates and variables specifying the agent and initiator of *a*, the consequences of the action on certain incremental entities (the article) and so on.

These three accounts of complement coercion suggest different processing predictions. The syntactic view implies that the amplitude of ERPs sensitive to syntactic complexity, such as the P600 (Osterhout and Holcomb, 1992; Hagoort et al., 1993; Hagoort, 2003), is increased at the noun *article* or at the determiner, which makes it clear the complement is an NP and not a VP. Type shifting is a micro-process that is expected to occur as soon as the meaning of the noun is accessed. It predicts a modulation of a fast ERP responsive to lexico-semantic processing. If independent processing evidence for type shifting were available, and the complement noun resulted in a larger N400, this would show that the N400 not only is a correlate of contextual pre-activation but also reflects combinatorial operations. The inferencing/binding model musters macro-processes such as the use of agent (the journalist) and situation information (a work context involving coffee breaks) to infer the most likely action and unify it within the semantic representation of 'began X'. The prediction is not necessarily a slower response than an N400, but it is a longer-lasting one.

The ERP patterns observed experimentally (Figure 24.1) tally well with the inferencing/binding model. The noun elicited a larger N400 in coercing than in neutral contexts such as *The journalist wrote the article*, in which the activity is part of the asserted content. This N400 was similar in latency and scalp distribution to the N400 produced by the noun in a context that renders it semantically anomalous, as in *The journalist astonished the article* (Baggio et al., 2010; Kuperberg et al., 2010). In the coercing case only, the negative effect lasted for several hundred milliseconds longer than a standard N400

(Baggio et al., 2010), suggestive of extensive computation. The lack of a P600 effect either at the determiner or at the noun indicates syntactic operations are not the primary source of processing complexity here.

24.5.2 The progressive

Observing an agent performing a sequence of actions, such as writing a letter, triggers the inference that the goal will be attained in finite time if no disrupting events take place. Similarly, reading the progressive clause *The girl was writing a letter* invites the inference that, barring unforeseen obstacles, the letter will be completed. A model that includes only the relevant actions and goals but does not list all possible disrupting causes, is a *minimal model* of discourse. As the brain can only grapple with tractable problems, it is not unlikely that it computes structures equivalent to minimal models. If so, an easy prediction would follow: expanding the progressive clause with the description of a disabling event, such as *The girl was writing a letter when her friend spilled coffee on the paper*, should trigger a recomputation of the current discourse model. This would occur at the word that signals that the goal-state inference should be withdrawn: for example, at the sentence-final word *paper*.

An ERP experiment using Dutch progressive constructions shows that recomputation has clear consequences for ERP signals (Figure 24.2). Unlike English, Dutch word order requires the verb to occupy the sentence-final position: *Het meisje was een brief aan het schrijven toen haar vriendin koffie op het papier morste*. The effects of semantic affinity between the context and the noun *papier* can therefore be distinguished from the recomputation triggered by the verb *morste* (spilled). The neutral condition featured the noun *tafelkleed* (tablecloth) instead, as an example of a not necessarily disrupting event. A larger N400 was elicited by the noun in the neutral condition: *paper* receives more contextual pre-activation than *tablecloth*, and hence it results in a smaller N400. At the verb, i.e. just 600 ms downstream, the effects were reversed, and were moreover qualitatively different. The verb *morste* evoked a larger sustained negativity in the disabling than in the neutral condition. The effect emerged later than a classic N400, lasted for longer and had a left-anterior distribution that differed from the centro-parietal topography of the N400 (Baggio et al., 2008). This sustained anterior negativity (SAN) was correlated with the off-line frequency of withdrawn goal-state inferences by participants.

24.6 Bayesian and logical theories of conditional reasoning

To show how neural data can guide the selection between computational-level theories, we consider probabilistic and logical theories of conditional reasoning. The Bayesian treatment considers a conditional to be

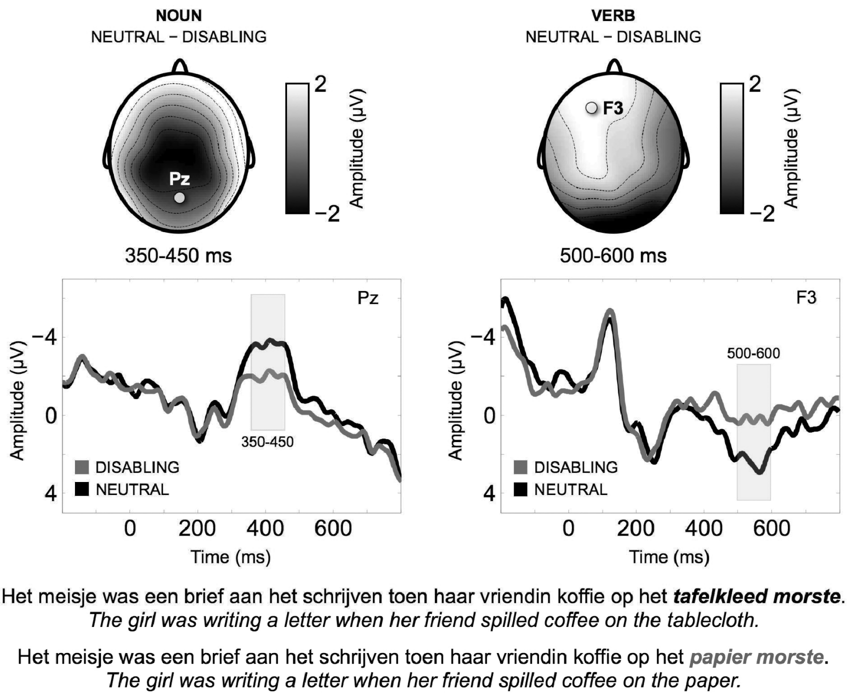

Figure 24.2 *ERPs elicited by the noun and the verb in neutral and disabling sentences. Waveforms show average ERP signals in each condition across participants from a parietal midline channel (Pz) and a left-frontal channel (F3), time-locked to the visual onset of the noun or the verb (0 ms). Negative values are plotted upward. Topographic maps show the mean difference between coercing and neutral conditions in the specified time windows. Modified from Baggio et al. (2008).*

semantically interpretable as a conditional probability, and logical models favour some kind of defeasible (i.e. non-monotonic) logic. Both models aim to be computational-level theories of the following type of data (Pijnacker et al., 2010) on *modus ponens* (MP) reasoning. There are two conditions, disabling and neutral:

MP-Dis
Lisa probably lost a contact lens (disabling condition (*D*))
If Lisa is going to play hockey, she will wear contact lenses (conditional premise)
Lisa is going to play hockey (categorical premise)
Lisa will wear contact lenses (conclusion)

MP-Neu
Lisa has recently bought contact lenses (neutral condition (*N*))
If Lisa is going to play hockey, she will wear contact lenses (conditional premise)
Lisa is going to play hockey (categorical premise)
Lisa will wear contact lenses (conclusion)

In the study by Pijnacker et al. (2010), participants endorsed *modus ponens* with material of type MP-Neu in 97.5% of the cases, as opposed to 51.1% with MP-Dis.[1]

The original *suppression task* was used by Oaksford and Chater (2003) to argue for a Bayesian model of conditional reasoning and against a logical approach. Bayesian probability is said to be the proper computational-level theory for conditional reasoning because conditionals are never certain and 'probability is the calculus of uncertainty'. (For a detailed discussion of the hypotheses that can be used to justify this assertion, see Paris, 1994.) Moreover, it is suggested that the Bayesian treatment fits the data much more closely than any logical analysis.

We now provide Marr-type analyses of logical and Bayesian reasoning in this conditional task and compare these to ERP data on the time course of processing.

24.6.1 Logical analysis

Informational level

The task is to represent the premises in such a way that inferences can be drawn (or not drawn); the appropriate notion of validity for non-monotonic reasoning is the following. View the premises of the argument as discourse; this needs to be integrated and a coherent discourse model must be constructed. It then has to be computed whether the putative conclusion holds in the discourse model.

Algorithmic level

Here processing considerations come to the fore, in particular the 'principle of immediacy': computation 'starts immediately with what it derives on the basis of the bottom-up input and the left context' (Hagoort, 2006).

For the disabling condition the computation proceeds as follows:

1. L [disabling condition]
2. $H \wedge \neg ab \to W$ [general form of conditional]; $L \wedge \neg ab' \to ab$ [integrating disabling condition and first premise]
3. H [categorical premise]
4. ?W [is W true in discourse model?] It is argued in van Lambalgen and Hamm (2004) that the required computation proceeds 'backwards':
5. W is true if $H \wedge \neg ab$ is true; we know H is true, and if L constitutes an unconditional abnormality for $H \wedge \neg ab \to W$ (meaning that $\neg ab'$ holds), then the antecedent $H \wedge \neg ab$ cannot be satisfied, whence W cannot be made true in the discourse model. If on the other hand it is judged that

[1] This is one variant of the so-called suppression effect (Byrne, 1989). In the original version the possibly disabling information comes in the form of a conditional second premise, which would in this case be: *If Lisa hasn't lost her contact lenses, she will wear them.*

L constitutes an abnormality only in special circumstances, we have that the antecedent of $L \wedge \neg ab' \rightarrow ab$ is false; hence, so is the consequent ab, from which it follows that W.

6. The computation for L [neutral condition] does not introduce $L \wedge \neg ab' \rightarrow ab$ together with L; since we do not have information about ab, we assume $\neg ab$, and the *modus ponens* argument goes through.

24.6.2 Bayesian analysis

Informational level

As before, we consider defeasible reasoning to consist in the construction of discourse models, which in this case carry a joint probability distribution which specifies, for instance, the conditional probability that Lisa will wear lenses given that she is going to play hockey. The *modus ponens* inference is represented by Bayesian conditionalisation:

> if B is a complete (non-probabilistic) description of one's knowledge, the posterior probability $P_1(A)$ given that B has occurred is equal to the prior conditional probability $P_0(A \mid B)$.

Algorithmic level

As processing constraint, we still have the principle of immediacy.

1. L [disabling condition]; introduces a conditional probability $P(\bullet \mid L) =: P(\ )_L$
2. The implication 'if H then W' is represented by a conditional probability w.r.t. the distribution $P(\ )_L$, as follows:

   $$\text{if } H \text{ then } W \Leftrightarrow \frac{P(H \wedge W)_L}{P(H)_L} = P(W \mid H)_L = P(W \mid H, L).$$

   [immediacy dictates that $P(\ )_L$ (which gives the *posterior* conditional probability) is used instead of P (which gives the *prior* conditional probability)]
3. H
4. In the last step one conditionalises on H in the expression $P(W \mid H)_L$, and one decides on one of the three answers 'yes, maybe, no'
5. The computation for L [neutral condition] is in principle the same, except that one may assume $P = P(\ )_L$.

