Contents

Preface

The purpose of this volume is to bring together a variety of work that has originated from Amsterdam, and a few places where work akin in spirit has been done (Berlin, Paris, Stanford). The reason is twofold. On the one hand the various authors have a very similar style (formal), spirit (making specific subjects fully explicit), and share an interest in closely related themes (which we dub 'questions and related topics'). On the other hand, all of this work has been distributed fragmentarily in the literature and over conferences and conference proceedings. As a consequence, researchers in the field often get to see only a glimpse of what we deem to be a rather coherent body of work, even though it also displays its own natural inconsistencies. With this volume we want to offer the reader the opportunity to get a better idea of the wealth and broad scope of what we immodestly call the Amsterdam style.

Deliberately we have chosen not to write a textbook or monograph. With this large number of authors and interrelated topics that would be by and large unfeasible. Moreover, the theme and style do not naturally lend themselves for a full course in classroom. Having the separate contributions as is, however, (and not a fully condensed canonical work), this offers a much better opportunity to see the Amsterdam style 'at work', and with this volume colleagues interested in specific subjects can easily access the relevant papers in a proper context now.

We did, of course, coordinate a few things. Very first versions of the contributions have been presented on a two-day workshop in Amsterdam (February 2004) where already first comments where exchanged. We have also asked the authors to look at related papers and refer to them, and fine tune their own contribution to the others wherever relevant. Finally we have written an extensive introduction which is meant to first give an overview of the field, to give an overview of the contributions to this volume and to put them in the context of the wider area of the formal semantics and pragmatics of questions.

One of the starting points is the 1984 dissertation of Groenendijk and Stokhof which we first place among alternative approaches to the (formal) semantics and pragmatics of questions. This work was seminal and has been continued by many researchers (in- and outside of Amsterdam) over the years. A next milestone is Groenendijk's 1999 "Logic of Interrogation", which has given a new swing to the semantic and pragmatic study of questions in a so-called 'update'-style framework. Many contributions to this volume ex- or implicitly build on this paper and it is therefore included as the opening paper. This also motivates the title of the present volume. Jeroen Groenendijk has used it as a title of a talk delivered at Mundial (München, 1997) which predates his logic of interrogation. Although it is referred to at a couple of places, the written paper does not officially exist, so we thought it appropriate to kidnap this very title.

As intended readers we aim at (advanced) students (graduate and PhD), fellow researchers in linguistics, more in particular those with an interest in semantics and pragmatics and especially in the semantics/pragmatics interface. Potential readers include the visitors of, e.g., the Amsterdam Colloquia, SALT and Sinn und Bedeutung. Prerequisites for reading this volume are a working knowledge of first order predicate logic and set-theory, and affinity with issues on the semantics/pragmatics interface.

Acknowledgements. The NWO Vernieuwingsimpuls project "Formal Language Games" has funded the research for parts of this volume, the work of the editors, and the workshop in February 2004; this is gratefully acknowledged. We also thank the CRiSPI editors, in particular Ken Turner and Kasia Jaszczolt, for their support, encouragement and inspiring comments; furthermore we would like to thank Nicholas Asher, Jonathan Ginzburg, Craige Roberts, Martin Stokhof, and Ede Zimmermann, in particular, and all those listed in the bibliography.

1

The Semantics and Pragmatics of Questions

Paul Dekker, Maria Aloni and Alastair Butler

With this introduction we aim to give a sketch of the research area in which questions are studied from the perspective of a semanticist, a formal linguist interested in the notion of 'meaning'. We start with explaining some general notions and insights in this area, and then zoom in on one of the most influential theories about questions, the partition theory of Groenendijk and Stokhof (section 1.1). In section 1.2 we concisely discuss some alternatives to the partition semantics, and some current issues in the debate about the meanings of questions, which will also pop up every now and then in the contributions to this volume. Then, in section 1.3, we have a thematic discussion of the contributions to this volume themselves, considering them one by one and in relation to each other. We end (section 1.4) with a sketch of some issues which, we think, still abide or have arisen from this volume as a whole.

1.1 General Background

1.1.1 The Notion of a Question

This volume is concerned with the formal study of questions and related topics. Questions are studied from various perspectives. From the viewpoint of a syntactician, questions are linguistic entities, sentences of a certain kind with distinctive features. They can display changes in word order, as witnessed by "Is Peter a good mathematician?" ver-

Questions in Dynamic Semantics.
Maria Aloni, Alastair Butler and Paul Dekker (eds.).
Current Research in the Semantics/Pragmatics Interface, Vol. 17.

sus "Peter is a good mathematician."; *Wh*-expressions, like "Who", "What", "Where", "How", etc., but also "Which students", "Which Canadians" and the like; and in spoken language, a question normally, but not invariable, comes with rising intonation, and in written language with a question mark. The syntactic and cross-linguistic analysis of such 'interrogative' expressions is a matter of ongoing debate.

For a semanticist, questions are the objects which are denoted by the above described type of syntactic expressions. Here the situation is similar to the (formal) study of indicative sentences. In such a study the aim is to find a domain of denotations (propositions mostly), in the form of suitable algebras which generate logical constructions (like that of conjunction, disjunction, negation) and logical relations (like entailment, synonymy and (in-)consistency). Likewise, the study of interrogatives requires one to develop a denotational domain in terms of algebras which motivate suitable constructions like the conjunction and disjunction of questions, and logical relations like that of question entailment and answerhood. Here, too, various approaches are possible and the respective benefits and deficits of these approaches is subject to ongoing discussion.

From a pragmatic perspective, questions are basically acts in a discourse or dialogue. According to, for instance, speech act theorists, simple questions come with some propositional content (their semantics), and the question act is that of asking whether the proposition is true. As will appear from this volume, however, we can also think of questions as a type of act, without disqualifying the idea that there are questions in the semantic domain. The main question then is how the two relate, a typical question about the semantics/pragmatics interface, which is one of the main threads throughout this volume.[1]

From an epistemological, or if you want philosophical, perspective, questions are the things which agents can be concerned with, the questions which a person may have, also if these questions are never explicitly expressed. Judy may wonder whether or not she will be in Paris next year, and this without explicitly asking anybody. One may

[1] An approach which also can be called 'pragmatic' or, rather, 'practical', is the one adopted in the areas of Artificial Intelligence where one studies question answering systems. Here questions are really queries, and the aim is to find, define and study efficient procedures for making proper queries, and especially for answering them in an automated way. Although, clearly, the aims turn out be very similar, the type of work reported on in this volume is purely theoretical. It seeks underlying principles of language, its meaning and use, and is not (directly) concerned with computation and efficiency. We will therefore not go into further detail about this type of computational research. See Monz (2003a) for a recent overview of relevant work.

also wonder "Who am I?", "Does God exist?", "What is the meaning of life?", or "How will the stockmarket develop?", again without posing the questions, or putting them into words. This immediately raises the question whether the objects of wonder and doubt are the same as the objects which constitute the semantic denotations of interrogatives. Do they draw from the same domain?[2] Maybe there are questions which one can face, but cannot put into words.[3] We prefer not to settle this matter, though, but take a pragmatic (Wittgensteinian) stance on this issue, and we will henceforth talk only about questions which can be denoted by utterances, also if we talk about the objects of wonder and doubt (see Wittgenstein, 1953).

More generally, we can ask whether the four sketched perspectives on questions are concerned with different subjects, or whether they study different aspects of 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 raised in a discourse, and then a suitable pragmatic question is, under what circumstances is this appropriate, what are the effects of this, and what would be, under given circumstances, a (relatively) good reply. Also, it seems to be a reasonably fair assumption that questions raised in a discourse are the questions people themselves face, or wonder about. And there seems to be a case for assuming, as well, that the objects of wonder and doubt are the same as or at least very similar to the denotations of interrogative sentences. In sum, we witness at least close correspondences between the various notions of and perspectives on questions.

However, and this will become clear from various contributions to this volume, the correspondences are not always that close. It seems a 'contemplative' use of the indicative sentence "Peter is a good mathematician." can be used to raise a question, while a 'rhetorical' use of "Is Peter a good mathematician?" typically serves to make a statement. If this is right, then we may have to re-evaluate the semantic denotations of these expressions, thereby giving up very close correspondences between either the syntactic notion of a question and a semantic one or

[2]Indicative sentences raise a similar issue: are the objects of knowledge and belief the same as the denotations of indicative sentences, e.g., propositions?

[3]It seems to be very hard to argue for this position, though. It would require one to come up with a question one can face but not express, but in order to come up with such a question it seems the question has to be stated, thereby rendering the argument vacuous.

between a semantic and a pragmatic one. It can also happen that questions asked are not really the ones people actually face, even though it can be explained that the reply to the question asked may help in answering the question faced. I can ask "Is Judy in Paris now?", not because I am interested in her whereabouts, but because I am interested in those of John, who will always follow her. (And the reason may be that I don't want my interlocutor to know that I am interested in John.) The reason can also be that I want to upset my interlocutor pointing his nose on the fact that Judy could be there, while he could impossibly go. Finally, it is still not excluded that the questions people face are different from the semantic denotations of interrogative expressions.

The upshot of this discussion is not to take a stand on the issue whether there is one unifying or underlying concept of a question. We mainly want to point out that something which gets described under one label (that of a question), may turn out to be different things after all. A more important moral is that, when the term "question" is used, it can be quite important to realize from which perspective it is used: does it concern something syntactic (for which we prefer to use the term "interrogative" in what follows), or some associated abstract semantic object, or some linguistic act, or an object of an epistemic attitude? A phrase like "Albert's question" can refer to either of these, and to properly assess what is said about Albert's question one should make the proper choice.

This volume contains contributions on questions (and related topics) from all four perspectives, although most adopt a semantic or a pragmatic perspective, or the perspective of the semantics/pragmatics interface. The notion of a question we reserve for 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.

In the remainder of this section we will proceed as follows. We start with discussing some of the classical insights in the formal study of questions and answers (subsection 1.2), and then zoom in on the partition semantics from Groenendijk and Stokhof (subsection 1.3). Next, in section 1.4, we show how the partition theory can be extended with a pragmatic component, and indeed can be motivated by it.

1.1.2 The Semantics of Questions

What is the meaning of an interrogative sentence? Maybe it is worthwhile to reconsider 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. As we will see later there is more to be said about the meaning of indicatives, but if we focus on this (crucial) 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 (Tractatus Logico-Philosophicus, Satz 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 invoked the slogan "Meaning equals truth conditions", and this slogan in turn has prompted the semanticist (who aims to describe and study the meanings of sentences) to specify for every sentence of a given language under what circumstances it is or would be true.

For instance, if Muriel says, in English, "It rains." to you, she has expressed the proposition that it rains, which is the proposition true in all and only the circumstances where it rains. By asserting it she claims that the actual world or situation is like one of those, so that if she is sincere and well-informed, and you are in the same situation, you may well conclude that it rains and take your umbrella when you go out. Of course Muriel may be wrong, she may be joking, but what counts in *understanding* the meaning of an indicative sentence equals understanding under which conditions it is true. These truth conditions thus can be taken to give the meaning of an indicative sentence.

A similar story can be told about interrogative sentences, be it not in terms of truth, but in terms of answerhood. Like we said, interrogative sentences are normally used to pose questions, and the purpose of posing a question normally is to get a true answer for it. So what is a true answer? Apparently this seems to be a proposition which (i) is true of the actual situation and which (ii) answers the question. Let us first focus on the second aspect. Clearly, "John came to the party yesterday.", even if true, cannot count as an answer to the question "Did Monica ever visit Prague?" (even though sometimes it can, in pragmatically deranged situations). Proper answers are like "Yes, Monica did." and "No, Monica never did.". Apparently, the question dictates what propositions count as an answer. 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 always are many more possible answers. Consider the question: "Who wants to join us on a trip to the beach.". Again, "John came to the party yesterday." does not count as a proper answer, but "Marc, Michelle and Maria want to join." does count as an answer, as does "Nobody wants to.". As a matter of fact, if you take the sentence frame "...want to join." and if you fill in the dots with any list of names, you get a sentence expressing a proposition which is a possible answer. The meaning of a question can therefore be equated with a set of propositions: those that constitute an answer to the question as opposed to those that do not. And now we can come back to point (i) above. What a question solicits is not just any possible answer to the question, but *a* or *the* true answer to the question.

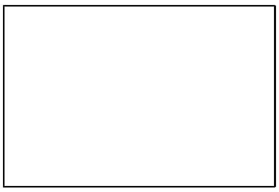
This time the conclusion ought to be that one knows the meaning of an interrogative sentence if one knows, given the circumstances, what counts as a true answer to that question. Since, however, this ought to be perfectly general, that is, since one should be supposed to know what would be a true answer in all possible circumstances, this means that the meaning of a question really resides in its answerhood *conditions*. Actually, this also expresses an age-old insight from Hamblin and Karttunen, and it has been taken up in one of the major semantic theories, like the partition semantics of Groenendijk and Stokhof discussed in the next subsection.

As an excursion, we want to point out that a similar strategy can be followed in the case of imperative sentences. The meanings of these sentences can be stated in terms of, not truth or answerhood conditions, but in terms of compliance conditions. One knows the meaning of an imperative, if one knows what has to be brought about in order to comply with the issued order. And like we can know the meaning (i.e. truth conditions) of an indicative sentence without knowing whether it is actually true or not, and like we can know the meaning (i.e. answerhood conditions) of an interrogative sentence without knowing what is actually the true answer, similarly we can know the meaning of an imperative (i.e. its compliance conditions) without knowing whether they will actually be satisfied. End of excursion.