In a more refined analysis of the disabling condition, one does not conditionalise on L, since this event is only said to be probable; instead one applies *Jeffrey conditionalisation* to obtain the following as posterior conditional probability:

$$\text{if } H \text{ then } W \Leftrightarrow \frac{P(H \wedge W)_L}{P(H)_L} P(L) = \frac{P(H \wedge W)_{\neg L}}{P(H)_{\neg L}} P(\neg L).$$

If we now compare the two computations, we see that on the logical model, the evaluation of the conclusion is both computationally intensive and the source of competing representations. By contrast, according to the Bayesian model, the computation of the posterior conditional probability in the disabling case requires most resources, whereas settling upon an answer from 'yes, maybe, no' requires the subject to set a criterion, but no further computation is necessary. This yields the following predictions for ERPs:

(i) On the Bayesian model, one expects a negative shift of the disabling case as compared to the neutral case when the conditional premise is processed.
(ii) On the logical model, the negative shift should occur while the conclusion is processed.

One also expects differences in the behavioural domain. The task is sufficiently analogous to the original suppression task to expect a decrease in MP endorsements of about 40%, perhaps a bit more because the disabling condition is introduced categorically, not hypothetically. It is not so clear what to expect on the Bayesian model, but the following line of reasoning seems plausible: since the categorical disabling condition is said to be probable, the posterior conditional probability of 'if H then W' must be low, and hence there should be a high percentage of 'maybe' answers.

Pijnacker et al. (2010) designed an EEG study to establish the time-course of brain processes subserving defeasible reasoning. The EEG was recorded while participants read a set of four sentences (of type MP-Dis or MP-Neu) and pressed keys corresponding to 'yes', 'no' or 'maybe' after reading the conclusion sentence.

Averages of the EEG signals were computed over all sets of type MP-Dis, and likewise over all sets of type MP-Neu. The average MP-Neu was then compared to the average MP-Dis.[2] The results were as follows:

1. no significant difference between average MP-Neu and average MP-Dis for the first sentence (neutral or disabling condition);
2. no significant difference between average MP-Neu and average MP-Dis for the conditional premise;
3. no significant difference between average MP-Neu and average MP-Dis for the categorical premise;
4. a significant (and long-lasting) negative shift of average MP-Dis compared to average MP-Neu for the conclusion, starting 250ms after the onset of the final word of the conclusion.

This result shows that until the onset of the final word of the conclusion, the computational load does not differ between the neutral and disabling cases. From that point onward, processing costs for the disabling case are

[2] This is a rough description; for an exact exposition see Pijnacker et al. (2010).

higher than for the neutral case. These results conflict with the probabilistic model outlined above: the Bayesian model predicts a heavy processing load after the second premise, and no processing load in the final step, which is just Bayesian conditionalisation. The logical model looks a bit better and may even provide a reason why a sustained anterior negativity is observed: we noted that the appearance of the conclusion triggers competition of representations, and it seems of some interest to observe that the sustained negativity reported by Pijnacker et al. (2010) is structurally similar to the one observed in case of ambiguous referents: 'David had told the two girls to clean up their room before lunchtime. But one of girls had stayed in bed all morning, and the other had been on the phone all the time. David told *the girl* that . . .' (van Berkum et al., 2003) – here the italicised NP is referentially ambiguous.

24.7 Methodological issues

The relations between formal semantics, psychology and neuroscience are bound to be complex and subject to change as new theoretical and experimental approaches emerge. Certain methodological and philosophical difficulties are, however, likely to persist. These include the pervasiveness of alternative explanations of experimental data, the logical weakness of reverse inference from data to theory and what we may refer to as the problem of mismatching resolutions, that is, the difficulty of mapping a vast array of heterogeneous linguistic operations to a much smaller set of known brain signatures. Here we attempt to illustrate the depth and significance of these problems with the aid of selected examples.

24.7.1 Alternative explanations

The history of science is replete with failures to conceive of all the theories that would account for the available evidence before a choice is made between a subset of those (i.e. the 'competing theories'). This is the problem of unconceived alternatives (Stanford, 2006), and it similarly affects the relations between semantics and neuroscience. Explanations of neurophysiological data based on formal semantics may indeed constitute unconceived theoretical alternatives, as the following example demonstrates.

Consider the pair of sentences *Before/after the scientist submitted the paper, the journal changed its policy.* A glaring difference between the two narratives is the order in which events are described: the order of clauses in 'before' sentences reverses the temporal order of events (first the journal changed its policy, and then the scientist submitted his paper) whereas 'after' preserves it by mirroring it with the order of clauses. In an experiment using these two sentence types, and measuring ERPs starting from the initial temporal preposition, Münte et al. (1998) found that 'before' resulted in a larger left-anterior sustained negativity than ‘after’, which lasted throughout the sentence. ‘Before’ may incur additional processing costs as the order of information provided by the two clauses is reversed to match the chronological order of events.

Besides temporal sequencing, entailment is a confounding variable that may be invoked to explain these ERP data. *After* entails that both events took place, whereas *before* can also be interpreted in a model in which the scientist was unable to submit her paper, perhaps due to the journal’s policy change (Anscombe, 1964). Speakers may rather express non-entailing meanings using modal constructions (*Before the scientist could submit the paper, the journal changed its policy*), but the same reading is available to comprehenders for indicative clauses. Such uses of *before* abound in ordinary discourse (e.g., *I lost my ticket before boarding the train*), and semantics has provided formal accounts of the asymmetry between *after* and *before* (e.g., Cresswell, 1977). *Before* may be more complex to process if indeed readers are attempting to determine whether the main event is likely to disrupt the goal-directed process described by the subordinate clause, and this may result in the computation of a more elaborate event structure than would be the case with *after*. Extended computation would be reflected by the sustained anterior negativity.

This example showcases the relevance of semantic theory to neuroscience. Semantics can supply tools for spotting confounds in existing experimental designs, thus broadening the scope of the theoretical possibilities from which explanations of data are drawn. The reverse type of inference, that is, from data to theory, is another area where productive interactions between semantics and neuroscience may occur.

24.7.2 Reverse inference

Above we presented ERP data showing a larger sustained negativity elicited by coercing nouns, the initial portion of which shares several features with the N400 (i.e., onset latency and spatial distribution). From this effect, and from the absence of an ERP response to syntactic complexity (P600) at the determiner and at the noun, a syntactic account of coercion as VP insertion was ruled out. Type shifting was ruled out on the grounds that a microprocess involving a single abstract aspect of the reference of an NP would produce a much shorter effect from the observed ERP. These two theoretical possibilities were therefore discarded on the basis of reverse inferences from data to cognitive function. These are logically weak because brain signatures, including ERPs, are hardly ever selectively correlated with specific cognitive processes (Poldrack, 2011). However, reverse inferencing can be constrained by (i) independent evidence of a different kind from neural data, (ii) considerations on the consequences for known experimental results of accepting a given explanation and (iii) cognitive models or arguments from cognitive plausibility.

Consider the analysis of complement coercion as VP insertion. Here linguistic evidence is mixed. Supporting evidence comes from raising patterns. Event-denoting VPs cannot raise to subject position: *The journalist began writing the article* is turned into the ill-formed *Writing the article began**. If entity-denoting NPs had the same syntactic structure as event-denoting VPs, they should behave similarly, and indeed entity-denoting NPs cannot raise to subject position either: compare *The journalist began the article* to the ungrammatical *The article began**. However, parallel raising patterns do not entail identity of syntactic structure – here is an instance of reverse inference *within* linguistic theory. Moreover, evidence against VP insertion is provided by passivisation. Event-denoting VPs cannot be passivised (*The article was begun to be written by the journalist**) whereas event-denoting NPs can (*The article was begun by the journalist*) implying differences in syntactic structure. These data show that VP insertion may be ruled out on purely formal grounds, which narrows down the set of theoretical possibilities – a move opposite in sign to bringing up unconceived alternatives. As for (ii), a link between the observed ERPs and VP insertion could still be drawn, but the consequences of suggesting that the N400 and (some) sustained negativities may correlate with syntactic processing would require extensive revision of our current understanding of ERPs: what neural process could result in the N400 and be common to both contextual pre-activation and VP insertion? A reverse inference relating the observed negativities to a semantic computation avoids extensive reinterpretation of previous results.

Type shifting involves assigning the NP a higher-order type: *the article* can then be treated as though it belonged to the class of its supposed VP synonyms such as *writing the article* or *reading the article*. Semantically, the target type of the coercing NP is an element of the set of functions from entities to truth values. This is defined by means of all possible entities, truth values and functions from the former set to the latter. The NP is moved into an open-ended class of predicates, but crucially it is not bound to any one in particular. Type shifting specifies that the NP now denotes a predicate, but not which one, nor even that it denotes an *event* predicate. Reverse inference is here constrained by strategy (iii): type shifting is not an adequate cognitive model of coercion as the operation it posits is irrelevant to the construction of gist. Inference to the intended activity and binding the result to an otherwise free variable in the event structure of the VP explain instead what the gist may be.

24.7.3 Matching resolutions

In an idealised model of the relations between semantics and cognition, a one-to-one correspondence can be drawn between semantic and neural computations. The model need not be a description of the relations between ontological domains: brain states considered in full detail, independently of measurement approximations, may be too fluid to be linked to theoretical entities. It is rather a thesis on the correspondences between what is being posited by theory and what can be measured experimentally. Thus, much as contextual pre-activation corresponds to the N400 (and vice versa), it may be possible to identify a single neural signature for each semantic operation that either is independently motivated (unlike VP insertion) or has functional equivalents across theories (like variable binding). The capacity of semantics and neurophysiology to resolve differences between computations would be matched. Neuroscience would produce proper neural correlates of semantic processes, that is, particular brain responses that co-vary with particular semantic processes, but not with anything else independently. Note how this would make reverse inference generally valid. Current research in psycholinguistics and neuroscience, however, points both to a *mis*match between the resolutions of semantics and neuroscience and to a series of emerging data analysis techniques that may eventually bring the state of the art closer to the idealised model.

Each signal domain in neuroscience captures a different aspect of the complex statistical dynamics that constitute cortical activity. Event-related potentials, in particular, are unlikely to deliver a number of brain signatures sufficient to reconstruct mirror images of semantic theories at the neural level. ERPs reflect only a subset of cortical signals, that is, the activity of large populations of neurons firing synchronously and within fixed deadlines in response to a stimulus. The averaging procedure that results in ERPs dampens all amplitude changes that show some temporal variability relative to stimulus onset. Temporal variability is especially likely to be a defining feature of discourse processes. Whereas the lexical N400 has remarkably stable onset and peak latencies, more variance is displayed by sustained negativities.

Baggio and Hagoort (2011) review studies on the cortical generators of the N400 and propose it reflects the amount of overlap in temporal cortex between active populations representing the context and populations activated by the incoming word. Overlap is proportional to a word's contextual pre-activation: the smaller the overlap, the larger the overall network's activity, the larger the N400 amplitude to the eliciting word. The excitation level of populations in temporal cortex is maintained via long-distance connections by persistent firing in prefrontal cortex. As a visual or an auditory word is perceived, currents reach temporal cortex via sensory pathways, where processing is tightly time-constrained: this accounts for the stable onset latency of the N400. Currents are then relayed to prefrontal cortex and back into the same temporal regions activated by feed-forward sensory processing: this re-injection of currents into temporal cortex produces the N400 peak. Typically, activity then wanes until the next word is received as input. However, activity may reverberate within the network until a stable state is reached (i.e. until a minimal model is computed), as may be the case in complement coercion and model recomputation. This would result in sustained negativities that may resemble 'overdriven' N400 effects if reverberating activity follows close upon the N400 peak. This model accounts both for the temporal stability of the N400 and for the temporal variability of sustained negativities. It is precisely the temporal variability of discourse processes that makes it unlikely that ERPs will provide the desired range of brain signatures.

The problem of mismatching resolutions can be alleviated by harnessing alternative signal domains such as oscillations, that is, amplitude changes in specific frequency bands that follow a stimulus in time but are not necessarily time-locked to its onset. In an EEG study by Hagoort et al. (2004), participants read sentences that contained either semantic violations (*Dutch trains are sour*) or world-knowledge violations (*Dutch trains are white*), and controls (*Dutch trains are yellow*). The distinction between sense and reference is one of the cornerstones of modern semantics. However, both types of violation elicit nearly identical N400 effects. This suggests a common processing mechanism: the expression *Dutch trains* primes semantic features in long-term memory including yellowness; activating the meaning of *yellow* is therefore less effortful than retrieving the meanings of *white* and *sour*. Two very different operations in formal semantics are mapped onto a single brain response – a clear instance of mismatching resolutions. However, considering a different signal domain (temporarily) restores the balance between theory and data. Hagoort et al. (2004) showed that semantic violations increase the amplitude of low-frequency (theta) oscillations, whereas world knowledge modulates high-frequency (gamma) power. The balance is only temporarily restored: theta and gamma oscillations are themselves instances of a many-to-one realisation of function as each correlates with a number of different cognitive functions. Oscillations, analyses of the temporal properties of ERP effects (Baggio, 2012) and non-linear measures of signal variability such as entropy and prediction errors (Baggio and Fonseca, 2012) may broaden the range of known neural correlates of semantic processes. Matching resolutions may, in addition, require a view of neural correlates as conjunctive sets of features across signal domains: for instance, processing referentially anomalous predicates (e.g. *white* in *Dutch trains are white*) may be uniquely tied to a combination of a larger N400, increased gamma oscillations (Hagoort et al., 2004), decreased entropy values (i.e. lower signal complexity; Baggio and Fonseca, 2012) and certain cortical activation patterns that may be revealed by functional magnetic resonancing imaging (fMRI) and other methods (Hagoort et al., 2004).

24.8 Conclusions

Scientific disciplines develop from an early stage of dependence from other fields, through a phase of relative autonomy, to finally position themselves within a broad network of related research programmes. Semantics is no exception. It grew out of philosophy and mathematical logic, it became self-sufficient as one of the formal sciences and it eventually developed ties with neighbouring fields such as computer science and game theory. The progression towards interactions with more distant disciplines, including neuroscience, is a predictable development. Semantics and neuroscience will not stand to one another in a standard theory–data relation. Semantics has its own data domains (e.g. intuitions, corpora), and theoretical neuroscience is now a burgeoning specialty. However, they are equally unlikely to remain shielded from each other. Processing predictions may be derived from semantic theories that can therefore be (indirectly) put to test using the tools of cognitive psychology and neuroscience. Conversely, cognitive data can in certain cases guide theory-selection in linguistics. The proviso 'in certain cases' reminds us there is no armchair answer as to whether semantic theories and cognitive data may be mutually (ir)relevant. The experimental semanticist's own *Entscheidungsproblem* appears to have no solution: there is no way to decide, for a set of alternative theories, whether on-line methods will be able to provide evidence for one over the others, that is, no way to determine beforehand which questions can be addressed experimentally with chances of success.

25

Semantics and computation

Matthew Stone

25.1 Introduction

Interdisciplinary investigations marry the methods and concerns of different fields. Computer science is the study of precise descriptions of finite processes; semantics is the study of meaning in language. Thus, computational semantics embraces any project that approaches the phenomenon of meaning by way of tasks that can be performed by following definite sets of mechanical instructions. So understood, computational semantics revels in applying semantics, by creating intelligent devices whose broader behavior fits the meanings of utterances, and not just their form. IBM's Watson (Ferrucci et al., 2010) is a harbinger of the excitement and potential of this technology.

In applications, the key questions of meaning are the questions engineers must answer to make things work. How can we build a system that copes robustly with the richness and variety of meaning in language, and with its ambiguities and underspecification? The focus is on methods that give us clear problems we can state and solve.

Language is large, and it is often a messy but routine business to create program constructs that account for linguistic data as well as possible given the background constraints otherwise imposed on system design. So the bread and butter of computational semantics is the development of machine-learning methods to induce and disambiguate symbolic structures that capture aspects of meaning in language. Linguistic issues are often secondary. I will not attempt a survey of machine learning in computational linguistics, or even computational semantics, here. Useful starting points into the literature are Manning and Schütze (1999), Jurafsky and Martin (2008), Màrquez et al. (2008), Agirre et al. (2009).

Instead, in keeping with the emphasis of this volume, I will explore the scientific overlap of computer science and semantics. My experience has always confirmed a deep affinity between the perspectives of the two fields. Recent developments in computational semantics bring an exciting new suite of tools, resources, and methods to the scene. These results promise not only to enliven the capabilities of the robots it seems we must inevitably talk to but also to profoundly enrich our understanding of meaning in language as a unique bridge between the physical, psychological, and social worlds.

In Section 25.2, I explore the natural connection between linguistics and computer science, through the parallels between the logical metalanguage of formal semantics and the instantiated representations of computational semantics. Section 25.3 reviews computational approaches to compositionality and shows how the challenges involved, particularly in disambiguation, have led to insightful new formalisms for the derivation of sentence meanings, as well as powerful tools for understanding existing grammars and formalisms. Section 25.4 turns to the computational lexicon, where the problems of carrying out inferences from word meanings has shaped computational theories of the organization of the lexicon and its relationship to common-sense inference, while the sheer need to scale systems up have led to fantastic databases of words and their occurrences in discourse. Finally, Section 25.5 considers the explanations we give of meaning in the broader context of language use. It is particularly important to show how to enrich our representations of meaning so we can interpret utterances as making contributions to interlocutors' ongoing activity. This requires us to link computational semantics with computational models of agency – characterization of interlocutors' rational action, as prompted by represented beliefs, desires, and reasons. The potential of computational semantics thus goes beyond mere operationalizing or short-circuiting of linguistic theory. It is computational semantics that transforms our discovery that the meanings of utterances are governed by rules into an explanation of how language works.

25.2 Representation and semantics

The key technical idea bridging computer science and semantics is that of REPRESENTATION. A representation is a symbolic structure in a system that can be understood to encode specified information – to carry meaning – because of mechanical processes that produce the representation as a function of appropriate states of the world and use the representation to guide the system's behavior in appropriate ways. (See Newell, 1982; Fodor, 1987; Gallistel and King, 2009; Smith, forthcoming.) Computer scientists' interests in the meanings of representations largely parallel semanticists' interests in the meanings of linguistic expressions.

Meaning in language, of course, brings distinctive problems. An instructive way of foregrounding these problems is through the development of an explicit theory that characterizes the truth conditions of sentences in a fragment of natural language. (See Davidson, 1967b; Larson and Segal, 1995.) We assume that we have an agreed metalanguage for which meaning is unproblematic (or outside the scope of our investigation). That might just be the natural language we use as theorists, English perhaps. We use the metalanguage to describe the meanings of sentences (or syntactic structures as analyzed by a syntactic grammar, or uses of the relevant expressions) in some object language of interest, German say. Our theory must pair each expression G of German with an English sentence E that says when G is true:

(1) G is true if and only if E.

In (2) I give a concrete example.

(2) "Schnee ist weiss" is true if and only if snow is white.

Since any interesting fragment of a natural language will be infinite, our theory must specify generative mechanisms for deriving these statements from a finite set of primitives.

Linguists generally adopt a formal metalanguage, for example the language of higher-order intensional logic (Montague, 1973b; Dowty et al., 1981), set theory (Barwise and Cooper, 1981), discourse representation theory (Kamp and Reyle, 1993), dynamic semantics (Groenendijk and Stokhof, 1991; Muskens, 1996), and so forth. These formalisms let us specify truth conditions precisely and without ambiguity. The use of a formal metalanguage also lets us understand the generativity of semantics as a straightforwardly computational requirement. Our goal is no more and no less than an algorithm – a finite specification of a mechanical procedure for pairing input expressions (of German, say) with output expressions in a suitable formal system (a logic of meanings). In doing semantics, we can naturally interface with techniques from computational logic to implement these algorithms, and thereby to help build, refine, test, or apply new ideas in semantics. I survey work along these lines in Section 25.3.

The linguistic problems of meaning are not limited to judgments of truth conditions, however. Native speakers' intuitions about meaning capture a diverse array of further relationships. For example, they can say when one sentence is more general than another or more specific, when one is incompatible with another or even its opposite, when one seems to suggest another or take it for granted. These judgments depend in part on compositional regularities about syntactic combination and logical vocabulary, but other information is crucial: These judgments also reflect the subtle interplay between a linguistic lexicon, organized by grammatical knowledge, and the rich body of world knowledge that invariably informs our descriptions and understandings of the world.

The line between grammar and common sense is blurry. It might be a botanical discovery that no oak is an elm. However, it seems to be part of the meanings of the words that nothing can be big and small. We did not discover the distinction; language invites us to make it. We might need chemists to tell us that iron oxidizes when it rusts. Native speakers, though, already know that something breaks when somebody breaks it; it is a single verb *break* in these different realizations. If we associate doughnuts with holes, it is only because we have learned that crullers are unpopular. However, it is language that packages the door you slam (a slab) together with the door you go through (an opening).