So far the discussion has been fully general, apart from some illustrative examples drawn from natural language. A formal semanticist however wants more: proposals about the meanings of certain types of expressions should be such that one can in principle *prove* (or if you want *disprove*) that certain desirable semantic consequences follow, and certain undesirable consequences don't. For this, taking a natural language, like English, as the direct object of study is undesirable because its syntactic analyses may be unclear, and it is full of ambiguities. A very general practice in formal semantics therefore consists in defining a formal language which mimics certain phenomena from natural language in an unambiguous way, make semantic proposals for this kind of language, and study the consequences of these proposals. This is not to say that such studies are no longer about natural language—ideally they are, be it indirectly. The way in which one can put the situation is that the expressions from the formal language represent the contents or meanings of expressions from natural language, be it in an unambiguous and perspicuous way. Besides, this allows one to study certain interesting aspects of meaning by themselves, without being bothered by other (interesting) aspects of meaning, which could only complicate things if studied in tandem. For instance, as one can see in this volume and in much of the literature, tense and temporal phenomena are totally abstracted away from and the focus of many papers is on a small language of predicate logic, extended with a question operator. Not because tense is irrelevant, but because the interpretation of questions (and their answers) is the prime subject of investigation here.[4]

1.1.3 The Partition Theory

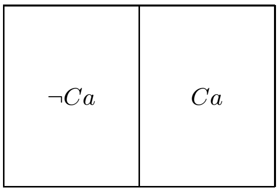
In the Groenendijk and Stokhof semantics for interrogatives (see, e.g., Groenendijk and Stokhof, 1984, 1997), questions "partition logical space". What this means can be best illustrated by means of some pictures. Logical space is a set of logical possibilities (possible worlds, possible situations or possible circumstances). We will keep on using the term 'possibilities' or 'worlds' from now on, without being committed to a particular interpretation of these terms. Logical space can be represented as follows:



[4] As, similarly, questions hardly play a role in any known semantics of the temporal system. Notice, though, that the interplay itself between questions and tense can be very interesting, but we do not know of any literature on this.

where all the points in the rectangle should be taken to constitute the possibilities. The sentences of some formal language can be evaluated on such a logical space by means of some given valuation function which tells us, for each possibility, whether the sentence is true there, or false, like in a standard (modal) predicate logical fashion. An indicative sentence like "Andrea is in Copenhague." (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 Andrea is in Copenhague.

Now consider the question "Is Andrea in Copenhague?" (formally $?Ca$). This polar question has as possible answers a positive and a negative one. 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 groups (propositional answers) have to be distinguished. This can be displayed as follows:

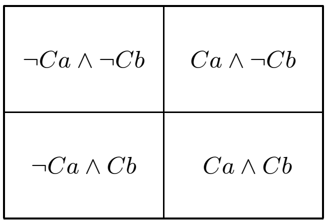


$?Ca$

This picture indicates an interest in knowing on which side of the vertical line the actual world resides: are we in a Ca-world, one in which Andrea is in Copenhague, on the right side of the line, or in a $\neg Ca$-world, where she is not there, on the left of the line. The differences between worlds on the same side of the line are immaterial to this question.

We can add the question whether Bernhard is in Copenhague, (formally: $?Cb$). This leads to a further subdivision, this time indicated by means of a horizontal line:

$?Cb$



$?Ca$

If we now, for the purpose of exposition, make the simplifying assumption that Andrea and Bernhard are the only relevant individuals, then the last picture is the same as the next one representing the question "Who are in Copenhague?" (formally: $?x\ Cx$):

$?x\ Cx$	$\neg\exists x Cx$	$Ca \wedge \neg Cb$
	$\neg Ca \wedge Cb$	$\forall x Cx$

The basic idea about exhaustiveness, and of the partition semantics, is that *Wh*-questions do not ask for some possible instantiation of the *Wh*-term, but they want a full specification of it. That is to say, as an answer to the question "Who are in Copenhague?" it is not sufficient to say that Andrea is, because that only tells us that the actual world is on the right of the vertical line, it does not tell us its location relative to the horizontal line, it does not tell us whether Bernhard is there or not. In that sense the mere proposition that Andrea is in Copenhague is only a partial answer to the *Wh*-question.

The pictures with their dividing lines (and in general many more lines can be added) indicate what, semantically speaking, questions are according to the partition semantics. The blocks in the partitions constitute sets of propositions (the possible answers), where propositions are taken to be sets of possibilities (those where the respective propositions are true). Moreover, they cut up logical space in non-overlapping parts, which together cover the whole space. In set-theoretical terms this means that a question $\mathcal{Q}$ is a set of sets of possibilities such that

1. $\bigcup \mathcal{Q} = \mathcal{L}$ (where $\mathcal{L}$ is logical space)
2. $\forall A, B \in \mathcal{Q}$: if $A \neq B$ then $(A \cap B) = \emptyset$

The first clause really says that the question has an answer in all possibilities: every possibility figures in some proposition, and the proposition in which it figures constitutes the full true answer to the question in that possibility. The second clause says that there is only one full and true answer in each possibility: if, with regard to the question, there may be a difference with another possibility, then that other possibility lives in another block, it is associated with a different answer. This is as we saw above. Even though Andrea is in Copenhague in two possibilities i and j, so that "Andrea is in Copenhague" is true in both i and j, if Bernhard is in Copenhague in i and not in j, then i and j

are in different blocks in the partition induced by the question “Who are in Copenhague?”. So while “Andrea is there and nobody else.”, “Bernhard is there but nobody else.” and “Andrea and Bernhard are there.” express three mutually exclusive propositions (three of the four possible answers to our question “Who is there?”), the answers “Andrea is there.” and “Bernhard is there.” are not mutually exclusive, and therefore not full answers to the question.

An exhaustive notion of a possible answer, as it can be modeled by partitions, turns out to be logically, empirically, and also pragmatically very well behaved. The last two benefits will be discussed in more detail in subsequent subsections. We want to end this subsection with a concise discussion of its logical benefits.

It is generally known that partitions are defined by equivalence relations. An equivalence relation on some set is reflexive, transitive and symmetric. It is easily seen that if a relation relates all elements which belong to the same block in a partition, and no element with any element residing in another block, then that relation is reflexive, transitive and symmetric, i.e., we have an equivalence relation. Conversely, if we have an equivalence relation over some set or space, then it induces a partition which puts related elements in one block, and no other ones. Since the relation is reflexive, transitive, and symmetric, all elements (possibilities) figure in at least one block, and no possibility figures in more than one, hence it is a partition.[5]

The formulation of a question in terms of an equivalence relation can be understood as follows: the question is insensitive to the difference between any two related possibilities, because for the ‘purpose’ of the question they are ‘equivalent’, in a rather literal sense. The question is, however, sensitive to the difference between two (or more) sets of mutually unrelated possibilities, because that is what the question boils down to: in which of the two (or more) sets does the actual world reside?

When questions are formulated as equivalence relations, we get a neat notion of question conjunction and question entailment in return. Conjunction is intersection and entailment comes down to the subset-relation in all possible models. Very standard Boolean relations thus apply to the logic of interrogatives as well. Let us expand a little bit on this before we proceed to the next subsection.

We sketched above that if we started with the question whether Andrea is in Copenhague (which induced a bi-partition, a division in

[5]Formally, if $\mathcal{Q}$ is a question, then the induced equivalence $R_{\mathcal{Q}} = \{\langle i, j\rangle \mid \exists A \in \mathcal{Q}\colon i \in A \;\&\; j \in A\}$; furthermore, if R is an equivalence relation, then the corresponding partition $\mathcal{Q}_R = \{\{j \mid \langle i, j\rangle \in R\} \mid i \in \mathcal{L}\} \setminus \emptyset$. Exercise: prove that $R_{\mathcal{Q}}$ is an equivalence relation, that $\mathcal{Q}_R$ is a partition, and that $\mathcal{Q}_{R_{\mathcal{Q}}} = \mathcal{Q}$.

two blocks), we could add the question whether Bernhard is there (another bi-partition). Multiplication of the two questions led to a four-way division as we have seen, and in general if we multiply any two independent questions, we get the product number of possible answers as a result. This is exactly what intersection of the corresponding equivalence relations gives us. (It is a very good exercise for the reader unfamiliar with this material to make this formally explicit and then prove this claim to be true.)

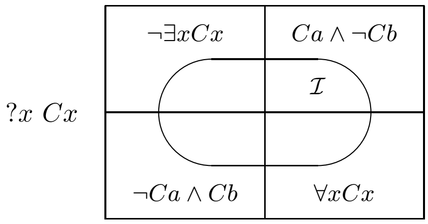
As for entailment, if we have two questions $\mathcal{Q}$ and $\mathcal{R}$, and if we look at the corresponding equivalence relations $R_{\mathcal{Q}}$ and $R_{\mathcal{R}}$, then $\mathcal{Q}$ entails $\mathcal{R}$ iff $R_{\mathcal{Q}} \subseteq R_{\mathcal{R}}$. In terms of partitions this boils down to the requirement that every block in $\mathcal{Q}$ is a subset of a block in $\mathcal{R}$, so every possible full answer to $\mathcal{Q}$ entails a possible full answer to $\mathcal{R}$. In terms of the examples we discussed, $?Ca \wedge ?Cb$ entails $?Ca$, because any full answer to the first entails a full answer to the second, and, likewise, $?x\ Cx$ entails $?Cz$, for any z, since if we have a full specification of the persons who are in Copenhague, we automatically know whether z is there, for any arbitrary z. In Groenendijk (1999) the very same entailment relation (specified in terms of the subset-relation) automatically generalizes to a few other cases, but before we can come to that, we have to address a couple of other issues in the theory of questions and answers.

1.1.4 The Pragmatics of Questions

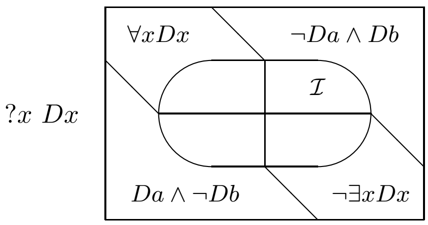
The partition semantics can be extended naturally when it comes to the use of questions, thereby making the whole framework much more sophisticated and of wider application. Besides, the pragmatics of questions can also be taken to motivate the partition semantics. In this subsection we will discuss some issues pertaining to the pragmatics of questions in discourse, as well as some subtle and instructive snags.

It is generally acknowledged that utterances (assertions, questions, etc.) are never or hardly ever evaluated against an empty 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 $\mathcal{I}$) which represents the current state of information:



The oval $\mathcal{I}$ 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. (It may be important to realize that, maybe, they have been dismissed mistakenly, we will come back to this below.) 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 possible alternative question ?x Dx:

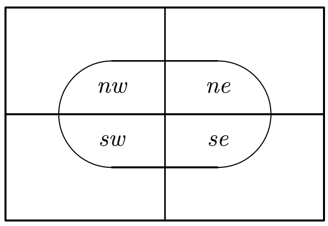


Notice first, that the two questions are logically independent. For instance, the answer $\neg\exists xCx$ to the first question does not entail (is not included in) any answer to the second question, and the answer $Da \wedge \neg Db$ to the second does not entail (is not included in) any answer to the first. So, semantically, there is no entailment relation between the two questions. However, inside the oval the two questions coincide, so pragmatically speaking, against the background $\mathcal{I}$, the questions are equivalent. It is important to note, though, that $\mathcal{I}$ after all might not include the actual world, and then the difference between the two questions becomes important. For the actual world might be one in which both $\neg\exists xCx$ and $Da \wedge \neg Db$; in that case the two propositions are (true) answers to the respective questions, but a person who believes to be in

$\mathcal{I}$ would feel licensed to draw two totally different conclusions.

With semantic and pragmatic notions of answerhood at hand, Groenendijk and Stokhof (1984) developed various notions of what is a better answer to a question relative to some background information $\mathcal{I}$. We will not discuss these here but refer the reader to the original dissertation and papers.

Let us now start from the pragmatic perspective and see how it can be seen to motivate a partition-style semantics. Robert van Rooij has shown that basic concepts from decision theory, in particular the concept of a decision problem, closely relate to such partitions (see, e.g. van Rooij, 2003). An agent who wants to eat in a Thai restaurant may face a decision problem, namely where 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 about in which direction it 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 picture:



A full and hopefully true answer to her question would directly help to solve her decision problem: if the restaurant is to be found direction northeast, then that's 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*.[6] van Rooij (2003) has not only spotted this

[6]Nothing here excludes, of course, the posing of questions just for purposes like 'simply wanting to know', 'curiosity', or for 'keeping the conversation going', and

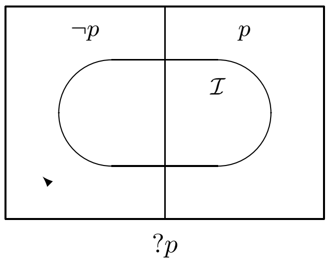
kind of formal correspondence between notions of decision theory and the partition semantics, but he has also worked out decision theoretic notions for comparing the relevance of questions and that of answers.[7]

In the previous paragraph we deliberately emphasized the clause *given the background information*, because this brings up two subtle points with which we want to end this section.

Let us go back to a simplified situation in which two interlocutors are facing two sets of apples: red ones and green ones. One of them wants to buy one group but doesn't know which, so she asks:

(1) Do the red ones taste better?
(Which apples taste better, the red ones or the green ones?)

The situation can be displayed as follows:



Where p is short for "The red ones taste better.". Again, the question cuts up logical space in two parts, and also the information set $\mathcal{I}$. If the actual world happens to be a $\neg p$ world then one might choose to buy the green apples, the red apples otherwise. However, our agent has mistaken information, since the actual world, indicated by the little arrow, lies outside her information set, her information excludes the (possibility corresponding to the) actual world, which means that she has got some mistaken beliefs. One mistaken belief may be that the apples are real, whereas, actually, they are fake. Now the interlocutor may realize this, and come up with the full and true semantic answer $\neg p$, corresponding to the statement that the green (fake) apples taste better than the red (fake) ones. (For, the actual world here resides in the $\neg p$ block.) However, realizing our questioner's mistake, and realizing for what purpose she might want to buy the apples, he'd better explain the mistake and reply that all the apples are fake.

the like. Probably the same semantic analysis, but probably a different pragmatic one can be applied to cover these cases.

[7] Actually, van Rooij treats plain questions and embedded questions alike in a so-called underspecified way, which allows various exhaustive, partial and scalar readings depending on the contextually given relevance ordering.

What this example teaches us is that we have to carefully distinguish the semantic and the pragmatic question posed, and that it makes sense, if we look at the pragmatics of questions, to consider the reason or relevance of asking a question, taking into account possibly mistaken information in the information set of the questioner. It moreover shows once more, that pragmatically speaking, questions are in a sense conditional on the assumption that the background information is correct. So here we witness another example where the question faced and the question posed, unbeknownst to the questioner, depart.