The overlap in these sources of information is both theoretically and empirically problematic. Computational techniques offer a way to make sense of the phenomena. They invite us to focus on representation – on the content of our knowledge and judgments, on the structures that can encode that content, and on algorithmic processes that can operationalize the relevant inferences. This focus enables a clearer understanding of knowledge of meaning and ties that understanding directly to explanations of our semantic intuitions. This focus also allows us more precisely to distinguish grammatical information from common-sense background knowledge, in terms of its form and content, or in terms of its status in learning and reasoning – without denying that key judgments require the synthesis of knowledge of both kinds. This perspective informs my review of computational lexical semantics in Section 25.4. Computational semanticists face urgent practical needs to bridge linguistic knowledge and real-world inference, so the frameworks, corpora, and databases they have developed for systematizing lexical inferences are particularly valuable.

In the end, our semantic competence reveals itself perhaps most directly and most profoundly in our ability to communicate. We can express our thoughts creatively in words; we can recover precise new ideas from others' creative utterances; we can ask questions, give answers, provide instructions; we can agree on or dispute the way things are. These skills – and the understanding of meaning they reveal – seem far removed from the abstractions of semantic theory. The gap has led to extreme rejections of those abstractions, such as the doctrine that the meaning of a word simply is its use in the language (Wittgenstein, 1953, I, §43). There are good arguments against a naive identification of semantics with anything people know or do (Putnam, 1975; Burge, 1979). Nevertheless, a purely abstract theory of meaning, disconnected from use, cannot satisfy us.

This is another case where techniques of computation and representation offer useful theoretical insights. The representational theory of mind comes into its own in explaining complex adaptive behavior by appeal to represented knowledge (Newell and Simon, 1976; Newell, 1982). The perspective is that of problem solving – the flexible, general but mechanistic synthesis of creative strategies to pursue a system's interests. Problem solving starts from a representation that specifies possible steps of reasoning and determines the form that a solution must take. It proceeds by searching systematically through the possibilities. Reasoning steps may involve reducing or transforming the problem to a simpler one, but they may also involve enriching the representation of the problem by taking into account represented background knowledge. Problem solving amounts to using represented information. When the system derives a result, it is because the system knows, in virtue of the information that it represents, that the result solves its problem.

The phenomena of communication thus invite us to develop a computational semantics embedded within a broader account of the represented contexts and goals of interlocutors in communicative exchanges. This is an important theme of research in computational semantics and pragmatics, which I survey in Section 25.5. Indeed, it is an important theme of research in semantics and pragmatics generally, and Section 25.5 charts a longstanding and dynamic intellectual interchange, spanning philosophy, linguistics, and computer science and bringing together common-sense intuitions, empirical data, formal representations, and computational models. The vast array of open problems that remain in the area offer many exciting opportunities for semanticists to continue to explore computational ideas and tools.

For computer scientists, there is a special methodological place for a computational theory of represented meaning and its role in communication. Such a theory promises to shape our understanding of intelligence in fundamental ways. The ability to engage in human-like conversation has defined the basic criterion for attributing intelligence to machines since Turing (1950). See Shieber (2004) for a history of the intellectual influence of Turing's ideas – and an updated defense of the Turing Test. Turing's proposal is a solid one. Even if the Turing Test would not detect everything we might consider intelligence, passing it remains a distant goal.

Meaning is at the heart of the challenge of such a theory, and of the artifacts we could build with it. So far, too much engineering is needed to implement representations for us to see their content as intrinsic. As designers, we interpret the representations as meaningful because this helps us to specify the operations the representations must support or to analyze the role of representations in the system. Nothing in the system itself privileges a description in terms of meanings. Indeed, our systems do not yet have anything like the kinds of meanings we have. (See Dreyfus, 1972; Searle, 1980; Winograd and Flores, 1986, for arguments for this skeptical position.)

Computers that talk as we talk will force us to sharpen our views. Perhaps, with Searle, we will come to think of meaning – the information our thoughts carry about the world – fundamentally as a sector of the subjective economy, on a par with qualia and the other mysteries of the conscious mind. On this view, questions about the possibility of meaning in systems are just questions about the place of consciousness in nature. If that is right, we might have to abandon meaningfulness as a goal for systems and retreat to "Weak Artificial Intelligence (AI)", the doctrine that our systems merely do what we do. However, like Turing (1950), I personally think that meaning is vital to our understanding of the action of intelligent agents. When we attribute meaning to somebody, we are not just commenting on their inaccessible private experiences; we are explaining their behavior in terms of the kind of engagement they have with the world. Weak AI sells meaning short.

The alternative is "Strong AI", the view that these computers will actually have semantics, in the sense that the architecture, function, and causal interaction of these systems with the world gives the referents of symbols an indispensable explanatory role in describing the systems. Dennett has suggested that this might be cheap; on his view, meaning is just a matter of perspective, taking an "intentional stance" (Dennett, 1987). However, most regard the realization of intrinsically meaningful representations as another distant goal. We do have some precise frameworks for thinking about when meaning can be explanatory (Newell, 1982; Pylyshyn, 1984) and when it is not.

Deficiencies of existing representations point to things meaningful systems would be able to do that current systems cannot. All are active areas of computational research. Grounding symbols in perceptual experience (Harnad, 1990) calls for linking linguistic abilities to perception and learning (Cohen et al., 2002; Roy and Pentland, 2002; Yu and Ballard, 2004). Deferring to experts (Kripke, 1972; Putnam, 1975) calls for tracking causal chains that connect meanings to one's linguistic community, and working actively through perception, deliberation, and action to support and resolve the status of symbols as meaningful (Steels and Belpaeme, 2005; DeVault et al., 2006; Oved and Fasel, 2011). Though symbol grounding is central to a certain kind of computational semantics – inquiry into the semantics we can realize through computational techniques – the issues involved are primarily philosophical and psychological, rather than linguistic. I will not discuss them further here.

25.3 Computation and compositional semantics

Computational semantics is predicated on mechanisms for constructing representations of the meanings of sentences. We shall see that it is straightforward to adopt established techniques from linguistic semantics, particularly the λ-calculus familiar from work in the Montagovian tradition. However, that is only one of many possibilities, and even implementations of standard compositional fragments using λ-calculus can draw distinctively on computational insights and perspectives. The key is again the distinctive role of representation in computational work.

Linguistic semanticists use terms in the λ-calculus principally as a way of naming functions. It is the functions that play a fundamental theoretical role as meanings; the terms just specify them. For example, semanticists generally understand the principle of compositionality to apply at the level of meanings. The meaning of a larger expression depends on the meanings of the parts and the way they are put together. See Szabó (2008). The combinatorial logic of the λ-calculus provides a natural algorithmic realization of this metatheory – we use λ-terms to map out the mathematical operations by which we compose our mathematical abstractions of meanings.

The λ-calculus is also an essential computational formalism. It goes back to early work by Church (1941) as a formalization of the notion of an effective procedure and served as the inspiration for LISP (McCarthy, 1960), the first high-level programming language. Normalizing λ-expressions is a fundamental model of computation, and the underlying data structures of functional programming – environments, closures, continuations – offer streamlined and well-studied methods to implement and normalize λ-terms (see Appel, 1992, or Abelson et al., 1996). More generally, explorations of the λ-calculus in computer science have led to powerful concepts and tools for modeling composition of functions as an algorithmic process. Shan and Barker (2006) and Barker and Shan (2008) showcase the linguistic applications of one such tool, DELIMITED CONTINUATIONS, which model the local context within which a scope-taking expression is evaluated. In their textbook on computational semantics, van Eijck and Unger (2010) use the built-in functions and types of the programming language Haskell as the basis for a systematic exploration of λ-calculus techniques; they take the reader from the fundamentals up to the limits of current research.

A complementary perspective comes from computational logic, where we are interested not only in normalizing λ-terms but also in solving algebraic equations assuming the equalities of the λ-calculus. Huet's higher-order unification procedure enumerates these solutions (1975). An accessible inference engine is λ-prolog (Felty et al., 1988; Miller and Nadathur, 2012), which can be used straightforwardly to specify compositional semantics (Pareschi and Miller, 1990). Another notable linguistic application of higher-order unification constructs representations of the interpretations of linguistic constituents under ellipsis (Dalrymple et al., 1991).

However, the λ-calculus is only one of a diverse set of formal systems that computational semanticists use to compose meaning representations. Computational semantics is concerned with the concrete representations, not with the abstract meanings. The goal is to construct symbol structures that we can interpret as representing desired meanings. This project invites us to build representations compositionally. Our REPRESENTATIONS of the meaning of a larger expression must be calculated from REPRESENTATIONS of the meanings of its parts and the way they are put together. This syntactic perspective brings profound differences to the typical understanding of compositionality because complex representations retain their constituents, where mathematical operations transform them. Much more flexible algorithms for specifying complex meanings are now possible. The possibilities sometimes seem to offer explanatory insights and theoretical elegance as well as practical engineering benefits.

Let us start with a simple case: UNIFICATION GRAMMAR (Shieber, 1986; Moore, 1989). This formalism derives semantic representations by accumulating constraints in tandem with a syntactic derivation. The constraints take the form of equations between terms which may contain variables. The formalism gets its name from the process, UNIFICATION, which determines values for variables to solve the equations.

In unification grammar, we can abstract meanings by using variables as placeholders; then we can derive concrete instances through equations that set the variables to appropriate values. For example, we might represent an unsaturated predication in two parts, an expression such as $walks(X)$ together with a specification X that indicates the argument position in this expression. Saturating the predicate is then realized by an equation unifying the argument position with a particular instance, as $X = chris$. The equation determines the corresponding saturated instance $walks(chris)$ as the overall meaning of the predication. Here is a general rule accomplishing this compositionally in tandem with syntactic derivation:

(3) $s[sem : E] \rightarrow np[sem : A] \;\; vp[sem : E, arg : A]$

In (3) syntactic productions are annotated with FEATURE STRUCTURES, records that pair attributes with corresponding values (in this case semantic representations). Using (3) thus imposes the constraint that the *sem* feature of the (subject) noun phrase must be equal to the *arg* feature of the verb phrase predicate. Thus if we have derived $np[sem : chris]$ as an analysis of *Chris* and $vp[sem : walks(X), arg : X]$ as an analysis of *walks*, then rule (3) lets us derive $s[sem : walks(chris)]$ as an analysis of *Chris walks*, by imposing the requirement that $X = chris$.

The treatment of quantification in unification grammar offers an instructive contrast with λ-calculus techniques. To model a quantifier like *everyone* in subject position, we need to instantiate the main predication to a bound variable, and then construct an overall meaning representation for the sentence by universally quantifying over this predication. So *everyone* needs to know about a predication (*pred*) and the argument position of the predication (*parg*) in order to construct its semantics. That means we should analyze *everyone* through a complex representation like $qnp[sem : \forall x.G, pred : G, parg : x]$. To use this meaning compositionally, we have a rule such as (4).

(4) $s[sem : E] \rightarrow qnp[sem : E, pred : P, parg : A] \;\; vp[sem : P, arg : A]$

In applying (4) to analyze *everyone walks*, we now derive equation $X = x$ unifying the unsaturated position of *walks* with the bound variable of the quantifier and another equation $G = walks(X)$ unifying the predication itself with the nuclear scope of the quantifier. The overall meaning representation $\forall x.walks(x)$ is thus assembled as the solution to a set of constraints – not through the function–argument discipline familiar from the λ-calculus.

These examples suggest the difference in perspective that comes from adopting constraint-satisfaction formalisms for meaning construction. If we model sentence meaning as the solution to a set of equations, it is natural to expect to find elements of meaning that are simultaneously determined by multiple equations, and, conversely, elements of meaning that are left unconstrained and must be resolved by context. By contrast, λ-calculus techniques expect each element in a meaning representation to be specified exactly once. The flexibility of constraint techniques is sometimes instructive for theories of linguistic semantics. For instance, constraint techniques offer new ways to analyze idioms and multi-word expressions. Each constituent can not only specify its own meaning but impose a constraint on the meaning of the whole (Sag et al., 2002). The approach offers an analogous treatment of concord phenomena in negation, tense, modality, and other semantic fields. For example, negative elements can constrain a clause to have a negative meaning without any one element being privileged as contributing the negation compositionally (Richter and Sailer, 2006). Conversely, constraint techniques offer a useful way to think about arguments that are optionally specified, for example in verb-frame alternations. Providing these arguments imposes a constraint on interpretation that is simply absent when these arguments are omitted (Palmer, 1990). Regardless of how these analyses are ultimately settled, familiarity with constraint semantics can help linguists distinguish between the fundamental empirical challenges of semantics and the technical obstacles that arise in formalizing insights with specific tools, including λ-calculus.

In fact, computational semanticists typically adopt constraint-satisfaction techniques because of their computational advantages. More expressive constraint languages are particularly useful for representing, reasoning about, and resolving ambiguity. A prototypical case is the ability to underspecify scope relationships during semantic composition. The essential idea is to augment the set of constraints imposed during meaning construction so that the meaning representations that satisfy the constraints correspond to all and only the possible readings of a sentence.

We can illustrate the idea with hole semantics (Bos, 1995). In this constraint language, we write logical formulas that describe what we know about meaning representations at a particular point in syntactic analysis and semantic disambiguation. HOLES are variables in the logic that range over meaning representations; holes have to be plugged by assigning them appropriate values. LABELS are unique names for substructures of semantic representations; labels allow us to describe constraints on particular occurrences of expressions. (Unification grammar, by contrast, only allows us to constrain the expression types that appear in meaning representations.) The constraint language allows us to specify the representational structure at a specific expression occurrence, to force a specific expression occurrence to plug a specific hole, and to constrain one expression occurrence l to occur as a subexpression of another l', written $l \lhd^* l'$. Solutions are formulas obtained by finding a suitable mapping from holes to labels in such a way as to satisfy the constraints.

To illustrate, consider the two readings of *every student solved a problem* given in (5).

(5) $\forall x.student(x) \supset \exists y.(problem(y) \wedge solve(x, y))$
$\exists y.problem(y) \wedge \forall x.(student(x) \supset solve(x, y))$

Hole semantics allows us to compactly describe the two formulas in terms of their substantial shared structure and an underspecified scope relationship, as in (6).

(6) $l_1 : \forall x.student(x) \supset h_1, l_2 : \exists y.problem(y) \wedge h_2, l_3 : solve(x, y),$
$l_3 \lhd^* l_1, l_3 \lhd^* l_2, l_1 \lhd^* h_0, l_2 \lhd^* h_0$

To satisfy (6), we need to plug the holes h_0, h_1, and h_2 – corresponding respectively to the full sentence semantics, the nuclear scope of the universal, and the nuclear scope of the existential – with labels l_1, l_2, and l_3 – corresponding to the universal quantification, the existential quantification, and the main predication. Dominance constraints ensure that the main predication is a subformula of the nuclear scope of both quantifiers and that both quantifications occur as subformulas of the full sentence semantics. There are two solutions: plugging $h_0 = l_1, h_1 = l_2, h_2 = l_3$ leads to left-to-right scope while plugging $h_0 = l_2, h_2 = l_1, h_1 = l_3$ leads to inverse scope.

If we instrument a constraint-based grammar so that semantic composition delivers descriptions of underspecified scope relationships, we can derive compact summaries of possible interpretations, rather than enumerating different possibilities separately. The computational savings are formidable. Blackburn and Bos (2005) offer a comprehensive tutorial on hole semantics. Moreover, other formalisms for computational semantics adopt a similar approach to underspecifying scope by constraining structural relationships among expression occurrences, notably including underspecified minimal recursion semantics (UMRS) (Copestake et al., 2001), the constraint language for lambda structures (Egg et al., 2001; Koller et al., 2003), and hybrid logic constraint semantics (Baldridge and Kruijff, 2002).

Different constraint languages embody different insights into the patterns of ambiguity that tend to arise together in wide-coverage grammars. We need the right set of constraints, in harmony with a perspicuous organization of the grammar, to be able to fold alternative analyses together into a single representation. In UMRS, for example, we can constrain the functor associated with a particular label to a small set of values; this way we can write a single semantic constraint that captures word-sense ambiguity. We can also separately constrain the argument positions present at a particular label, without committing to the arity of the functor; this helps with the variation in argument structure seen across different syntactic frames. Finally, UMRS privileges "flat" semantics – conjunctions of predications characterizing the same generalized individuals, as found in Davidsonian event semantics (Davidson, 1967a), Hobbs's ontologically promiscuous semantics (1985b), and the original formalism of minimal recursion semantics (Copestake et al., 2005). A special set of constraints makes it easy to conjoin semantic constraints in a common scope. Copestake et al. (2001) show how to use these constraints effectively in conjunction with Head-Driven Phrase Structure Grammar (HPSG) syntax to derive useful and compact underspecified semantic representations in practical wide-coverage grammars.

In reasoning about ambiguity, it is often helpful to abstract away from concrete syntactic structure as well as concrete semantic representations. One technique is to take syntactic dependency relationships as the input to semantics, rather than a full syntax tree. This makes it easier to describe systematically the ambiguities that arise in binding and scoping complements and modifiers, since all complements and modifiers are represented as dependents of a single lexical item. An influential approach is the glue logic presented by Dalrymple et al. (1993) and Dalrymple et al. (1997), originally developed for LFG. The basic prediction of glue logic is that any scoping of complements and modifiers is possible, as long as the constructed meaning representation type-checks and contains exactly one copy of the material contributed by the head and each of its dependents. This can be modeled as an inference problem in a fragment of linear logic. Lev (2007) summarizes the resulting ambiguities in an underspecified formalism. Similar insights can be used to assemble semantic representations for other dependency formalisms, including lexicalized TAG (Kallmeyer and Joshi, 2003).

Linguists interested in scaling up compositional semantic theories to larger fragments can now draw on a range of systems that are capable of delivering semantic representations with wide coverage. For English, examples include the *English Resource Grammar in HPSG*[1] (Copestake and Flickinger, 2000) with UMRS semantics; the *C&C tools and Boxer*[2] for CCG parsing and DRT semantic representations (optionally including anaphor resolution) (Curran et al., 2007); and the *XLE tools and ParGram project grammars for LFG and glue logic*[3] (Butt et al., 2002). These systems model a large fraction of the words and syntactic constructions found in written texts and can associate these analyses with semantic representations that specify interpretive dependencies and scope relationships. Unfortunately, these grammars have rather impoverished analyses of much of the fine structure of linguistic

[1] www.delph-in.net/erg/. [2] http://svn.ask.it.usyd.edu.au. [3] www2.parc.com/isl/groups/nltt/xle/.

meaning because of the scarcity of semantic resources and the limits of disambiguation techniques.

For what they cover, computational techniques offer an attractive way to explore the predictions of formal analyses because they can systematically explore the possibilities for interactions among grammatical specifications. To systematically describe the structure and meaning of general texts, we need diverse specifications, which leads to proliferating analyses even for simple sentences. Alexander Koller (p.c.) reports that the English Resource Grammar yields about 65,000 readings for (7).

(7) But that would give us all day Tuesday to be there.

Such statistics illustrate how dangerous it can be to rely on pencil and paper alone to assess the predictions of theories.

More generally, the semantic representations embodied in wide-coverage systems go a long way to explain how knowledge of meaning can actually be used in real time in language processing. The constraint-based approach allows for monotonic accumulation of information about meaning during incremental processing. With UMRS, for example, it is possible to give semantic representations that summarize the information available about meaning after each of the successive steps of analysis in a language processing pipeline – starting with part-of-speech tagging, continuing through syntactic attachment, word-sense disambiguation, recognition of predicate–argument structure, and so forth. These techniques thus allow for a wide range of reasoning methods to be applied to resolve ambiguities and, moreover, enable them to proceed by inferring additional semantic constraints rather than by enumerating and comparing individual readings. These techniques come with little cost because it is often surprisingly elegant to instrument syntactic specifications to deliver a flexible and precise constraint semantics.

The success perhaps offers lessons for semantics. We aim to account for links between words and the world. Whatever does this must supervene on human practices and so must ultimately depend on individual speakers' cognitive representations of meaning. The success of computational techniques suggests that semantic theory too might best be served by describing the algorithmic construction of cognitive representations of meaning, rather than the compositional relationships among meanings themselves. There is now a sizable contingent of researchers in linguistics and cognitive science who adopt just this view (Jackendoff, 1990; Hamm et al., 2006; Pietroski, 2008, among others). The jury is out; representationalism is not without its theoretical challenges (see Steedman and Stone, 2006). So readers interested in following up the linguistic consequences of distinctively computational formalisms are entering a lively and important theoretical debate.

25.4 Computation and lexical semantics

Compositional semantics gives us representations to capture aspects of the logical structure of meaning. However, it typically abstracts away from the rich particulars of linguistic content – what specific entities and concepts does a sentence describe, and what specific claim does it make about them? This utterance content depends on a wide range of substantive knowledge about the world, not just the logical structure of meaning. Thus, to develop precise representations of linguistic content we need a corresponding formalization of the conceptual and inferential relationships among word meanings. The project is complex because it ties the organization of grammar to speakers' knowledge of the common-sense world and to the patterns of use which reveal our ordinary ways of thinking and talking about what matters to us.