That questions can be conditional on background information can also be made explicit, and this can also be motivated from a choice- or decision-making perspective. Suppose I am in doubt whether or not to go to the party tonight. The presence of a certain constellation of guests might make it attractive for me, whereas other constellations might put me off. So, in order to make a good decision I may ask "Who comes to the party tonight?". But now the answerer may face a problem, because a full answer would have to include me or not, and since I have not yet decided, he cannot know. Besides, the decision of others to come to the party may as well depend on their expectation of me being there. So an appropriate answer could be: "Well, if you decide to go, then so-and-so will be there." A most probably inappropriate answer would be "Well, if you don't go, then so-and-so will be there."

My question thus is understood in a conditional way, and I might as well have asked directly: "If I go the party, then who will be there as well?" This question asks for a specification of those present and absent in the case where I go, and asks nothing about the cases in which I don't go. It turns out that the interpretation of such conditional questions can be elegantly modeled, but at the cost of giving up true partitions in favour of so-called 'pseudo-partitions': zooming in on the set of possibilities in which I go, we find a true partition, but none of these is distinguished from any of the possibilities in which I don't go.[8]

1.2 Current Issues

There are a couple of issues which plague the literature on the semantics of questions, and in this section we take a brief look at four of them.

[8]Velissaratou (2000) has elaborated such an analysis for conditional questions. Questions like "If Felix goes to Paris, then who will do the household?" partition the set of possibilities with Felix in Paris, but don't distinguish them from those in which Felix is not, since the very conditional antecedent makes these possibilities irrelevant. We refer to Velissaratou (2000) and Dekker (2004) for a more detailed investigation.

Three of them—the topics of exhaustification, structured meanings and dynamic interpretation—play a notable role in the contributions to this volume, and while the fourth on "knowing who" does not, it is certainly worth addressing here, because it will definitely play a role in future extensions of the proposals made in this volume.

1.2.1 Exhaustification

The first issue concerns the idea that the meanings of questions are exhaustive. Before we can make this precise, it is expedient to make the question language precise. Like we said, the language is that of predicate logic, extended with a question operator. The formulas of predicate logic will also be referred to as indicatives, and if ϕ is an indicative, and $\vec{x}$ a (possibly empty) sequence of variables $x_1, \ldots x_n$, then $?\vec{x}\ \phi$ is an interrogative.

The question operator $?\vec{x}$ queries the possible values of the variables $\vec{x}$ under which the embedded formula ϕ is true. In case $\vec{x}$ is empty, $?\vec{x}\phi$ is a polar question, (a *yes/no* question). If $\vec{x}$ consists of one variable x only, as in $?xCx$ ("Who comes?"), it asks for the extension of C; if $\vec{x} = xy$ consists of two variables, as in $?xy(Bx \wedge (Gy \wedge Sxy))$ ("Which boys saw which girls?"), it asks for the set of pairs consisting of a boy and a girl the boy saw.

Groenendijk and Stokhof's semantics of questions, which is quite similar to that of Higginbotham and May (1981), Higginbotham (1996), can be specified as follows, relative to a model 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 in each possibility. For the interpretation of free variables we use the usual assignments g of values from D to variables as a parameter. By $g'[\vec{x}]g$ we mean that assignment g' which is like g except (possibly) for the values it assigns to the variables $\vec{x}$:

- $[\![?\vec{x}\ \phi]\!]_{M,g} = \{\{w' \mid \forall g'[\vec{x}]g\colon [\![\phi]\!]_{M,w',g'} = [\![\phi]\!]_{M,w,g'}\} \mid w \in W\}$

Relative to some world w, a question denotes the full and true answer to the question. It is a proposition true in exactly those possibilities where exactly the same valuations of the variables $\vec{x}$ render ϕ true, respectively false. If $\vec{x}$ is the empty sequence, then relative to some world w this boils down to the set of possibilities $\{w' \mid [\![\phi]\!]_{M,w',g} = [\![\phi]\!]_{M,w,g}\}$, which is the set of worlds w' where ϕ has the same truth values 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. If $\vec{x}$ is non-empty, things get more interesting. Consider $?x\ Cx$ ("Who comes?") relative to w. Some calculations show that this denotes the proposition true in exactly those worlds w' where the denotation of C is the same as in w. If $n_1, \ldots, n_j$ is an enumeration of all and only the people who come in w, then the full and true answer is the proposition that $n_1, \ldots, n_j$ come and nobody else. Here we see what is exhaustive about this semantics: it requires a full specification of the possible values of the queried variables, and a closure statement stating that this is indeed the full set of possible values. In general we see that indeed the meaning of a question is a set of propositions. Each world is associated with one full possible answer, and as it so happens it partitions logical space: in each world there is only one full and true answer, and worlds in which this answer is the same are grouped together and they are distinguished from worlds where the answer is different.

Earlier treatments of questions by Hamblin (1973) and Karttunen (1977) are also based on the idea that the meaning of an interrogative resides in its answerhood conditions. They differ, however, in the way they spell this out, namely in a non-exhaustive way. For completeness, let us consider Hamblin's semantics for interrogatives, slightly adapted to the present format (by $g[\vec{x}/\vec{e}]$ we mean the assignment which is like g except that it assigns $\vec{e}$ to $\vec{x}$:

- $[\![?\vec{x}\ \phi]\!]_{M,g} = \{\{w' \mid [\![\phi]\!]_{M,w',g[\vec{x}/\vec{e}]} = 1\} \mid \vec{e} \in D^*\}$

In this definition $\vec{e}$ is assumed to be any sequence of individuals with the same length as that of the sequence $\vec{x}$ of variables queried. Again the meaning of an interrogative is specified as a set of propositions (possible answers), but its relation to the question is quite different from that of Groenendijk and Stokhof (and Higginbotham). The main difference is that the possible answers are not (meant to be) exhaustive.

Consider $?x\ Cx$ ("Who comes?"). Some calculations show that the possible answers according to the last definition are the propositions that d comes, for any individual in the domain, i.e., the proposition that Marc comes, the proposition that Muriel comes, etc., this for any entity in the domain. Or consider $?xy(Bx \wedge (Gy \wedge Sxy))$ ("Which boys saw which girls?"). This time the answering propositions are taken to be that Marc saw Muriel, that Menno saw Mathilde, etc., for any pair $\langle d, d' \rangle$ where d is a boy and d' a girl. In case $\vec{x}$ is the empty sequence as in $?p$ ("Does it rain?") there is only one possible answer: p ("That it rains.").

The latter definition can be modified somewhat, in that, relative to some possibility, we only select the possible answers true in that possibility, and we can take the conjunction of all true answers in a possibility, thereby generating something like an exhaustive specification. The underlying ideas are different, though.

One advantage of the exhaustive approach to question meanings is that it automatically comes with a straightforward logic of interrogatives and that it also neatly fits in with pragmatic and decision-theoretic approaches to natural language (as seen in the previous section). It is not so obvious whether the same points can be made in favour of the non-exhaustive approaches.

Besides, as Groenendijk and Stokhof rightly argue, their (exhaustive) semantics of unembedded interrogatives directly applies to embedded interrogatives. Consider:

(2) Marc knows who come.

(3) Muriel wonders who come.

Example (2) can be taken to express that there is a true answer to the question "Who comes?" and even though the speaker may fail to know the answer, she expresses that Marc knows it. Intuitively, this is not just a singular proposition of the form "Menno comes." which Marc is said to know; rather it says that, relative to a domain of relevant individuals, Marc knows of each of them whether he or she comes or not — indeed the exhaustive interpretation. And in example (3), Muriel is not said to be concerned with the truth or falsity of a singular proposition of the form "Judy will come.", but with a set of exhaustive propositions possibly answering the question "Who comes?", and trying to figure out which of these is the actually true answer. In both cases, the exhaustive interpretation of the embedded interrogative seems to be the right object of knowledge and wonder (see Heim, 1994).

So far, the odds seem to favour the exhaustive interpretation of interrogatives. However, one type of example may speak in favour of non-exhaustive interpretations, questions with so-called 'mention some' readings. Typical examples include:

(4) Who's got a light?

(5) How can I get to the station?

(6) Where can I buy an Italian newspaper?

These type of questions are normally (not invariably!) used to ask for one verifying instance only. If I have found someone who has a light, I don't care about who else has got one. If one asks the road to the station, one is not assumed to be interested in the infinite number of ways one could get there. And 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 pedanticly superfluous.

There is a lot of literature on this subject. Do interrogatives have two types of meanings? Are they ambiguous? Or can we derive one of them from the other? We will not go into a discussion of these matters here, since the subject will return in more empirical detail in the next section and in the contributions to this volume themselves.

1.2.2 Structured Meanings

An approach to the semantics of interrogatives which seems to be more radically different from the ones above, is the so-called 'categorial' or 'structured meanings' approach (von Stechow, 1991, Krifka, 2001, e.g.,). 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 (answerhood conditions) as the fundamental notion, but constituent answers.

The main idea is that questions basically are functions, and that their possible answers supply the arguments to these functions in order to yield a proposition. Consider the examples from above again, this time as they are formulated in the structured meanings framework:

(7) Who comes? $(\lambda x\ Cx)$[9]
Marc. $((\lambda x\ Cx)(m) \Leftrightarrow Cm)$

(8) Which boys saw which girls? $(\lambda\langle x, y\rangle\ Sxy)$
Marc Judy. $((\lambda\langle x, y\rangle\ Sxy)(\langle m, j\rangle) \Leftrightarrow Smj)$

(9) Does it rain? $(\lambda f\ f(r))$
No. $((\lambda f\ f(r))(\lambda p\ \neg p) \Leftrightarrow (\lambda p\ \neg p)(r) \Leftrightarrow \neg r)$

If we take sentences to denote propositions, then every interrogative denotes a function from answer-type denotations to propositions. If the interrogative hosts *Wh*-elements, as in the examples (7) and (8), then the required answer types are those of the (tuples of) *Wh*-elements. In case of a polar question (9), the argument type is a function on the domain of propositions, basically "Yes." $(\lambda p\ p)$ and "No." $(\lambda p\ \neg p)$.

It is relatively easily seen that the structured meanings interpretation of interrogatives is strictly richer than its propositional counterpart. For we can *derive* the latter from the former (but not the other way around):

- Let $\mathcal{S}$ be the structured meanings interpretation of an interrogative; then the corresponding propositional interpretation
$\mathcal{Q}_{\mathcal{S}} = \{\{w' \mid \forall \vec{e} \in D^*\colon w' \in \mathcal{S}(\vec{e}) \text{ iff } w \in \mathcal{S}(\vec{e})\} \mid w \in W\}$

---

[9] Just for completeness, if x is a variable of type a, and β an expression of type b, then $\lambda x\ \beta$ is an expression of type $\langle a, b\rangle$ with interpretation: $[\![\lambda x\ \beta]\!]_{M,g}$ = that function h from a-type things to b-type things such that $\forall d \in D_a$: $h(d) = [\![\beta]\!]_{M,g[x/d]}$. As we can see in the next example, we can also abstract over tuples of variables, and apply these abstracts to tuples of arguments. As is well-known $(\lambda x\ \beta)(\alpha) \Leftrightarrow [\alpha/x]\beta$, provided that no free variables in α get bound by the substitution for x in β (λ-conversion).

This fact indicates that anything that can be done on the propositional approach can be done on the structured meanings approach as well, in an indirect way. This comes at a price, though. In the first place a structured meanings account must assume that questions and their characteristic answers live in many categories: in principle they can be functions of any type of arguments to propositions. Furthermore, question-embedding verbs like "wonder" and "know" (as in "know who", "know whether" etc.) cannot directly apply to the meanings of their embedded arguments, because their structured meanings interpretation first has to be recast into their propositional interpretation.

It must be said, however, that this price is not paid for nothing. As we can see from the examples (7–9), a structured meanings interpretation of interrogatives gives us a direct means to interpret (non-propositional) constituent answers: the function associated with the interrogative simply applies to the interpretation of the argument and the result is the propositional answer (which can be true or false by the way). Things are not that easy on a propositional approach. First notice that on a propositional (partition) approach, the following questions are pairwise equivalent:

(10) Is it raining?
Is it not raining?

(11) Who wants an icecream?
Who does not want an ice cream?[10]

Every full answer to the first question of these pairs also fully answers the second, intuitively, and formally. However, an affirmative reply ("Yes.") to the first question of (10) implies that it is raining whereas as a reply to the second question of (10) it implies that it is not raining.[11] The examples in (11) are probably clearer. A constituent answer like "Judy." to the first of these questions means that Judy wants an icecream, while if it answers the second question it means that Judy does not want one.

These observations imply that partition interpretations of interrogatives are not rich enough to (directly) interpret corresponding constituent answers, so that other means have to be looked for. One way to go is to assume that constituent answers are elliptic, and that a reply like "Judy." is really short for, for instance, "Judy [does not want an ice cream].", where the material in brackets has been elided and

[10] This pair of examples is from Zeevat, p.c.

[11] One has to be cautious here, though, because it seems we could answer the second question with "Yes, it *is* raining.", "Yes, it is not raining.", "No it is raining." and "No, it is not raining." Whatever the rules are, it is certain that languages differ with respect to the ways in which negative questions get answered.

must be reconstructed on a syntactic level. Groenendijk and Stokhof argue for a semantic approach. They resort to a previous or deeper level of the interpretation of interrogatives, where questions are associated with relational abstracts, which are very much like the functions from the structured meanings approach. These relational abstracts lie at the basis of the derived partitions, but they can be re-used when it comes to the interpretation of constituent answers, very much in the same way as these are interpreted on the structured meanings approach. But if these relational abstracts are indeed semantically relevant, then the propositional and the structured meanings account of questions and answers are not that wide apart after all.

Quite a reverse story, of course, has to be told about full propositional answers. A reply "Marc and Judy want an ice-cream (and nobody else)." to the first question of example (11) can be directly interpreted on the partition approach as it selects one block from the partition associated with the question. In order for the structured meanings approach to deal with such a reply it seems it must first turn the question *function* into the corresponding partition (as defined above) before it can interpret the reply in a similar way.

We leave this discussion here, since the issues involved will show up again in some of the contributions to this volume, and in our discussion of them in section 3.

1.2.3 Knowing Who and Which

There are two more or less technical issues which any theory of questions has to face, but which are best explained in terms of the most rigorously formulated partition theory, the solutions of which seem to carry over to the other frameworks.

In the models $M = \langle W, D, I \rangle$ for the partition semantics, names or individual constants are assumed to be 'rigid designators', i.e., they denote the same individual in every possibility.[12] This is enforced for a good reason. In this way, a reply like "Judy comes (and nobody else)." counts as a good full possible answer to the question "Who comes?". Let us see this by computing the possible answers to this question relative to an arbitrary variable assignment g:

- $\{\{w' \mid \forall g'[x]g\colon [\![Cx]\!]_{M,w',g'} = [\![Cx]\!]_{M,w,g'}\} \mid w \in W\} =$
  $\{\{w' \mid \forall d \in D\colon [\![Cx]\!]_{M,w',g[x/d]} = [\![Cx]\!]_{M,w,g[x/d]}\} \mid w \in W\} =$
  $\{\{w' \mid I_{w'}(C) = I_w(C)\} \mid w \in W\}$

The above mentioned reply denotes the following proposition:

[12] Formally, $\forall w, w'\colon I_w(c) = I_{w'}(c)$, for any individual constant c.

- $\{w' \mid \forall d \in D\text{: } d \in I_{w'}(C) \text{ iff } d = I_{w'}(j)\} =$
  $\{w' \mid I_{w'}(C) = \{I_{w'}(j)\}\}$

Clearly, if "Judy" is rigid, say $I_w(j) = d$ for any possibility w, this is one of the full possible answers, namely the proposition true in those w' such that $I_{w'}(C) = \{d\}$. If, however, "Judy" were not rigid, the reply would not correspond to any of the possible answers to our question.

The above example shows that there are good reasons for a rigid interpretation of names, or individual constants. However, it has a pretty nasty by-effect. Consider the question "Who is Judy?" ($?x\ x = j$), on the assumption that "Judy" is rigid, say $I_w(j) = d$ for any possibility w:

- $\{\{w' \mid \forall g'[x]g\text{: } [\![x = j]\!]_{M,w',g'} = [\![x = j]\!]_{M,w,g'}\} \mid w \in W\} =$
  $\{\{w' \mid \forall d' \in D\text{: } [\![x = j]\!]_{M,w',g[x/d']} = [\![x = j]\!]_{M,w,g[x/d']}\} \mid w \in W\} =$
  $\{\{w' \mid \forall d' \in D\text{: } d' = d \text{ iff } d' = d\} \mid w \in W\} =$
  $\{W\}$

The question turns out to be trivial. It has only one possible answer, which is the trivial proposition, true in all possible worlds. This means that any answer to any question whatsoever entails (is included in) the one and only answer to this question. Obviously, this is not what we want, because we can ask such questions like "Who is Judy?" in a non-trivial way, and we can make contingent assertions like "Marc knows who Judy is." and "Bernhard does not know who Judy is.". If "Judy" is interpreted rigidly this has to remain inexplicable. Indeed, we face a dilemma, as Aloni (2001) has it: 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 in a reply to a constituent question. We cannot have it both ways, it seems.

Aloni (2001) has shown a way out of this dilemma, with a technique she has also shown to be very useful for the analysis of attitude reports and epistemic operators in dynamic semantics. It would go too far to give the details of her analysis here, so we will only sketch the outlines. The basic idea is that even though quantification and reference are concerned with the domain of individuals, this concern is modeled from the perspective of a conceptual cover, a way of 'seeing' the domain.

We can assume names to be non-rigid, i.e., they are individual concepts, functions which assign a, possibly different, individual to each possibility as the referent of the name. (This can be taken as the default interpretation of names in an epistemically oriented semantics.) 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. Another conceptual cover is the domain itself, as, for instance, when we are in direct perceptual contact with the whole domain. Many other ways of 'seeing' the domain are possible, though.

The main technical contribution is that quantifiers (and variable-binding question operators) are also interpreted relative to 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: it is as if it asks "Who among Marc, Judy, ..., and Muriel is Judy?", which is quite silly indeed. However, if the question operator is interpreted from another perspective the question is not at all trivial any longer. 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 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 is neatly accounted for in Aloni's semantics.

Moreover, if the perspective associated with a question $?x\ Cx$ is that of a 'naming' cover, then any list of names will constitute a proper answer, as we would like to have it in the first place. Interestingly, this approach also explains why the very same answer to the very same question can be appropriate or inappropriate depending on the circumstances, more in particular, on the assumed perspective. Thus, to adapt an example from Aloni, a teacher can ask in the classroom:

(12) Do you know who Sandra Roelofs is?

A proper answer in this situation seems to be something like "The Dutch wife of the 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 to point out one of the visibly present individuals. (And conversely, indeed, your teacher in classroom would not be very happy if, in response to her question, you would go out, kidnap Sandra Roelofs, bring her to the classroom and say, "This is Sandra Roelofs.".) With Aloni's conceptual covers, these data can be neatly accounted for, independent of the general framework used to deal with the interpretation of questions.

Another issue has to do with *which*-questions. A relatively 'flat' rendering of "Which boys saw which girls?" (slightly different from the one we implicitly assumed above) looks as follows: $?xy\ (Bx \wedge (Gy \wedge Sxy))$. This is slightly non-compositional, since, for instance, we cannot really isolate a part corresponding to the phrase "which girls", but with some ingenuity the analysis can be amended at this point. Somewhat more worrying is the fact that the contents of the *which*-phrases and what is predicated of or questioned about their interpretations is treated on equal par. The following pairs of examples may show that we need to be more distinctive:

(13) Which males are bachelor?
Which bachelors are male?

(14) Judy knows which males are bachelor.
Judy knows which bachelors are male.

According to the 'flat' analysis, the questions in examples (13) are analysed 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, according to the lexical meaning of that term in English ('bachelor' = 'unmarried male'). By the same token, the embedded questions in examples (14) would be the same, so both sentences ought to be equivalent as well. Intuitively, however, these equivalences do not hold: the first question of (13) makes (contingent) sense, whereas the second does not seem to. An obvious reply is, for instance: "Well, all of course!". For the same reason the first statement of (14) can be of interest, while the second need not be.

There is a principled way out of this problem, corresponding to the analysis of *which*-phrases on Krifka's structured meanings approach. According to Krifka (2001), the first question of (13) is a function from individuals to propositions to the effect that the individuals are bachelor. It is a partial function, though, restricted to the set of males. This function is non-trivial because some of the males may be bachelor, and others may not be. A similar analysis of the second question of (13) shows it to be trivial. It is a function from individuals to propositions to the effect that the individuals are male. Since this time the partial function is restricted to the set of bachelors, the question is trivial: all of them are male, of course. Quite the same idea can be used to explain the contrast between the two sentences in (14).

Krifka's 2001 analysis can be generalized, and exported to other frameworks for the analysis of questions, because it appears to be an instance of a much wider phenomenon in natural language. It has been argued every now and then in the literature that quantified noun phrases in a sense presuppose their domain of quantification. (This idea is as old as Aristotle, and in the linguistics literature it has been argued for convincingly by Milsark (1974) and Diesing (1992), and recently Moltmann (to appear).) If we apply the same idea to *which*-noun phrases the facts seem to fall right into place.

Consider again "Which males are bachelor?". 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 bachelor. This makes intuitive 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 stated, this question is indeed trivial, since all the bachelors are, by definition, known to be male.

We will not go into further detail on this issue here, because the proper treatment of presuppositions, and especially that of domain presuppositions, is a matter of current debate. The discussion here was mainly meant to show that a quite puzzling question around the interpretation of *which*-questions can, and probably should be, resolved by means of an independently needed treatment of the presuppositions of noun phrases more generally, which, at present, is outstanding.

1.2.4 Dynamic Semantics

One can, but need not, agree that the meaning of a sentence resides in its so-called 'update potential', contrary to the view exposed above that it resides in its 'truth conditions'. Even if one does not, it has proven worthwhile to study how assertions change or are intended to change the context: 'common grounds', representations of the contents of discourses, the information of the interlocutors, or what have you Stalnaker (1978), Kamp (1981), Heim (1983a), Seuren (1985), Groenendijk and Stokhof (1991a), Veltman (1996). As will appear from the contributions to this volume, and as has earlier been shown in different types of frameworks (like those of Roberts (1996), Hulstijn (1997), Asher and Lascarides (1998), Cooper (1998), Ginzburg and Sag (2000)), basically the same holds for questions in discourse.

Whether or not one accepts the view that meanings are context change potentials, it is beyond doubt that the semantics/pragmatics interface cannot ignore the question how utterances depend on, and can be taken to modify, the 'common ground'. In this respect interrogatives, like imperatives and permission utterances, are much more convincing examples than simple assertions are. Discourses or dialogues which are aimed at the exchange of information can be seen as games of stacking and answering 'questions under discussion' (Ginzburg, 1995) or as processes of 'raising and resolving issues' (Hulstijn, 1997). Such processes are not un-structured: they are governed by structural rules which can be deemed linguistic (in a broad sense), and by very pragmatic principles of reasonable or rational coordination. Especially by adopting a dynamic view of interpretation, one is able to lay bare such systematic properties and effects of questions and assertions in practice.

From the very start, there have been two closely related approaches to the dynamics of discourse, a representational and a non-representational one. Hans Kamp's discourse representation theory (Kamp 1981, as well as its successors like, e.g., UDRT, Reyle 1993, SDRT, Asher and Lascarides 2003) is of the first type, which, as its name indicates, aims to represent the cumulative contents of discourses. Amsterdam formulations of the dynamics of discourse are, arguably, of a non-representational nature (Jeroen Groenendijk and Martin Stokhof's dynamic predicate logic and Frank Veltman's update semantics). Irene Heim's file change semantics is a perfect blend: it employs a representational metaphor (that of updating 'files') while it also comes with a non-representational semantics for these updates. It is, of course, obvious, that a representational semantics is a much more powerful tool than a non-representational one, since many more operations are conceivable on highly structured representations, than on the less structured semantic objects. Nevertheless, it seems to be worthwhile to see how far the scope of a non-representational semantics can be stretched. For the latter does not commit itself to the reality or form of the representations people actually use when computing meanings and interpretations. Any cognitive theory of interpretation ought to be in principle compatible with its findings. Such a point can hardly be upheld for a representational semantics, since if it turns out that the representations used would not be realistic in a psychological or cognitive sense, in a way this would refute the theory.

All contributions to this volume adopt this non-representational stance. Information (of the interlocutors or in the common ground) is generally modeled in terms of sets of possibilities, viz., those which are compatible with that information. Update of information consists of the elimination of possibilities. If we know or learn more, less possibilities turn out to be compatible with the information we have, and in the extreme case we could be left with only one possibility, totally specifying what (we think) exactly are the ways things are Roberts (1996). Of course, hardly anybody would like to achieve this goal. (Except, if he exists, God, who would know this by definition.) Since we are agents with practical needs and finite capabilities, we are confronted with only very limited subsets of the infinite sets of questions we could raise, and therefore updates in discourse should be guided by the questions we have, we actually pose, or which others may think we might be interested in.

Here is where Hulstijn's 1997 'raising and resolving issues' kicks in, and, likewise, the 'questions under discussion' from Ginzburg (1995), Roberts (1996). At any point in a discourse or dialogue several questions may be 'alive' because they are ex- or implicitly raised, or assumed to be relevant. In order to account for such a state in discourse, we therefore cannot simply do with the set of possibilities compatible with the information assumed and exchanged so far. It should also indicate the relevant differences which the interlocutors wish to distinguish between. Information states or common grounds therefore ought to be (at least) sets of ordered possibilities, for instance partitions of parts of logical space. As in Groenendijk and Jäger's papers, these states can be updated in basically two ways. Assertions can be used to reduce the relevant part of logical space by the elimination of possibilities, as no longer being potentially actual. Questions can be used to fine-tune the structure, and increase the number of distinctions one is interested in. From this very sketchy description we can already deduce two general and reasonable constraints (which are not inviolable, though, as we will see later). For instance, it should make no sense to assert something which is already entailed by the common ground at a certain point in a discourse; and it ought not to make sense to ask a question which is entailed by previous questions in the discourse. Much more detail will be provided in the various contributions to this volume.

There is one problem for a non-representational update semantics which we have to mention and which we cannot solve here. How to deal with conflicting information, corrections, and withdrawal of information? In a representational semantics it is fairly easy to correct the assertion that Judy is in Paris with the statement "No, Judy is in Prague." One could simply wipe out the record for "Judy is in Paris" and replace it by one recording that she is in Prague. (In general, this is not without pitfalls, though.) However, if we have reached a state modeled by possibilities in which Judy is in Paris, it is not clear how we could or should extend this set of possibilities to one in which Judy may not be in Paris, and leave other independent information intact. (Anyway, it is unclear on both a representational and non-representational account what should count as 'independent information'.) For such corrections current systems of dynamic semantics offer only a blind 'die or survive'-scenario. If new information contradicts currently established information, we can accept it, and reach the absurd state, the empty set of possibilities which excludes all possibilities from being actual. Or we can refuse the update, and say "Ho, stop, this is not what we have agreed upon.". Of course, none of these options is very practical or reasonable, and in actual practice corrections and the presentation of conflicting information normally leads to a negotiation of what has to be accepted after all. It may be clear, though, that this type of discussion goes beyond the confines of straightforward systems of update semantics, and it must be submitted that, so far, no solution to this issue has been offered in the literature.

1.3 This Volume

Before we engage in a thematic discussion of the contributions to this volume, it may be useful to explain the order in which they appear. The twelve contributions are grouped in four sections of three papers each, which display their thematic coherence. As will become clear from the subsequent discussion, there are also many cross-connections though. The first three sections start with what may be labeled a 'classical' contribution. The first section (on update semantics) starts with Jeroen Groenendijk's "The Logic of Interrogation" which can be taken to be the starting point of the whole volume, and which has appeared as such in the Proceedings of SALT IX, 1999. The second section (on topic and focus) starts with Gerhard Jäger's "Only Updates", which has appeared in the Proceedings of the Tenth Amsterdam Colloquium, 1996. The other papers in this section are true elaborations of this paper. The third section (on implicatures and exhaustiveness) starts with Henk Zeevat's "Exhaustivity, Questions and Plurals in Update Semantics". This is a substantially revised version of his "Questions and Exhaustivity in Update Semantics", which has appeared in the Proceedings of the International Workshop on Computational Semantics, 1994. These 'classical' papers appear as the first in each of the three sections, the further order of papers is alphabetical. The last section (on intonation and syntax) provides a truly new angle on the subjects discussed, so it does not contain any classical paper—or not yet, for that matter.