Computational research, with its ability to manage large databases of linguistic structures and examine large corpora of linguistic evidence, brings unique insights into the complexity of lexical semantics. This section reviews research into three different aspects of word meaning: WORD SENSES, conceptual distinctions that are needed to capture lexical inferences; SEMANTIC FRAMES, linguistic and conceptual structures that connect lexical and compositional inferences; and SEMANTIC FIELDS, associations among concepts that explain the plausibility or naturalness of the ensembles of meaning we characteristically use.

To make my presentation more concrete, I will refer throughout to a specific example, the English verb *charge*. The word originates, via Norman French, in a Latin root referring to the activity of loading a wagon. This sense is now rare, if not entirely forgotten. Instead, *charge* is now the word we use for payment by credit card, for the supply of energy to electronic devices, and for the formalities of proceedings in criminal courts. There are lots of new things to talk about, and we have pressed our old words into service! The examples in (8) illustrate these (and other) uses.

(8) a. The brigade charged the enemy positions.
b. The cavalry charged.
c. Kim charged my cellphone for me.
d. The battery charges in around 3 hours.
e. They charged us fees for their services.
f. The bank charged interest on the loan.
g. They charged us a commission to sell the armoire.
h. I charged $200 on my credit card.
i. The board charged the committee to study the proposal.
j. The DA charged them with murder.
k. Prosecutors charge that Quimby took $10,000 in bribes.

An inventory of WORD SENSES attempts to specify, in formal terms, a list of the qualitatively different relationships that words in a language can express. The examples in (8) show that *charge* has senses meaning “to bear down on in attack”, “to supply with electrical power”, and “to demand payment”, among others. These particular labels come from the electronic lexical database *WordNet*[4] (Miller, 1995; Fellbaum, 1998), a standard resource in computational lexical semantics. We return to WordNet and its inventory of word senses and lexical relationships below. Computational techniques have proved helpful not only in systematizing word senses for broad coverage, as WordNet does, but also in clarifying and streamlining the methodology for positing word senses in response to corpus evidence and native speakers’ linguistic judgments.

An inventory of SEMANTIC FRAMES, meanwhile, attempts to specify the qualitatively different syntactic realizations that a language can allow for the same word sense. Consider (8a) and (8b). Evidently, in using *charge* describing an attack, English speakers have the option of spelling out the quarry as a direct object noun phrase, but they also have the option of leaving the quarry implicit. In either case, the attacker is the subject. Contrast this with (8c) and (8d). In describing the provision of energy to a device, *charge* can also be used either transitively or intransitively. However, it is the device that is always specified, either as the direct object in the transitive frame, as in (8c), or as the subject in the intransitive frame, as in (8d). Different syntactic realizations depend both on the combination of arguments that are expressed overtly, as in the previous cases, and also on the syntactic category through which those arguments are realized. Examples (8e)–(8g) all describe goods and services requiring payment but use *for* plus a noun phrase, *on* plus a noun phrase, and *to* plus a verb phrase.

Computational semantics approaches these differences through databases of semantic frames, such as *VerbNet*[5] (Kipper et al., 2008) and *FrameNet*[6] (Baker et al., 1998). Each frame identifies the roles or participants implicitly related to a target concept and describes the different constructions that allow these participants to be specified in construction with a word used to express the concept. As is the case with word senses, computational techniques for analyzing semantic frames support linguistics by helping to organize corpus data, speakers’ judgments, and their connections to specifications of grammar.

Finally, the data in (8) illustrate the importance of lexical information in describing and resolving semantic ambiguities. Look at the arguments of *charge* in (8e)–(8g). The data reflect an obvious constraint: what can be charged, in the sense of demanded as payment, is quite limited in scope. It includes not just *fees*, *interest* or *a commission*, as here, but a family of associated items – *expenses*, *fines*, *prices*, *sums*, *amounts*, *a fortune*. Similar items recur

[4] http://wordnet.princeton.edu/. [5] http://verbs.colorado.edu/~mpalmer/projects/verbnet.html.
[6] https://framenet.icsi.berkeley.edu/fndrupal/.

as what can be paid, deducted, earned, and so forth. By identifying these clusters, we learn more about how to identify what sense of *charge* is at play in a particular example. We also get new insights into what words have similar meanings, including not only the similarity of payment words like *fees* and *interests* that we find in a common cluster but also the indirect similarity we find among verbs like *charge*, *pay*, and *deduct* that take similar clusters as arguments. We find analogous clusters at other argument positions: the military units that typically get orders to charge, as in (8a); the devices that typically require a charge, as in (8c); the crimes one can be charged with, as in (8j). In these cases, where clusters clearly showcase expressions that people tend to use, we can see that they will be statistical constructs giving information about frequent events and the common perspectives speakers take on them, as well as encoding restrictions about what makes sense. Computational semanticists have combined lexical resources, corpus data, language processing techniques, and statistical inference to find many ways of clustering meanings for applications. See Turney and Pantel (2010) for a review. These studies provide important tools for understanding the evidence that speakers must use in learning, disambiguating, and reasoning with the meanings of words and expressions.

Armed with this perspective, let us tour the landscape of computational lexical semantics in more detail.

A linguist looking to study word senses can build on a range of research results. First, there are large-coverage lexical databases. In English, the prime example is WordNet[7] (Miller, 1995; Fellbaum, 1998). WordNet is not just a dictionary. It provides an inventory of concepts, specifies key relationships among concepts, and maps out the many-to-many correspondences between concepts and words.

The basic entries in WordNet, corresponding to word senses or concepts, are SETS OF WORDS that can be used synonymously – in the right context – to convey the same concept. For example, WordNet lists *bill* as a synonym for *charge* in defining the sense of demanding payment. These entries are called SYNSETS for short. When a word is ambiguous, WordNet represents each sense with corresponding synset which includes that word. In keeping with the ambiguities seen in (8), *charge* is associated in WordNet with many synsets.

WordNet also describes a number of semantic relationships among word senses. TROPONYMS of a verb are more specific verbs that describe the specific manner in which something unfolds. Troponyms are a special case of WordNet's HYPONYM links that connect terms with more specific instances. The WordNet troponyms of *charge* (in the synset of demanding payment) include *levy* and *invoice*. WordNet's HYPERNYM links, meanwhile, connect words to more general terms. WordNet's hypernyms for *charge* (demand payment) include *account* and *calculate*.

[7] http://wordnet.princeton.edu/.

WordNet[8] has been an inspiration for similar efforts across a wide range of languages. Because it links concepts to semantic relationships, across a wide range of vocabulary, it can be thought of as a coarse semantic network. Researchers have used it to measure the distance among concepts (Budanitsky and Hirst, 2006) and, perhaps more interestingly for semantics, to acquire meaning postulates that connect the meanings of different words and help to automate inferences such as entailment (Bos and Markert, 2005).

The specific inventory of senses that WordNet offers, however, is open to criticism. The conceptual distinctions among senses are not always clear, not only because of overlaps among the senses themselves but also because of interactions between lexical semantics, compositional semantics, and argument structure. It is striking, for example, that WordNet attempts to distinguish three senses of *charge*, one for demanding payment from somebody in a specific case, another for pricing a service in general at a certain amount, and another for updating an account by entering a certain amount as a charge. It will be difficult to tease these cases apart in the interpretation of a specific sentence, since in the normal case, the way businesses demand payment is to prepare an invoice claiming the current general price against the customer's account, effectively undertaking all three kinds of charging. Indeed, perhaps we can say everything we need to say about demanding payment if we approach the different cases syntactically and give a compositional semantics that supplements a single word sense with appropriate generic or presupposed interpretations for arguments that are not explicitly realized. At the same time, WordNet's coverage of world knowledge is limited. For example, none of these senses of *charge* is related in WordNet to the obvious common-sense implication of both (8e) and (8f) that someone has bought something, someone has sold something, someone has paid someone, and so forth.

A different thread of research in computational semantics is prompted by these limitations. This research focuses explicitly on evidence and methodologies for inventorying word senses in a language and identifying the word senses at play in specific uses. A key principle is Yarowsky's one sense per collocation heuristic, which says that statistically reliable associations of words – collocations – are good indications of a distinct underlying concept (Yarowsky, 1993). We have seen some examples for this in the case of *charge*. Kilgarriff and colleagues (Kilgarriff and Rundell, 2002; Kilgarriff et al., 2004) describe WordSketches, a way of finding key collocations in large corpora and presenting the results interactively to support lexicographers in identifying and distinguishing prominent word senses. These are the basis for wide coverage efforts to build better dictionaries – especially educational dictionaries for (human) language learners.

Given an array of word senses, we can now ask native speakers to indicate which word sense is at issue in particular utterances. We can use the

[8] www.globalwordnet.org/wordnets-in-the-world/.

resulting annotated corpora in linguistics to understand patterns of use, and in computer science to train and evaluate methods for disambiguating word senses. Over the last few decades, the Senseval and Semeval projects have carried out a wide range of annotation projects in support of the research community and made the data available. (See Kilgarriff and Palmer, 2000; Edmonds and Kilgarriff, 2002; Mihalcea and Edmonds, 2004; Agirre et al., 2009.) Senseval has focused on providing comprehensive data about a limited range of phenomena of theoretical and practical interest; the corpora are not broad coverage.

A number of resources now offer a more comprehensive picture of aspects of lexical semantics. FrameNet[9] (Baker et al., 1998) is a pioneering example. FrameNet combines a regimented analysis of a wide range of verbs with annotated data classifying attested uses. It focuses specifically on the alternative patterns of meaning and structure exhibited by verbs as in (8). FrameNet consists of an electronic database that describes several thousand English verbs. Each verb sense is associated with a frame, which identifies a broad class of eventualities and specifies the roles that different participants may play in these eventualities. For example, FrameNet captures the payment sense of *charge* by linking *charge* to the *commerce_collect* frame, a subframe of the *commerce_money-transfer* frame that explicitly indicates how the seller comes to have money as a result of an economic transaction. The frame maps out five privileged roles: the buyer, seller, goods, and money, as well as a rate role when money is specified per unit of goods. (The frame also suggests common modifiers for this type of eventuality, including manner, means, place, purpose, reason, time, and the unit of measure for goods in the transaction.) In addition, FrameNet describes the alternative patterns of syntactic realization through which roles can be realized. These patterns are documented by attested textual examples, which illustrate both the different possibilities for realizing specific role fillers and the possibilities for leaving some role fillers implicit. You can get a sense of this data from the fragments presented in (9).

(9) a. <u>Firms</u> [seller] have a right to charge <u>what the market will bear</u> [money] . . .
b. <u>Nimslo</u> [seller] will charge <u>£9.99</u> [money] <u>to produce 18 prints</u> [goods] . . .
c. <u>The new lender</u> [seller] will charge <u>its legal expenses</u> [money] <u>to you</u> [buyer].

VerbNet[10] (Kipper et al., 2008) offers a similar electronic database of verbs. In fact, the VerbNet project distributes a mapping between VerbNet entries and corresponding entries in WordNet and FrameNet. VerbNet offers more fine-grained verb senses than FrameNet, but coarser-grained specifications

[9] https://framenet.icsi.berkeley.edu/fndrupal/.
[10] http://verbs.colorado.edu/~mpalmer/projects/verbnet.html.

of the semantic roles associated with those word senses. However, what makes VerbNet particularly useful is that it is linked with *PropBank*[11] (Palmer et al., 2005), a large corpus of text that has been annotated not only with syntactic parse trees but also with predicate–argument relationships and semantic roles. With VerbNet, it is therefore possible to get quantitative information about the distribution of lexical semantic patterns for verbs. In computational linguistics, these resources provide the starting point for machine learning methods to disambiguate the senses of verbs and the roles of their arguments. However, the data are also a natural starting point for empirical tests of linguistic theories of argument structure and word meaning.

Of course, there is more to lexical semantics than verbs. Pustejovsky (1991a), for example, argues that we also need to assign frames to nouns and adjectives to account for the participants in lexical semantic relationships, implicit, and explicit, and to formalize the syntactic patterns for filling these roles. Resources beyond verbs remain rather limited, however. A notable exception is the *Penn Discourse Treebank*[12] (Prasad et al., 2008), which extends corpus-based models of argument structure to discourse connectives. These are words like *but*, *however*, and *instead* that serve to express rhetorical relationships in discourse (Webber et al., 2003). The Penn Discourse Treebank marks up the textual source for the explicit and implicit arguments of these relationships. Example (10) illustrates.

(10) As an indicator of the tight grain supply situation in the US, market analysts said that **late Tuesday the Chinese government**, *which often buys US grains in quantity*, **turned** instead **to Britain to buy 500,000 metric tons of wheat**.

The underlined *instead* relates the boldfaced clause describing China's purchase of wheat from Britain to the non-restrictive relative clause which describes the understood alternative: China's normal purchases of US grain.

As difficult as they are to build with wide coverage, even semantic frames are quite shallow in the kinds of inferences they support. The difficulties are exacerbated by interactions between lexical semantics, compositional semantics, and common-sense inference. Consider the examples in (11).

(11) a. They charged me twice.
b. If they charged $25 a day, how many days would you stay?
c. It was excellent work for what they charged.

Dictionaries of semantic frames do indicate that *charging* as in (11a) is a kind of commercial transaction involving a buyer and a seller, but there is no real model of what happens in such situations. Deeper knowledge would be required to reach the conclusion – obvious to any human reader, and

[11] www.ldc.upenn.edu/Catalog/catalogEntry.jsp?catalogId=LDC2004T14.
[12] www.ldc.upenn.edu/Catalog/CatalogEntry.jsp?catalogId=LDC2008T05.

crucial to inferences we would like to automate about the information, attitude, and coherence of the text – that (11a) describes a problem or error. Conversely, understanding whether a *charge* sentence describes a generic offer, as considered (hypothetically) in (11b) or a specific completed transaction, as seems to be the case in (11c), is ultimately a matter of recognizing a hidden generic interpretation. Argument structure provides an important clue, since it is natural to leave the buyer unspecified in a generic offer, as in (11b), provided that is a grammatical realization of a verb's semantic frame (as it is for *charge*). However, we also need to know the grammatical and discourse context, because the buyer may be omitted, since it is presupposed in context, as in (11c).

Traditionally, systems and resources have been very limited in tracking these kinds of interactions among compositional semantics, lexical semantics, and context. This is one motivation for recent workshops on RECOGNIZING TEXTUAL ENTAILMENT (RTE). RTE is the problem of deciding whether one text can be inferred from another, given plausible resolution of ambiguities and common-sense background knowledge. The RTE competitions have developed a set of standardized tasks, data sets, and evaluation protocols to assess the performance of systems on this inference problem. RTE was spearheaded by *the PASCAL Network of Excellence*[13] and has since become part of the *Text Analysis Conference*[14] managed by the National Institute of Standards in the United States. The resources distributed for past competitions remains a natural starting point for new research projects.

While much research on RTE focuses on shallow and machine learning techniques, RTE has in fact prompted a number of projects with substantial interest for formal semantics. Bos and Markert (2005), for example, integrate a formal semantic framework based on discourse representation theory with automated theorem proving and common-sense inference rules derived from WordNet. Nairn et al. (2006), meanwhile, identify the factuality of embedded clauses by modeling the lexical meaning of implicative verbs and its interaction with compositional semantics, including complementation and negation.

In general in computational linguistics, richer linguistic resources – such as the lexical meanings encoded in WordNet, FrameNet, or VerbNet – only exacerbate the already urgent problem of disambiguation. With syntax and compositional semantics, we have some hope that the combinatorial structure of grammatical derivations can zero in on plausible readings, perhaps with the help of coarse surface patterns. If we must also disambiguate lexical alternatives like the different senses of *charge* at issue in (8), it seems we need a qualitatively richer and deeper understanding of what makes semantic relationships plausible to native speakers. However, we presently have no way to derive such understandings from available representations of grammatical or world knowledge.

[13] www.pascal-network.org/. [14] www.nist.gov/tac/.

What we do have in abundance, though, are patterns of word use from corpora. Linguists have argued that these patterns offer robust, statistical evidence about word meaning (Harris, 1954; Firth, 1957). Concretely, heuristics like one sense per discourse or one sense per collocation, which help to motivate word senses in the first place, also provide leverage for resolving the ambiguities. When we find common combinations of words, we can assume that they are to be interpreted in their specific senses that normally occur together. This heuristic provides a corpus-based metric for semantic plausibility that can inform a wide range of larger projects, from engineering approaches to disambiguation to the elaboration of psycholinguistic models.

Most analyses begin by creating a measure of similarity between word distributions. Similarity is a trigger for inferring relationships between words and generalizing from one word to another. The key difference is the knowledge sources for computing similarity. The simplest are techniques such as the influential model of latent semantic analysis (Landauer et al., 1998, LSA), which simply starts from a matrix describing which words occur together in the same document in a text collection. LSA uses a statistical technique called principal component analysis (Jolliffe, 2002) to infer weighted clusters of words that explain most of the statistical variation in the matrix. These patterns intuitively correspond to document topics or semantic fields. Other clustering methods start from recognized syntactic relationships in large corpora. For example, Pereira et al. (1993) and Lee (1999) use the joint distribution of English verbs and their object nouns to infer clusters and measure similarity. Background knowledge can also be added when it is available. Resnik (1999) creates a measure of semantic similarity by enriching the WordNet hierarchy with probability information derived from the frequency of occurrence of words in text.

These measures of semantic similarity give shallow but robust techniques for reasoning about meaning on a large scale. Clustering the arguments of verbs gives a computational reconstruction of the linguistic notion of a selectional restriction (Resnik, 1996; Light and Greiff, 2002). More generally, models of semantic distance make it possible to measure whether a possible analysis of a sentence is semantically similar to examples we have seen in training data and assess how likely it is to be correct (Dagan et al., 1999). In fact, these distributional predictions correlate closely with human judgments of semantic plausibility (Padó et al., 2009).

Meanwhile, the presence of specific patterns in large collections of text is often a good proxy for specific real-world relationships. Computational semanticists have used distributional patterns to establish logical relationships such as whether operators are downward entailing (Danescu-Niculescu-Mizil and Lee, 2010). They have discovered semantic relationships at the level of the lexicon, including hyponymy and part–whole relationships (Hearst, 1998; Pantel and Pennacchiotti, 2006; Snow et al., 2006). Moreover, they have captured real-world inferences, including inferences about the typical duration or order of common events (Chambers and Jurafsky, 2008, 2009; Gusev et al., 2010).

As a result of these successes, many engineers are looking to replace logical models with distributional models that provide a useful proxy for linguistic semantics across a wide range of tasks. See, for example, Mitchell and Lapata (2010) and Baroni and Lenci (2010). That has clear limits – among other things in handling context-dependent expressions such as pronouns or ellipsis, and in connecting language to other representations of the world. However, linguists would do well to understand the basis for the models and appreciate why they are powerful and necessary in computational investigations.

25.5 Computing meaning in context

The techniques of Sections 25.3 and 25.4 allow us to derive meaning representations which feature precise real-world predicates in grammatically specified logical relationships. Such representations do not, as yet, make explicit the understood links between linguistic expressions and the discourse contexts. Accordingly, computational semanticists typically subject these representations to a further stage of resolution and inference to recover these links. The models that computational semanticists use continue a tradition that extends to seminal early projects from the AI literature, such as Charniak (1973), Hobbs (1978), Webber (1983). In many respects, the work offers similar insights and techniques to work on discourse in formal semantics (Karttunen, 1976; Kamp, 1981b; Heim, 1982). However, because of its emphasis on common-sense inference and naturally occurring data, computational work tends to adopt modeling assumptions and mathematical techniques whose relationship to linguistic ideas may not be immediately apparent. This section sketches the most important computational techniques, specifically in relation to comparable formal proposals.

At the outset, note that the goal of these techniques is actually to recover the intended interpretation of context-dependent elements in specific utterances. Imagine the instruction in (12) addressed to a robotic kitchen assistant, for example.

(12) Put the dough hook back onto your mixer.

We expect the robot to comply with this instruction. To settle on a specific action to perform, the robot must figure out who *your* refers to, what is meant by *the mixer* and *the dough hook*, and where the dough hook goes *back onto*. Computational semanticists hope to deliver answers to such questions by combining models of meaning with models of context.

Linguistic theory is an important ingredient in computational models. Following Kaplan (1989b), we can represent the contributions of context-sensitive elements with variables in the semantic representation. For (12), for example, we will want to find a person p for *your*, objects m and h for *the mixer* and *the dough hook*, and an action type a that will represent the content of the instruction. As in DRT (Kamp and Reyle, 1993), we can use the discourse context to establish a list of possible values for variables. This will involve documenting specific available referents; for example, we might wind up with a symbol m_1 that identifies the specific KitchenAid Pro 6-quart stand mixer that the user is equipped with. However, it will also require us to spell out referents that can be inferred indirectly – it is a fact that each mixer of this general type comes with its own dough hook, which we might therefore represent with a complex term as $h_1(m_1)$ to illustrate the functional dependency. The relationship matters: Even if we know about many dough hooks in the kitchen, we will take *the dough hook* to mean the one the mixer comes with.