1.3.1 Update Semantics

Jeroen Groenendijk's paper "The Logic of Interrogation" carries its pun right in the title. Interrogations are normally carried out to gain new information. Logic, as traditionally conceived, is only concerned with conclusions based on pre-given premises which already entail these conclusions. They ought not bring us something new. Adopting a broader view, however, 'logic' is concerned with valid reasoning, be it from the structure of our minds, language, practices, or reality (which is where logic or $\lambda o \gamma o \varsigma$[13] etymologically stems from). In accordance with the Gricean program, Groenendijk sets out to make logic and pragmatics

[13]The classical Greek word was used for a wide variety of concepts such as language, understanding, reason, doctrine, structure, and principle.

meet, and to account for particular aspects of games of information exchange. The core notion here is not that of a logically valid conclusion, but that of a 'pertinent' move in a dialogue game.

In order to lay bare the very characteristics of them, Groenendijk focuses on a very specific type of dialogue game, with two players, the interrogator and the witness, each of which has its own obvious role to play. The interrogator raises issues, and the witness is supposed to answer them. Good deal. This allows for a very straightforward definition of a 'pertinent' move, which is, basically, non-redundant: a question from the interrogator is pertinent if it raises a new issue; a statement from the witness is pertinent if it contributes new information. Interestingly, but not unexpectedly, this goes right across the notions of entailment proposed in logical systems for games of argumentation. Entailed questions and assertions are superfluous and therefore, pragmatically, deviant. Interesting contributions are those that are not superfluous.

On the basis of these quite basic insights Groenendijk succeeds in showing why some elementary discourses are or are not felicitous (or 'pertinent' as he calls it), and why they get their most likely interpretation. As a response to "Who rescued Bea?" the reply that Alf rescued Bea and no-one else implies that Alf was the sole Bea-rescuer; in response to the question "Whom did Alf rescue?", however, the very same answer gets the quite different interpretation that Bea was the only one rescued by Alf. In Groenendijk's formal language, and in keeping with his notion of pertinence, these facts fall right into place. This is a neat example of how, concentrating on a special design toy language, one can account for some apparently fundamental data. The results, it must be observed, are similar to the observations from Jäger on *only*, and it must be emphasized, as Groenendijk himself notices, that 'real discourse' can be much more flexible and creative than artificial models are. In this respect the empirical data on intonation reported by Šafářová are rather telling.

Balder Ten Cate and Chung-chieh Shan provide an axiomatization of Groenendijk's logic of interrogation which is both logically and linguistically most interesting. Groenendijk's notion of entailment can be captured by means of the logical notion of interpolation, and more in particular in terms of Evert Beth's definability theorem. Established logical findings, thus, do not only contribute to our understanding of the logic of interrogation, but suitable variants of it also suggest interesting modifications of this logic. One of these is a suitable modification of the logic to allow variable domains, and the linguistic and computational consequences of this move are discussed.

Paul Dekker advocates a broader perspective on games of information exchange. Without committing anyone to the very special role of interrogator or witness, his idea is that all interlocutors come with their own information and questions, and that the ideal is that the very questions get answered on the basis of the information distributively present. There are many ways in which this goal can be achieved, if it is achievable at all. An interesting result is that the aim of the participants in a conversation is to seek to achieve these goals, sometimes by making queries and statements that might not directly contribute to the envisaged goals. The devise of efficient strategies, therefore, does not seem to be totally obvious, and is left to pragmatic or decision theoretic types of reasoning about the discourse, its possible goals, the interlocutors, and the information they have about that.

The three perspectives on games of information exchange, Groenendijk's arguably more linguistic one, ten Cate and Shan's more logical one, and Dekker's more pragmatic one, raise a number of principled issues. Some data are neatly accounted for in Groenendijk's approach, i.e., the interpretation of focused answers to specific questions. The merits of, e.g., counterquestions, it seems, can hardly be explained without resort to the pragmatics of discourse. In either case we need to have access to a reasoning component, dealing with entailments between questions and answers. Obviously ten Cate and Shan's system provides a very first and promising start, but in the end we would need a richer epistemic logic to reason about the facts of discourse and the information exchanged.

All three contributions raise the issue where, if at all, the borderline should be drawn between logic and pragmatics. Logic, narrowly conceived, is engaged with valid entailment relations between sets of indicative sentences. It must be clear from these contributions, though, that logic naturally expands its scope to interrogative sentences as well. Moreover, in order to establish the relevance of utterances in a discourse, it is required to *reason* about the point they can be taken to make. Lots of work for an epistemic logic. It is not clear, though, how much of this can be put on the logician's agenda. Many, or even most, day-to-day inferences draw from practical or pragmatical assumptions about the people who are engaged in games of information exchange. Logic can be used to model these assumptions, but it certainly should not be taken to motivate them. The main, and moderate, moral seems to be, then, that no principled distinction can be drawn as yet, and that we would like existing (logical and pragmatical) formalisms to interact, in the most productive ways.

1.3.2 Topic and Focus

Rooth (1985) has effectively drawn attention to the ambiguity, and intonation sensitivity, of the following pair of examples:

(15) In Saint Petersburg, $[\text{officers}]_F$ always escorted ballerinas.
In Saint Petersburg, officers always escorted $[\text{ballerinas}]_F$.

The first appears to be a (universal or generic) claim about ballerinas, the second one is about officers. Another telling pair of examples is from Pieter A.M. Seuren (p.c.):

(16) Frederick always/only $[\text{sleeps}]_F$ at work.
Frederick always/only sleeps at $[\text{work}]_F$.

If the emphasis is on *sleeps*, it seems to indicate that Frederick is a hangabout. If the emphasis is on *work*, Frederick appears to be an incorrigible workaholic. Gerhard Jäger can be credited for observing another kind of context-sensitivity:

(17) Who is wise?
Only Socrates is wise.

(18) Which Athenian is wise?
Only Socrates is wise.

In the first example, Socrates is claimed to be the only wise person in the world. In the second, it seems, Socrates is claimed to be the only wise Athenian. All three pairs of examples can be taken to show that information structure is relevant to interpretation, and the three contributions to this section can be taken to capitalize on that.

Jäger's paper was the first to extend the coverage of the dynamic paradigm to topic and focus sensitive phenomena associated with the use of the term "only". It defines a neat system **ULQA** which accommodates the updates with both questions and assertions in a Groenendijk-style manner. An intriguing, innovation is the treatment of *Wh*-questions as questions embedded under a (possibly restricted) universal quantifier. Thus:

(19) Who is wise?

is interpreted as asking for each individual in a relevant domain whether he or she is wise or not. Similarly:

(20) Which Athenian is wise?

asks for each Athenian whether he or she is wise or not. Jäger accounts for these data by rendering the interpretation of in particular atomic formulas context dependent in the following sense: any such formula At only provides a proper update of an information state if it addresses a current question under discussion. While the information state is modeled as the set of possible answers to current questions, an update with At does not simply preserve the possibilities where At is true, but only those which figure in an answer that strictly implies the truth of At.[14] As a consequence, quantified sentences get restricted to individuals which are known to satisfy certain properties, or whose possession of that property is under discussion. Consider again:

(21) Only Socrates is wise.

The contents of this sentence are rendered by the formula: $\forall x(Wx \rightarrow x = s)$. In the system of *ULQA* the universal quantifier is restricted to the people who are known or questioned to be wise. So in case this sentence serves as a reply to question (20), it is taken to assert that Socrates is the only wise Athenian. In response to the question "Who is wise?", however, it is generally taken to assert that Socrates is the only wise person in the world. (In response to no question, the reply is trivial.)

The other two contributions to this section can be seen to render the effects of domain restriction in a more sophisticated manner, linguistically and empirically speaking. Jäger models contextual restriction by means of an implicit modal operation in the interpretation of atomic formulas (universal quantification over possibilities in possible answers), and relative to information states which are partitions. Maria Aloni, David Beaver, Brady Clark and Robert van Rooij and Paul Dekker employ more fine-grained question meanings, the so-called abstracts underlying these partitions: sets of (sequences of) individuals satisfying the property under discussion. Subsequent quantifiers can thus be explicitly restricted to these sets of (sequences of) individuals. Besides this, both Aloni et al. and Dekker make Jäger's type of modality explicit: in Aloni et al. it appears as an operator ∂ which presupposes that certain questions are under discussion; Dekker employs an abstract operator *ELSE* which can be used to identify a set of individuals currently known to possess properties under discussion.

Elaborating on Gawron, Aloni et al. combine an update semantics of questions with an explicit analysis of (free) focus and its pragmatic and semantic role. On this account, questions introduce topics, formalized as dynamic information states. An introduced topic structures the context as in Groenendijk (1999), but it can also be presupposed by subsequent focused structures and it has the potential to restrict subsequent quantification. In this proposal, then, the dynamics of questions

[14] This is not totally unproblematic, for the interpretation of an (embedded) conditional such as $p \rightarrow q$ is trivial if $?p$ is not a question in the input information state. Exercise: show triviality of $p \rightarrow q$ in the empty information state $W \times W$.

does not only involve their potential to raise issues which structure the factual information shared in conversations, but also concerns their impact on the felicity (or congruence) and meaning of their focused answers. The paper also models the distinction, put forward in Beaver and Clark (2003), between focus sensitive operators like *only* and topic sensitive operators like *always*. The focus sensitivity of the former derives from a grammatical mechanism, whereas the interpretation of the latter is a purely pragmatic matter, and determined by discourse topic.

Paul Dekker's elegant analysis minimally defines topical domain restriction and uses it for a compositional analysis of (quantified) constituent answers, like "Who gave what to whom? Mary a picture to a boy". Constructions like these are known in the linguistic literature as 'stripping' or 'bare argument ellipsis' or 'gapping' (Ross, 1970), and are problematic for syntactic approaches to ellipsis because, for example, they do not respect constituency. Dekker's theory shows that a semantic/pragmatic analysis of gapping can be given where the reconstruction of the missing material follows as a case of dynamic topical domain restriction. It is minimal in the sense that it does not need to resort to keeping track of information about variables. Discourse information (indicative as well as interrogative) is modeled directly, and anaphoric take up and domain restriction is not mediated by the (arbitrary) choice of variables. All relevant information is modeled as a pure set-theoretic construct out of objects in the domain. The paper also provides an analysis of the particle *ELSE* which can be used in a proper and compositional interpretation of locutions like "Nobody else" and "Somebody else", as a matter of fact, the result of a decomposition of Zeevat's epistemic exhaustivity operator (see Zeevat, 1994b, a predecessor of Zeevat, this volume).

An important issue arising from these contributions concerns the relation between the logical notions of entailment, answerhood and pertinence defined purely in terms of propositional content versus the more discourse oriented notions of anaphora, topical domain restriction and congruence depending more on discourse information than on factual information. Jäger's implicit account of topical domain restrictions purely in terms of partitions had some empirical drawbacks, showing that a proper account of discourse phenomena require more fine-grained structures, e.g. dynamic information states as in Aloni et al, or equivalently, sequences of witnesses as in Dekker's contribution.

1.3.3 Implicatures and Exhaustiveness

As we already have seen, exhaustification is a crucial issue in the theory of questions and answers, but its impact is certainly not confined to that. Exhaustification in a sense refers to limits, and it gives you a/the bit of information that allows you to know all the other information you needed to know. Thus, as we have seen, (23) in reply to (22) can be taken to mean (24):

(22) Who has sneakily eaten from the pie?
(23) Amanda, Ben, and Curt and Donny.
(24) Amanda, Ben, Curt and Donny are the ones who have sneakily eaten from the pie.

But with scalar predications other exhaustification effects show up:

(25) How fast may I drive here in an urban area?
(26) You may drive 50 kilometers an hour.
(27) How slow may I drive on the highway?

In reply to question (25), answer (26) can be taken to mean "50 and no more", while in reply to (27) the very same answer can be taken to mean "50 and no less". Also:

(28) Prof. Vamp can prove this theorem in five minutes.
(29) Prof. Champ can lecture for five hours.

Typically, example (28) can be used to refer to an upper limit, indicating that Vamp can do it in five minutes *or less*; example (29) typically indicates a lower bound, Champ can lecture for five hours *or more*. Exhaustification thus is a highly context dependent and flexible notion, and not just a question of the relevant domain but also of the relations that elements of that domain have entered into with one another. One of the main issues in the literature pertains to the question how much of the exhaustification effects should be assigned to the semantics (logical form, (lexical) meaning) of the various constructions, and how much to pragmatics (i.e., implicatures, world knowledge). The three contributions to this section approach the phenomena of exhaustification from various perspectives.

Approaches to exhaustification prior to Groenendijk and Stokhof and Zeevat were purely stipulative, e.g., they derived effects of exhaustification with a universal operator Szabolcsi (1981), with definiteness Moltmann (1992), and with maximality Rullmann (1995). But such operators fail to capture exhaustification in general: it is a smarter notion. Henk Zeevat provides an attempt to use semantic tools to get a proper grip on what underlies the concept of exhaustification. Exhausted interpretations basically are the strongest interpretations of free variables (discourse markers), given a set of (primitive) meaning postulates. It is extraordinarily successful, as it applies uniformly to questions, answers, focus, plurals and scalar implicatures, but it still faces problems:

the set-up assumptions are costly/stipulative, there still are the cross-world identity problems (and the problematic notion of an 'ontological alternative'), and it relies on meaning postulates to an extreme extent.

Robert van Rooij and Katrin Schulz's contribution deals with the particle 'only' and its relation with exhaustification. The analysis systematically distinguishes between a semantic and a pragmatic contribution of 'only'. The sentence "Only Mary smokes" means that nobody except Mary smokes and has the pragmatic implication that Mary smokes. The account of the semantic contribution of 'only' is based on Groenendijk and Stokhof's rule of exhaustive interpretation in contrast with alternative approaches (e.g., Rooth, 1985, 1992) where 'only' is taken to quantify over focus alternatives, rather than over 'background' alternatives (as in von Stechow, 1991). The pragmatic contribution of 'only' is characterized as a conversational implicature formally derived by Gricean maxims formalized in terms of operations mapping sentences to their minimal interpretations. These same operations are shown to derive the exhaustive interpretation of answers without 'only'. In the latter case, exhaustification ceases to be a semantic operation and is understood as a pragmatic interpretation function that strengthens the semantic meaning of a sentence.

Benjamin Spector's contribution also deals with a pragmatic notion of exhaustification. Defending a globalist account of implicatures against recent attacks (e.g., Chierchia, 2002) the article offers a precise formalization of the Gricean reasoning underling scalar implicatures and shows that exhaustification of answers can be obtained by the same pragmatic mechanisms. Gricean implicature derivations typically rely on the assumption of a set of alternatives against which the used sentence is compared to. Spector gives a perspicuous characterization of the alternatives involved in the derivation of exhaustive meanings, identifying them with the positive answers to the question under discussion, thus raising the interesting empirical question of why exhaustive answers are never among these alternatives. Given this choice of alternatives the analysis is shown to imply an asymmetry between positive and negative answers, while only the former are predicted to be interpreted as exhaustive. These predictions seem to be correct when tested on interesting data involving answers with (combination of increasing and) decreasing quantifiers.

Many issues on the semantic-pragmatic interface arise from these contributions. The contributions from Van Rooij and Schulz and Spector offer a purely pragmatic explanation of exhaustification of answers as derived by Gricean reasoning. Applications for exhaustification in natural language however gives a long list: e.g., questions, answers, focus, quantifiers, scalar implicatures, Evans effects, plurals, clefts, comparatives, free relatives and degree relatives (see Butler, 2001), and it is not clear how a purely pragmatic analysis can be extended to cover these genuinely semantic phenomena. Zeevat's dynamic analysis seems to blur the distinction between semantics and pragmatics, and its operator explains exhaustification of answers as well as a large number of semantic data. Nevertheless, as it is clear from all three contributions, exhaustification and scalar implicatures have a common core that should be explained and a Gricean analysis of the latter phenomenon, although not totally without stipulation—in the choice of the relevant alternatives, is less costly than an explanation in terms of Zeevat's operator.

1.3.4 Intonation and Syntax

The papers that we've seen thus far have concentrated almost exclusively on matters of meaning and use. But this has only been achieved with the (muted) accompaniment of basic assumptions about the forms taken by interrogatives and related constructions (e.g., focus constructions). The papers of this section are more explicit about the consequences for the form-meaning mapping of the theories they explore. To put it another way, they show exacting concern for (i), what semantics and pragmatics require from other areas of linguistic theorising, (ii), what semantics and pragmatics can offer to relieve other areas from internal problems, and (iii), what semantics and pragmatics can get by without (that is, how explicit does the linguistic code need to be?). In particular, the focus is on connections with intonation and syntactic forms.

Maria Aloni, Alastair Butler and Darrin Hindsill start the section off with an analysis in the framework of Bidirectional Optimality Theory (BiOT) that predicts the placement of nuclear accent within a focus. From the start they harness the advantages of a default framework by making a syntactic constraint, the Nuclear Stress Rule, a weak constraint. This salvages an otherwise problematic constraint with clear counterexamples, yet a strong intuitive appeal. This is also an interesting move from the perspective of constraint origins, since constraints that follow from syntactic form are frequently hard; and indeed the hardest constraint is the Focus Set Rule, which is essentially another constraint on form, requiring the accent to fall within the syntactic scope of the focus. Their setup also has interesting consequences for views on optimisation, as well as language acquisition, suggesting that the production task needs only unidirectional optimisation, while the interpretation task crucially relies on bidirectional optimisation, that is, optimising with respect to the hearer and speaker perspectives. This paper also raises a very interesting theoretical question. In linguistics it is generally assumed that syntactic rules are forbiddingly hard (specific structures are either right or wrong) while pragmatic constraints can be overruled. Aloni et al.'s paper shows that a neat account of focus and stress can be obtained by ranking pragmatic constraints harder than syntactic ones. Besides thus motivating an optimality theoretic account of the phenomena, this raises the question whether focus and stress should be assigned a special place in an overall syntactic theory, or whether we have to rethink the impact of structural and pragmatic rules more in general (and if so, how). Of course the issue is much more general than we can handle in a volume like this, so it is left for further study.

Alastair Butler offers a novel take on a range of so-called intervention effects that can arise in interrogatives with WH-phrases. Existing syntactic accounts of such phenomena have become extremely involved, and largely internally inconsistent, assuming ad-hoc constraints on logical forms (e.g., Beck, 1996a) or stipulation (e.g., Rizzi, 1990, Pesetsky, 2000) (see Butler and Mathieu, 2004 for a recent overview). Here the syntax is extremely simple, while the burden for an account is shifted to the semantics, following a trend initiated by Honcoop (1998). Of course, assumptions about form are required for the account to go through. But the demands placed on syntax are very slight and lead to the least controversial of positions, with requirements that are consistent with all major theories of syntax. And here we see another of this volume's recurring themes: the methodology of the approach is to concentrate on a specially designed toy language with an explicit semantics that derives apparently fundamental data without any additional stipulation. This time the data captures the diversity in coding strategies for WH-interrogatives cross-linguistically. It is striking indeed to see how such minimal tools can be used to uniformly account for a vast set of cross-linguistic data which may have seemed to be so heterogeneous at first glance.

Using a framework that combines Veltman's update semantics with a simple semantics for questions, Marie Šafářová shows how it is possible to pinpoint a consistent interpretative role for intonation patterns, again with a toy language especially designed for the (intonation) data to be accounted for. Specifically, she argues that the properties of rising declaratives can be captured uniformly by taking the final rise to be a kind of "intonational adverb", comparable with *it might be that.* This is in sharp contrast with previous accounts, which have typically attributed a meaning of 'questionhood' to the rising declarative, owing to the questioning effect that results from its use. Such a position is tenable because the questioning effect is shown to fall out from the semantics/pragmatics set up as a derived pragmatic effect, following from the uncertainty that is actually signalled. We therefore have a significant instance where semantics/pragmatics is able to do without a triggering interrogative form, allowing for declaratives to be consistently coded as statements. Not only is this a very welcome extension of the empirical scope of linguistic theory. It also serves to correct a widespread theoretical assumption that final rises (on both declaratives and interrogatives) are associated (one-to-one) with questionhood. Empirical data do not at all support this assumption, and Šafářová shows how to correct it from a theoretical (semantic / pragmatic) perspective. Innovative as the findings (empirically and theoretically speaking) may be, it leaves the interested linguist with the burning question: why should we have thought so in the first place? One of the morals may be that, however transparent they are, intuitions need not be decisive, neither in logic, nor in language.

To sum up, the contributions of this section give a taster as to how the tools assembled from findings in semantics and pragmatics can be used to tackle problems that have originated from other areas of study (here, intonation and syntax). These are interesting developments, as they promise to breathe new awareness into areas that have been widely researched, but have lacked conclusive outcomes. Of course, what gets opened up here is a two-way street: semantics and pragmatics, as practised in this volume, have much to learn from the other areas of linguistic theorising.

1.4 Remaining Issues

So far we've stressed the relevance of the work which this volume reports upon for semantic and pragmatic theory. But are there implications for other areas of linguistic theorising (e.g., syntax, morphology, intonation, language acquisition, language evolution)? How will these findings fit in with the findings of other areas? Can they be used to strengthen existing viewpoints in other areas, perhaps resolving internal inconsistencies, or will they lead to an importing of radically new ideas, or a syphoning off of the burden of explanation? That such questions can now be addressed is testimony to the maturity of the ideas this volume presents. A couple of open questions have become manifest throughout this volume, and we will briefly comment upon them, without suggesting particular answers.

In the first place, the whole notion of a question is as open as it was at the start of this introduction. We can take the moral from Šafářová and keep to a uniform syntactic distinction between declaratives and interrogatives but then it remains unclear how to assess the results of the other proposals which build on a semantic/pragmatic distinction, at least on the level of logical form. Another open issue pertains to the interpretation of questions which can also be identified syntactically: *where*-, *how*- and *why*-questions. These have not been addressed explicitly in this volume and it remains to be seen whether the same semantic / pragmatic tools like the ones advocated can be used to deal with these types of questions.

In the second place, various contributions (in particular those of Aloni et al., Butler, Dekker, and Zeevat) have pointed at the close correspondence, logically, and cross-linguistically, between *Wh*-questions and indefinites. At present it is not clear how to evaluate such correspondences. Should we assume a universal category, or should or could we deem these correspondences to be accidental by-products of interpretational mechanisms? (For, as observed by Butler, the use of an indefinite may license a *namely*-continuation, or a *who-then*-question, but it is not clear whether this should be accounted for structurally or by means of pragmatic mechanisms.)

In the third place, various proposals incorporate notions of presupposition, contradiction, and correction in discourse. None of these provide or build upon an elaborate theory of accommodation and revision. This is fortunate to the extent that the proposals, with their specific targets, probably ought to be independent of that. Nevertheless, the proposals remain incomplete as long as there is no consensus on the appropriate form of a theory of accommodation, and current literature does not seem to supply that.

An actual theme, in the fourth place, is whether questions can be outscoped, or to what extent. This volume does not directly deal with embedded questions, like we find in *wonder who*-, and *know whether*-constructions, where questions arguably figure in the scope of structural operators. Nevertheless, their interpretation is highly relevant for judging the interaction between semantics (meaning) and pragmatics (interpretation). On the face of it, questions can also be embedded in other questions, that is, if we take a run of the mill syntactic analysis of multiple *wh*-questions. In more classical proposals, like that of, e.g., Groenendijk and Stokhof (1984), multiple *wh*-phrases are treated as unary, but polyadic operators; some proposals in this volume suggest that more compositional approaches are possible, which for instance allow one to combine an interrogative noun phrase like "Which professors" with an interrogative verb phrase like "failed which students".

Finally, questions can be embedded under generalized quantifiers so as to yield, e.g., pair list readings. The phenomenon has already been discussed in Groenendijk and Stokhof, among others, and recently Krifka (2003) has given this discussion a new twist. There is no room here for an elaborate discussion of this phenomenon of embedding questions, but a little reflection will show that an unlimited possibility of embedding is not linguistically realistic. Only a few type of quantifiers and operators allow questions in their semantic scope, and it is not clear beforehand which ones do, and why.

In the fifth and final place, hardly anything has been said about the computation of questions, the generation of answers, and (automated) information retrieval. Arguably, the contribution from ten Cate and Shan comes closest to that, but not yet as close to be interesting for the computational community. This is a pity in as far as the focus on the semantics and pragmatics of questions answers should in principle allow the prospect of bridging theoretical and practical endeavours. 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 the single step we can take in one volume. The Chunnel was not built in one day either. We hope this volume shows, not only, that much of the ground-preparing work on the theoretical level still remains to be done; at the same time, as well, that the theoretical work is shifting its focus towards more practical matters, as indeed can be expected from research on the semantics / pragmatics interface.

Part I

Update Semantics

2

The Logic of Interrogation

Jeroen Groenendijk

2.1 Logic and Conversation

On the standard view, logic is concerned with reasoning, more in particular with fixing criteria for the soundness and validity of arguments. If we apply standard logic in natural language semantics, we inherit this basic trait, and can only expect our logical semantics to have descriptive and explanatory value for the kind of linguistic phenomena that are related closely enough to what the logic is about.

Reasoning is just one particular language game. And if we think of our daily conversations, it does not have the same central position it has in logic. Cooperative information exchange seems a more prevailing linguistic activity. It is reasonable to assume that such a predominant function has a distinctive influence on the structure of natural language, which forms the subject matter of linguistics. For example, it is a widespread (and age-old) idea, that the organization of discourse is largely determined by a mostly implicit process of raising and resolving issues, and that even sentential structure, including the intonational contour of utterances, can only be properly understood, if we take that to heart. If there is some truth in this, then linguistic semanticists should be worried by the fact that by and large they base themselves on a logical paradigm that is biased to such an extent towards reasoning rather than exchange of information.

As a response to this fear, one might point out that Gricean pragmatics is as much part of an overall theory of meaning, as logical semantics is. And the Cooperation Principle, which is at the heart

Questions in Dynamic Semantics.
Maria Aloni, Alastair Butler and Paul Dekker (eds.).
Current Research in the Semantics/Pragmatics Interface, Vol. 17.

of it, precisely is a principle of rationality which governs information exchange. Grice proposed to use it in the explanation of linguistic phenomena that lie beyond the reach of logical semantics as such. Among other things, he employed the principle in a defense of standard logic —in particular the truth functional analysis of the logical connectives— against the allegation that it leaves important aspects of meaning unaccounted for. He argued that standard logic together with the general assumption that we follow the Cooperation Principle does provide us with the means to account for such additional features of meaning. Hence, we are in no need to *replace* the standard logical analysis by some other type of interpretation, we only have to *combine* logical semantics with general pragmatic strategies to cover the relevant facts.

One way to look at the logical investigations carried out in the present paper, is to view them as an attempt to turn the Cooperation Principle as such into the key notion of logical semantics. Instead of centering the logic around the explication of what makes a piece of reasoning into a sound and valid argumentation, we intend the logic to judge whether a conversation proceeds in accordance with the principles of cooperative information exchange.

2.2 The Game of Logic

In logic we use a simple picture of an argument. An argument is conceived of as a sequence of sentences, of which all but the last one are called the premises, and the last sentence is called the conclusion of the argument. One can look upon an argument as the proceedings of a language game. If the game is played according to the rules, then the truth of the premises guarantees the truth of the conclusion. If such is the game of logic, then the logical notion of validity arbitrates whether the game was played according to the rules.

Argumentation is just one particular language game. For one thing, although there may be spectators, it is a solitary game, whence we can leave the player out of the logical picture. The more typical case, at least from a linguistic perspective, are dialogue games, which involve exchange of information among two or more participants. If we generalize the picture of the game of argumentation sketched above, then we arrive at the following.

A discourse is a sequence of utterances, the proceedings of a particular language game. The task of a logical analysis consists in providing us with logical notions which enable us to arbitrate the game, to characterize an utterance as a pertinent or impertinent move in the game.