Given this information, the remaining challenge is to predict likely interpretations, taking into account the recent history of the conversation, the situation in which the conversation is playing out, and the broad commonsense background that interlocutors take for granted. A common perspective is that this context can be modeled as a knowledge base or information state (Poesio and Traum, 1997; Larsson and Traum, 2001). Linguists should think of the information state as a realization of Stalnaker's common ground (1973, 1978, 1998). Stalnaker's proposal links the problem of communication to the inherent dynamics of coordinating agents in a way that brings out the natural commonalities between human–human conversation and the engineering enterprise of supporting human–computer interaction. Agents that coordinate need to track the joint information that each can naturally expect the other to rely on in understanding one another's actions (Lewis, 1969). Tracking the common ground is thus as much a feature of collaborative agent designs in AI (Power, 1977; Grosz and Sidner, 1990; Lochbaum, 1998; Carberry and Lambert, 1999) as it is in models of human inquiry in linguistics and the philosophy of language.

Computational semanticists are, however, typically more explicit about the rich structure of information states in conversation. This goes beyond the content interlocutors have agreed to in the conversation, as emphasized by Stalnaker (1978). For example, the information state also records the organization of the ongoing conversation into hierarchically structured discourse segments (Grosz and Sidner, 1986). Each of these segments is associated with a distinct conversational purpose that it addresses, which is achieved in part through the purposes of its constituent segments and contributes in turn to meeting the goals of later and larger segments. Moreover, the information state must model interlocutors' attention in conversation, which establishes some potential resolutions of meaning as salient and others as more remote. See Ginzburg (2012) for a recent formal model of the organization of dialogue that explores the consequences of rich models of conversation for linguistic grammar. Clark (1996) and Roberts (2012b) offer more programmatic arguments for bridging pragmatic models of context with the models of joint activity often used to build collaborative agents in AI. Concretely, in the context of (12), we can imagine appealing to a diverse set of factors in our information state, including the broad outlines of the ongoing recipe, which frames the purposes and organization of the conversation; general functional knowledge about the available items, including when, how, and why they are typically used, and the specific history of utterances and real-world actions that have taken place thus far in the cooking project. Note that while it is currently prohibitively time-consuming to build knowledge bases of this kind at a large scale, AI research offers a powerful repertoire of tools for representing the relevant information and drawing the relevant inferences. See Brachman and Levesque (2004) or Koller and Friedman (2009) for different approaches.

We can now model the resolution of underspecified aspects of meaning, as a process of default inference that shows how the interpretive requirements of an utterance are most plausibly met in the context. Concretely, we assume that any utterance with context-dependent elements will be associated with a specification of the information in the context that we use to resolve the unknown values. For (12), something like (13) is in order:

(13) $dough(d) \wedge hook(h) \wedge nn(h, d) \wedge addressee(u, p) \wedge poss(p, m) \wedge mixer(m) \wedge result(a, on(h, m)) \wedge past(on(h, m)) \wedge contributory(a)$

This information is quite heterogeneous. (13) includes the constraint that the referent of *your* must be the addressee of the current utterance u, which falls under Kaplan's (1989b) concept of the CHARACTER of an indexical item. (13) includes anaphoric presuppositions (Kripke, 2009) triggered by particular lexical items, such as the constraint $past(on(h, m))$ that encodes the requirement, from the word *back*, that the end-state of action a must already have been realized at an earlier stage of the conversation. Reference resolution is modeled by constraints contributed by the semantics of the definite noun phrases: something we can see either as an additional presupposition, as is usual in DRT, or just as a representation of the speaker's inferred referential intentions (Kripke, 1977). Meanwhile, the requirement that the action described make a natural contribution to the ongoing task, represented as the constraint $contributory(a)$, is almost certainly a speaker presupposition that is more or less independent of grammar and encodes general background knowledge about what kinds of discourse contributions make sense in the current context. Computational semanticists tend to be rather sanguine about running such diverse constraints together. Hobbs et al. (1988, 1993), for example, refer to the full set of interpretive constraints derived in the course of utterance understanding simply as logical form.

Resolution proceeds by posing the interpretive constraints, such as those in (13), as a query against the information state, represented as a knowledge base, as sketched above. The query yields a "top proof" – one that uses maximally salient information, most probable premises, or makes the fewest assumptions. As a side effect, the proof specifies a substitution replacing variables in the interpretive constraints with contextually defined values. This substitution then determines the contextually resolved meaning of the utterance.

Techniques of this kind first come to prominence in the middle 1980s. Mellish (1985) and Haddock (1987) used constraint satisfaction to resolve reference; Dale and Haddock (1991) used it to generate references. These techniques made minimal use of logical inference in processing queries. Hobbs et al. (1988, 1993) used a model with a full set of inferential mechanisms, including the ability to make abductive assumptions, which in effect allows for partial and probabilistic matches against the context. They show how the inference resolves a wide range of "local pragmatic" effects. Their examples included reference resolution, bridging, and noun-noun compounds – all featured in (12) – as well as metonymy and coercion of predicates.

A major challenge to this approach is the need to model the dynamic local contexts which we must use to reason about nested contextually dependent elements. To make the problem concrete, consider a variant of (12).

(14) Put the dough hook on each of your mixers.

The correct interpretation here resolves *the dough hook* to a functional expression $h_1(x)$ interpreted within the scope of *each of your mixers* and represented in terms of the corresponding bound variable x. To start, it is hard to get nested interpretive constraints right in the first place: the relevant components of meaning sometimes seem to take scope in complex ways (Kamp and Rossdeutscher, 1994) and sometimes seem relatively orthogonal to the rest of sentence meaning (Potts, 2005). Given nested interpretive constraints, Bos's (2003) influential implementation of the anaphoric presupposition theory of van der Sandt (1992) formalizes nested scope correctly in linguistic terms but offers limited facilities for bridging and other inferential relationships in nested dependencies. A more sophisticated technique is due to Krahmer and Piwek (Krahmer and Piwek, 1999; Piwek and Krahmer, 2000). They model local contexts using hypothetical reasoning in constructive logic. A constructive proof of $A \supset B$ is a proof of B that uses A as an extra assumption; constructive proofs also guarantee, in ways classical proofs do not, that existential claims are backed up by specific instances that satisfy them. The two properties make it possible to characterize the information available for bridging reference in a nested scope and to extract a suitable representation of a dependent discourse referent like $h_1(x)$ from a demonstration that the interpretive constraints that apply in the nested scope are satisfied. Because of the close affinities of constructive and modal logic, similar techniques carry over to inference mechanisms that use modal logic to characterize the changing information of interlocutors in conversation (Stone, 2000).

Another challenge to the approach is the problem of ranking interpretations. The formal mechanisms proposed by work such as Hobbs et al. (1993) lack a comprehensive treatment of the dynamics of attention, and more flexible formalisms, as explored, for example, by Stone and Thomason (2002) or Asher and Lascarides (2003b), are not robust enough to apply broadly to interpretation. In fact, most work on preferences in interpretation has focused on special cases of resolving pronoun references and abstracted away from the interactions that are generally possible in constraint-satisfaction models by processing single references at a time. An effective heuristic is to assign referents dynamic prominence based on their syntactic realization. The idea goes back to Hobbs (1978); Strube (1998) offers a recent empirical assessment and defense of simple strategies against more complex models. However, it is clear that the prominence of a referent is a function not only of its recent syntactic realization but also of the discourse relation that connects the current sentence to the ongoing conversation (Grosz et al., 1995; Kehler, 2001; Asher and Lascarides, 2003b). For example, the preference for continued reference to the subject across a whole subsequent utterance is a feature of extended descriptions and narratives; it does not apply when an utterance presents a parallel or a contrast to previous discourse (Kehler, 2001). Meanwhile, when cause–effect relations are at issue, whatever preferences are in play are easily overridden by commonsense background knowledge. In practice, of course, the added discourse and world knowledge that is necessary to model and test interpretive preferences at a large scale is generally unavailable – though semantic generalizations discovered from corpora, of the sort discussed in Section 25.4, may soon change this. Instead, computational work uses machine learning methods to find shallow cues and patterns that provide good guides to reference (see Ng, 2010).

25.6 Conclusions

My aim in this chapter has been to offer an overview and introduction to computational semantics that lets linguists see the overlap between engineering questions and scientific questions. I have specifically aimed to highlight the potential of computational tools and resources to support scientific investigations. In offering this survey, I hope to have suggested how closely interwoven computational techniques already are with the perspectives and results of formal semantics. I cannot imagine serious theory building in semantics that does not engage with computational infrastructure for exploring broad annotated corpora, formal grammars, lexical databases, and contextual inference. These tools can be strikingly easy to use. Where they seem obscure, it may be because they reflect insights not yet fully assimilated into the perspectives of linguistic semantics.

This is not to say that formal semantics and computational semantics are the same thing. There is a big disjuncture between engineering projects – the challenges of disambiguation, or the needs of applications – and questions linguists are interested in. Linguistic science inevitably focuses attention on telling analyses of rare events that highlight empirical distinctions among comparatively esoteric proposals. In most cases, however, computational semanticists still struggle to discover simple and robust techniques that get the frequent cases right. The gap can be extreme.[15] The divergent goals of linguistics and computer science do limit the possibilities for collaboration. However, this is no obstacle for linguists to take up computational techniques on linguistic terms and adapt those techniques to ask and answer questions of linguistic interest.

That said, many of the divergences we see when we consider superficial analyses of well-studied languages like English disappear in the broader purview of meaning. For example, both formal semantics and computational semantics make headway by regimenting and formalizing speakers' intuitions. They are the raw data for semantic theorizing, but they are also the raw data for machine learning and evaluation experiments. Thus, linguists and computer scientists can find common cause in working to annotate deeper aspects of utterance structure and interpretation. This remains profoundly challenging for both fields. Likewise, both formal semantics and computational semantics bring increasing concern for underdocumented languages. These languages can be the most useful testbed for new methodologies and applications, but they also turn out in many cases to instantiate theoretically significant typological properties. Here computer scientists and linguists find common cause in exploiting and deepening our understanding of linguistic diversity while empowering speakers and making information more broadly accessible. Let us close, then, with the optimistic prospect that formal semantics and computational semantics continue to join together in the exploration of such synergies.

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[15] The IBM speech group in the 1970s was famous for an aphorism from its director (possibly apocryphal): Every time I fire a linguist, my performance goes up.

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