In this paper, we study a simple dialogue game from this perspective:

Definition 2.1 (The Game of Interrogation) Interrogation is a game for two players: the *interrogator* and the *witness*. The rules of the game are as follows:

A. The interrogator may only raise issues by asking the witness non-superfluous questions.

B. The witness may only make credible non-redundant statements which exclusively address the issues raised by the interrogator.

The game of interrogation is a logical idealization of the process of co-operative information exchange, which makes stiff demands on the witness. The elements of the rules can be linked to elements of the Gricean Cooperation Principle: The requirement that the witness makes credible statements is related to the Maxim of Quality; that the statements of the witness should be non-redundant, and the questions of the interrogator non-superfluous, relates to the Maxim of Quantity; and that the witness should exclusively address the issues raised by the interrogator is a formulation of the Maxim of Relation.

From a linguistic perspective, our interest does not lie in the game as such. The empirical success of the logic of interrogation depends on whether it can be used in the explication of structural linguistic facts. We will give an illustration of that in Section 11 of the paper.

2.3 The Tools of Interrogation

Relative to a suitable language, and a semantic interpretation for that language, the logic of interrogation has to provide us with logical notions by means of which we can arbitrate the game. As a language for the game of interrogation, we use a simple query-language, a language of first order predicate logic enriched with simplex interrogatives:[1]

Definition 2.2 (Query-Language) Let PL be a language of predicate logic.
The *Query Language* QL is the smallest set such that:

i. If $\phi \in PL$, then $\phi \in QL$;

ii. If $\phi \in PL$, $\vec{x}$ a sequence of n variables $(0 \leq n)$, then $?\vec{x}\,\phi \in QL$.

[1] For more discussion about the language and its interpretation, see Groenendijk and Stokhof (1997), in particular Section 4.

In case the query-operator binds no variables, prefixing it to an indicative results in a *yes/no*-question. E.g., $?\exists xPx$ asks whether there is an object which has the property P. If the query-operator binds a single variable, a single *who*-question results. E.g., $?xPx$ asks which objects have the property P. When two variables are bound, as in $?xyRxy$, we get a question asking for the denotation of a two-place relation, it asks for a specification of which pairs of objects stand in the relation R. So, in general, we interpret an interrogative $?x_1 \ldots x_n\, \phi$ as asking for a specification of the actual denotation of an n-place relation.

We call the formulae of PL the *indicatives*, and the other formulae in QL the *interrogatives* of the language. We use ϕ, ψ, etc., as meta-variables which range over all sentences. Adding an exclamation point, as in $\phi!$, restricts the range to the indicatives, and adding an interrogation point, as in $\phi?$, to the interrogatives of the language. We refer to a sequence of sentences $\phi_1; \ldots; \phi_n$ as (the proceedings of) an *interrogation*, and use τ to range over such (possibly empty) sequences.

It is a convenient feature of the game of interrogation, that given the strict casting, we do not have to indicate who said what: interrogatives are uttered by the interrogator, indicatives by the witness. If the players were allowed to change roles, the proceedings of the game should include an indication of the source of each utterance.

2.4 Partitioning Logical Space

We state the semantics of the language in two steps. As our point of departure, we take a standard denotational semantics, and on top of that we define a notion of interpretation in terms of context change potentials.

As for the indicative part of the language, we assume a standard truth definition: $\|\phi!\|_{w,g} \in \{0,1\}$, where w is an element of the set of possible worlds W (first order models), and g an assignment of an element of the domain D to the individual variables. We assume a single domain for all worlds. Furthermore, we assume that the individual constants (names) of the language are interpreted as rigid designators.[2]

For the interrogatives in the language, we employ a *partition-semantics*. We take the denotation of an interrogative in a world to be the set of worlds where the answers to the question are the same:[3]

[2]These are not very natural assumptions to make in an epistemic setting. See Aloni (2001) for a discussion of the issue, and an analysis which makes it possible to lift these assumptions.

[3]See Groenendijk and Stokhof (1984, 1997) for extensive discussion of the partition semantics for interrogatives.

Definition 2.3 (Semantics of Questions)
$\|?\vec{x}\,\phi\|_{w,g} = \{v \in W \mid \forall \vec{e} \in D^n \colon \|\phi\|_{v,g[\vec{x}/\vec{e}]} = \|\phi\|_{w,g[\vec{x}/\vec{e}]}\}$.

Whereas an indicative $\phi!$ *selects* a subset of the set of worlds: the worlds where $\phi!$ is true, an interrogative $\phi?$ *divides* the set of worlds into a number of (mutually exclusive) *alternatives*. For example, the question $?\exists xPx$ divides the set of worlds into two alternatives: the alternative consisting of the worlds where some object has the property P, and the alternative consisting of the worlds where there is no such object in the domain. The question $?x\,Px$ divides the set of worlds in as many alternatives as there are possible denotations of the property P. And the question $?xy\,Rxy$ divides the set of worlds in as many alternatives as there are possible denotations of the relation R.

The meaning of an interrogative corresponds to a *partition* of the set of possible worlds W. Hence, it also corresponds to an *equivalence relation* on W. It is the latter way of modeling a question that we will employ in formulating the context change potential of interrogatives.

2.5 Structuring the Context

In general, a semantics for a language in terms of context change potentials states the interpretation of a sentence as an operation on contexts. Hence, in order to formulate such a semantics for a particular language, we have to decide on a suitable notion of context.

Our query-language consists of two different types of sentences, with different functions, and different effects on the context. The function of indicatives is to provide *data*, the function of interrogatives is to raise *issues*. So, we could look upon a context as consisting of two elements: data and issues.[4]

We can model contextual data as a set of worlds, those worlds which are compatible with the data provided by the preceding discourse. Then, in general, the context change potential of an indicative will be to *eliminate possible worlds*.

We can model contextual issues as an equivalence relation on the set of possible worlds. If two worlds are non-related, i.e., if they belong to different contextual alternatives, then it is a contextual issue whether the actual world is like the one or like the other. The differences between related worlds, i.e., worlds which belong to the same alternative, is not a contextual issue.

Since interrogatives raise issues, their context change potential

[4]The terminology is taken from Hulstijn (1997), who defines an update semantics for questions in a similar way.

is to *disconnect* certain worlds, creating new or more fine-grained contextual alternatives. The context change potential of an interrogative consists in *eliminating pairs of worlds*—without eliminating the worlds themselves from the data: interrogatives do not provide data, they only raise issues.

Instead of splitting the context into two separate elements, a subset of the set of worlds representing the data, and an equivalence relation on the set of worlds representing the issues, we combine the two in modeling a context as an equivalence relation on a subset of the set of possible worlds. Or, equivalently:[5]

Definition 2.4 (Structured Contexts)
A *context* C is a symmetric and transitive relation on the set of possible worlds W.

Two worlds are contextually related iff they both belong to the divided subset and to the same alternative. A world w belongs to the divided subset iff $\langle w, w\rangle \in C$, which by abuse of notation, we write as $w \in C$. The set of contexts is partially ordered by $\subseteq$. The minimal context is W^2, the *initial context* of ignorance and indifference, where no data have been provided, and no issue has been raised. The *absurd context*, $\emptyset$, results if the contextual data are inconsistent. An *indifferent context* is a context such that $\forall w, v \in C\colon \langle w, v\rangle \in C$, a context where all worlds in the data are related, i.e., a context where there are no (unresolved) issues.

2.6 Changing the Context

In defining the context change potentials of the formulae of our query-language, we restrict ourselves to the sentences, the closed formulae of QL. The definition uniformly interprets indicatives and interrogatives as functions from contexts to contexts, but they have a different kind of effect on the context:

Definition 2.5 (Context Change Potentials)

i. $C[\phi!] = \{\langle w, v\rangle \in C \mid \|\phi!\|_w = \|\phi!\|_v = 1\}$;

[5]What is used here as the notion of context, a symmetric and transitive relation on the set of possible worlds, could also be taken as a notion of semantic content, replacing the usual notion of a proposition as a set (property) of possible worlds. The content of any sentence can then be taken to consist of a (possibly empty) assertive part, and a (possibly empty) interrogative part. The content of a sentence can be a mix of asserting/presupposing data and raising/supposing issues.

ii. $C[\phi?] = \{\langle w, v\rangle \in C \mid \|\phi?\|_w = \|\phi?\|_v\}$;
iii. For $\tau = \phi_1; \ldots; \phi_n$, $C[\tau] = C[\phi_1] \ldots [\phi_n]$.

An indicative $\phi!$ eliminates a pair of worlds from the context as soon as $\phi!$ is false in one of the worlds of the pair. In effect, this means eliminating worlds from the contextual data. An interrogative $\phi?$ eliminates a pair of worlds (disconnects two worlds) if they belong to different alternatives, i.e., if the two worlds differ in such a way that the question would receive a different answer in them. Interpreting an interrogation, a sequence of a mix of interrogatives and indicatives, is just interpreting the sentences in the sequence one by one.

It can easily be checked that all context change potentials in the language have the *classical update property*: $\forall C, \phi : C[\phi] \subseteq C$.[6] Further we note:

Fact 2.1 (Indicatives and Interrogatives)

a. $\forall C, w, v\colon \langle w, v\rangle \in C \;\&\; w, v \in C[\phi!] \Rightarrow \langle w, v\rangle \in C[\phi!]$.
b. $\forall C, w\colon w \in C \Rightarrow w \in C[\phi?]$.

Fact 1b says that interrogatives cannot eliminate worlds from the data, they can only eliminate pairs of worlds, i.e. disconnect worlds, leaving both of them in the data as such. Fact 1a says that indicatives cannot disconnect worlds: if two worlds are connected in the data, then if both remain in the data, they remain connected.[7]

Now that we have specified the logical language and its semantics, we turn to a specification of the logical notions by means of which we can arbitrate whether an interrogation is played according to the rules of the game.

2.7 Consistency and Entailment

One of the elements of the rules of the game of interrogation, the *Maxim of Quality*, is that the witness may only make *credible* statements. From a minimal, purely logical perspective, giving the witness every benefit

[6] This is why in the title of the paper it says: *Classical Version*. Originally, the logic of interrogations presented here was designed in a non-classical, dynamic setting, which lacks the classical update property. The richer system, also allowing for anaphoric relations across utterances, will be discussed in another paper. See also Groenendijk (1998).

[7] This fact about the complete division of labor between indicatives and interrogatives is specific for the language at hand, and not a necessary feature. Mixed cases of sentences which both provide/presuppose data and issues can be accommodated without difficulty.

of the doubt, her statements can be judged credible as long as she does not contradict herself. This requirement is covered by the logical notion of contextual consistency:

Definition 2.6 (Consistency)
ϕ is *consistent with* τ iff $\exists C\colon C[\tau][\phi] \neq \emptyset$.

A sentence ϕ is consistent with a preceding sequence τ, if there is at least some context C such that after an update of C with τ, a further update with ϕ does not lead to absurdity.

Since interrogatives do not eliminate worlds from the data, but can at most disconnect worlds in the data (Fact 1b), as long as the context is not absurd, an interrogative will always be consistent with it. Hence, the Quality Maxim cannot fail to be obeyed by the interrogator, only the witness may fail to do so.

Two other elements of the rules, both instances of the *Maxim of Quantity*, are that the witness may only make *non-redundant statements*, and that the interrogator may only ask *non-superfluous questions.* From a minimal, purely logical perspective, a statement is redundant, and a question superfluous, in case it is already entailed by the preceding context:

Definition 2.7 (Entailment) $\tau \models \phi$ iff $\forall C\colon C[\tau] = C[\tau][\phi]$.

A sentence ϕ is entailed by a preceding sequence τ, if after an update of a context C with τ, a further update with ϕ will never make a difference.

Contrary to what is the case in the game of reasoning, entailment is a vice rather than a virtue in the game of interrogation. Although defined in a uniform way, non-entailment means something different for indicatives and interrogatives:

Fact 2.2 (Informativeness and Inquisitiveness)

a. $\tau \not\models \phi!$ iff $\exists C, w\colon w \in C[\tau]$ & $w \notin C[\tau][\phi!]$.

b. $\tau \not\models \phi?$ iff $\exists C, w, v\colon \langle w, v\rangle \in C[\tau]$ & $\langle w, v\rangle \notin C[\tau][\phi?]$.

Indicatives, and only indicatives, can be *informative*, which means that at least in some context, some world is eliminated. Interrogatives, and only interrogatives, can be *inquisitive*, which means that at least in some context, some pair of worlds is disconnected.

The notions of consistency and entailment are standard logical notions. New is at most that they indiscriminately apply to statements and questions, and that we focus on the use of these notions in the formulation of Quality and Quantity requirements for the cooperative exchange of information, instead of as criteria for the soundness and validity of reasoning.

In fact, the latter would only make sense for the indicative part of the language. Which is not to say that, e.g., $\phi?\models \psi?$, or $\phi!\models \psi?$, makes no sense. The latter means that $\psi?$ is a superfluous question to ask after having been told that $\phi!$, i.e., that $\phi!$ has already completely resolved the issue raised by $\psi?$. It is not unusual to read this as: $\phi!$ *gives a complete answer to* $\psi?$, which is only a bit unnatural given that in $\phi!\models \psi?$, the answer precedes the question. However, when read in the other direction, $\psi?\models \phi!$, the entailment only holds in case $\models \phi!$, which is only logical, given that questions provide no data. What $\phi?\models \psi?$ means is that the question $\psi?$ is superfluous after $\phi?$ has already been asked, which is the case if whenever the issue raised by $\phi?$ is resolved, the issue raised by $\psi?$ cannot fail to have been resolved as well.

Although the familiar notions of contextual consistency and entailment have a minor role to play in the logic of interrogation as minimal requirements on the sensibility of utterances as moves in a game of information exchange, we have not yet touched upon the more central aspect, which is that information provided by the witness should be relevant to the issues that have been raised by the interrogator. We turn to that heart of the matter now.

2.8 Licensing and Pertinence

The last element of the rules, the *Maxim of Relation*, is that the statements of the witness should *exclusively address the issues* raised by the interrogator. This requirement is covered by the new logical notion of licensing:

Definition 2.8 (Licensing)
τ *licenses* ϕ iff $\forall C, w, v\colon \langle w, v\rangle \in C[\tau]\ \&\ w \notin C[\tau][\phi] \Rightarrow v \notin C[\tau][\phi]$.

A sentence is contextually licensed if whenever a world is eliminated from the data, all worlds related to it are eliminated as well, i.e., the whole alternative to which the world belongs is eliminated. Licensing forbids the elimination of some world in some alternative, leaving some other world from the same alternative in the data. In eliminating some world, a sentence would be informative, but if it does not eliminate a whole alternative at the same time, the information provided does not exclusively address the contextual issues. The sentence would provide irrelevant information, information not directly related to the contextual issues.[8]

Note that since interrogatives never eliminate any world from the data, they are trivially licensed. As was the case with consistency, licensing only puts constraints on the statements of the witness, but reckons any question from the interrogator to be relevant.[9] Note also that if an indicative $\phi!$ is inconsistent with τ or is entailed by τ, then $\phi!$ is trivially licensed by τ.

Consistency and non-entailment are added to the requirement of licensing in the over-all notion of pertinence, the logical notion which arbitrates whether an interrogation is played according to the rules:

Definition 2.9 (Pertinence) ϕ is *pertinent after* τ iff

i. ϕ is consistent with τ (*Quality*)
ii. ϕ is not entailed by τ (*Quantity*)
iii. ϕ is licensed after τ (*Relation*)

As indicated, the three elements of logical pertinence can be related to the Gricean Conversational Maxims (leaving *Manner* out of consideration) which constitute the Cooperation Principle. But whereas the Gricean notions are usually thought of as belonging to a level of pragmatics which comes on top of logical semantics, here they make up the logic as such. In the logic of interrogation the notion of pertinence plays the same methodological role as the notion of entailment normally does. Whereas the latter arbitrates the game of argumentation, the former arbitrates the game of interrogation.

2.9 Putting Licensing to the Test

Intuitively, a good criterion for logical relatedness of a sentence ϕ to the contextual issues is the following: If ϕ gives any information in the context at all, then ϕ at least partially resolves the contextual issues. The latter is the case if at least one of the contextual alternatives is eliminated.[10] The notion of licensing meets this criterion:

---

[8] In Jäger (this volume), a similar relevance notion can be found, but baked right into the semantics as such, and not as a logical notion which comes on top of the semantics to arbitrate appropriateness.

[9] This is a feature particular to the present set-up. One could add requirements of relatedness for the questions of the interrogator as well.

[10] The notion of resolution, defined as eliminating at least one alternative, is the usual notion of a giving a partial answer in a partition semantics for questions, next

Fact 2.3 (Adequacy Test) τ licenses ϕ iff for all contexts C:

if $\exists w\colon w \in C[\tau]$ & $w \notin C[\tau][\phi]$
(*if* ϕ *is informative in* $C[\tau]$),
then $\exists w \in C[\tau]\colon \forall v\colon \langle w, v\rangle \in C[\tau] \Rightarrow v \notin C[\tau][\phi]$
(*then* ϕ *is resolvent in* $C[\tau]$).

This says that τ licenses ϕ is materially the same as: for any context C, if ϕ is informative in C after τ, then ϕ is resolvent in C after τ. I.e., as soon as ϕ eliminates a world from the data, ϕ cannot fail to eliminate a contextual alternative.

At first sight, this property may seem weaker than licensing. Relative to a particular context, a sentence ϕ can be informative and resolvent, in case next to eliminating some whole alternative, ϕ also eliminates some world in some other alternative without eliminating that alternative as a whole. However, if that were the case, then there would also be some other context where ϕ is informative, but not resolvent. It is by quantifying over *all* contexts, that being resolvent when informative, amounts to the same as licensing.[11]

That logical relatedness requires addressing contextual issues, is most clearly indicated by the fact that an indicative ϕ is licensed iff the corresponding *yes/no*-question $?\phi$ is contextually non-inquisitive:

Fact 2.4 (Relatedness Test)
Let ϕ be an indicative. τ licenses ϕ iff $\tau \models ?\phi$.

We refer to this fact as the Relatedness Test, because it gives a way of judging whether an indicative utterance is related to the contextual issues. If when ϕ is uttered, the corresponding question whether $?\phi$ is inquisitive, this means that the question is new, and not already present. Hence, the utterance is not licensed by the issues that have

to the notion of giving a complete answer, defined as $\phi \models \psi?$. Unlike the notion of an answer defined in the next section, both notions have in common that they allow for over-informative answers. The main feature of the present approach is that it starts out from precisely forbidding that.

[11] There is no space to go into this here, but there is also an important difference between the notion of licensing and the notion of being resolvent when informative. Unlike the latter notion, licensing is *grounded*. By this we mean that being licensed is the same as being licensed in the initial context of ignorance and indifference, updated with whatever went on in the discourse. The notions of consistency and non-entailment are grounded as well, which means that pertinence is also a grounded notion. So, in calculating pertinence one only has to reckon with one single minimal context. Whatever counts as appropriate there, is appropriate *per se*.

already been raised (and are not yet resolved) in the context.

Pertinence is a notion of contextual appropriateness, where the latter is usually taken to relate to presuppositions. Pertinence is a presuppositional notion:

Fact 2.5 (Presupposition Test)
$\neg\phi$ is pertinent after τ iff ϕ is pertinent after τ.

Putting the last two facts together, we can say that under the notion of pertinence, an indicative sentence presupposes the corresponding *yes/no*-question, in the sense that it should be non-inquisitive in the context, i.e., it should be a contextual issue.

In Section 11 we shall see, that taking the intonation contour of sentences into account, indicative sentences may also presuppose stronger *who*-questions.

2.10 Pertinent Answers

The new notion of licensing also gives rise to a new logical notion of an answer. An answer can be characterized as the special case of an indicative being licensed in the context of a single interrogative:

Definition 2.10 (Answers)
$\phi!$ is an *answer* to $\psi?$ iff $\phi!$ is licensed by $\psi?$

In Section 7, we noted that inconsistency and entailment imply relatedness. Hence, tautologies and contradictions are borderline cases of trivial and absurd answers. Apart from absurd and trivial answers, which answer any question, there are two (non-equivalent) answers to *yes/no*-questions:

Fact 2.6 (Yes/No)
ϕ is an answer to $?\psi$ iff $\models \phi$ or $\models \neg\phi$ or $\phi \Leftrightarrow \psi$ or $\phi \Leftrightarrow \neg\psi$.

Adding Quality and Quantity to the requirement of Relation, we arrive at the more informed notion of pertinent answers:

Definition 2.11 (Pertinent Answers)
$\phi!$ is a *pertinent answer* to $\psi?$ iff $\phi!$ is pertinent after $\psi?$.

Being a pertinent answer just excludes absurd and trivial answers:

Fact 2.7 (Pertinency and Contingency)
ϕ is a pertinent answer to $\psi?$ iff ϕ is an answer to $\psi?$ & $\not\models \phi$ & $\not\models \neg\phi$.

Only non-trivial questions ($\not\models \psi?$) have pertinent answers, and only equivalents of *yes* and *no*, are pertinent answers to non-trivial *yes/no*-questions. As for single *who*-questions, such as $?x\,Px$, an atomic sentence like Pa is a (pertinent) answer:[12]

Fact 2.8 (Literal Answers) $[\vec{c}/\vec{x}]\phi$ is an answer to $?\vec{x}\,\phi$.

Given the presuppositional nature of licensing and pertinence, answerhood is preserved under negation:

Fact 2.9 (Negative Answers)
ϕ is a (pertinent) answer to $\psi?$ iff $\neg\phi$ is a (pertinent) answer to $\psi?$.

Sentences which only state something about the cardinality of the set of objects that have the property P, are also answers to the question $?x\,Px$. For example, $\exists xPx$ and $\forall xPx$ are (pertinent) answers to $?x\,Px$.

The notion of an answer defined in terms of licensing differs from the standard notion of an answer in a partition theory of questions, which, as we mentioned in Section 7, is formulated as $\phi! \models \psi?$. The standard notion is both less and more demanding than the one defined here in terms of licensing.

The standard notion of an answer is less demanding in that it allows for *over-informative answers*, whereas the notion of an answer in terms of licensing typically does not. Under the standard notion, if ϕ counts as an answer to $\psi?$, then for arbitrary χ, also $\phi \wedge \chi$ counts as an answer to $\psi?$. Under the present notion, it does so only if χ as such, is also an answer to $\psi?$:

Fact 2.10 (Conjoined Answers) If ϕ is an answer to $\psi?$, and χ is an answer to $\psi?$, then $\phi \wedge \chi$ is an answer to $\psi?$.

[12] This feature makes it possible to link the logically elegant partition view of questions with a notion of answers that meets linguistic intuitions. In Groenendijk and Stokhof (1984) and elsewhere, we argued at length on logical grounds against Hamblin's and Karttunen's semantic analyses of questions. Nevertheless, almost without exception, linguistic semanticists fall back on these analyses, because they dislike the notion of exhaustive answers that seems to be baked into the partition view. Under the present notion of an answer, linguists can have their cake and eat it.

Given that answerhood is also preserved under negation, other logical operations which can be defined in terms of negation and conjunction, like disjunction, also preserve answerhood.

The standard notion of an answer is more demanding in that it is a notion of *exhaustive* answering. E.g., whereas under the present notion $Pa \wedge Pb$ counts as a (pertinent) answer to $?x\, Px$, under the standard notion it does not. Only an explicitly exhaustive answer, like $Pa \wedge Pb \wedge \neg\exists x(Px \wedge x \neq a \wedge x \neq b)$, is an answer under the standard notion. Under the notion defined here, the explicitly exhaustive answer can be characterized as a better, a more informative answer:[13]

Definition 2.12 (Comparing Answers)
Let ϕ, χ be pertinent answers to $\psi?$.
ϕ *is a more informative answer to* $\psi?$ *than* χ iff $\phi \models \chi$ & $\chi \not\models \phi$.

In fact, the explicitly exhaustive answer counts as an *optimal answer* to the question, in the sense that there are no pertinent answers to $?x\, Px$ which are more informative. Note that: If ϕ is an optimal answer to $\psi?$, then $\phi \models \psi?$.

The focus of the present paper is not so much on the relation of answering as such, but rather on the more general issue of the role of the logical notions of licensing and pertinence in arbitrating the appropriateness of utterances from the perspective of cooperative information exchange. The following section is devoted to the discussion of some examples.

2.11 An Illustration. And Nothing Else

The examples given below are only intended as an illustration of, and partly as further motivation for, the logical notions introduced above, in particular the new notion of licensing. We make no claims to the effect that we present linguistic analyses, or provide alternative explanations as compared to other approaches.

2.11.1 Resolving an Ambiguity with an Issue

Consider the following example. Out of context, and without intonational information, (1a) is ambiguous between (1b) and (1c):[14]

[13] Precisely because the notion of licensing forbids over-informativeness, we obtain this easy way of comparing answers in terms of informativeness. Compare this with the much more intricate notions of comparing answers in Groenendijk and Stokhof (1984, 1997).

[14] English is not the perfect language for this type of example, because of the easy availability of *do*-support. Lacking *do*-support, Dutch would be better.

(1) a. Alf rescued Bea. And no-one else.
b. Rab; $\neg\exists x(Rxb \wedge x \neq a)$
c. Rab; $\neg\exists x(Rax \wedge x \neq b)$

However, after the interrogative in (2a), or with the intonational information indicated by underlining in (2a), the ambiguity in (1a) is resolved:

(2) a. (Who rescued Bea?) <u>Alf</u> rescued Bea. And no-one else.
b. $?x\,Rxb$; Rab; $\neg\exists x(Rxb \wedge x \neq a)$
c. $?x\,Rxb$; Rab; $\neg\exists x(Rax \wedge x \neq b)$

Only (2b) is a plausible interpretation for (2a), and not (2c). Alternatively, after the interrogative in (3a), or with the intonational information indicated by underlining in (3a), (3a) can only be interpreted as (3c), and not as (3b):

(3) a. (Whom did Alf rescue?) Alf rescued <u>Bea</u>. And no-one else.
b. $?x\,Rax$; Rab; $\neg\exists x(Rxb \wedge x \neq a)$
c. $?x\,Rax$; Rab; $\neg\exists x(Rax \wedge x \neq b)$

Our logic of interrogation accords with the difference between (2a) and (3a). Both the interrogations (2b) and (3c) are pertinent. The interrogatives $?x\,Rax$ and $?x\,Rxb$ are both inquisitive. And both the sequence of indicatives in (3b) and in (3c) are contingent. More importantly, Rab is licensed by (is an answer to) both $?x\,Rxb$ and $?x\,Rax$. And $\neg\exists x(Rxb \wedge x \neq a)$ is licensed by $?x\,Rxb$; Rab, just as $\neg\exists x(Rax \wedge x \neq b)$ is licensed by $?x\,Rax$; Rab.

Given that $?x\,Rxb$ asks for the specification of the (whole) denotation of the property $\lambda x Rxb$, the answer that a has that property may leave the interrogator with the question whether anyone else does. And this is precisely the issue that $\neg\exists x(Rxb \wedge x \neq a)$ addresses. We can also inspect this by performing the Relatedness Test: the *yes/no*-question $?\exists x(Rxb \wedge x \neq a)$ is non-inquisitive after $?x\,Rxb$; Rab. Hence, $\neg\exists x(Rxb \wedge x \neq a)$ is contextually licensed, it is an issue the witness is entitled to address.

But *not* the other way around: the sequences in (2c) and (3b) are impertinent. The sentence $\neg\exists x(Rax \wedge x \neq b)$ is not licensed by $?x\,Rxb$; Rab. And the sentence $\neg\exists x(Rxb \wedge x \neq a)$ is not licensed by $?x\,Rax$; Rab. That Alf rescued no-one else but Bea, can be informative in a state in which the question has been raised who rescued Bea, without being resolvent after the answer has been given that Alf rescued Bea, and hence, is not licensed by the context.

A simple counterexample against licensing, is the situation where the interrogator already knows that one and only one person rescued Bea. She wants to know who it was. After her question to that effect, and having been told by the witness that it was Alf, the state of the interrogator is a state of indifference. Still, that Alf rescued no-one else, can very well be informative in her state. Only she did not ask for that. That Alf rescued no-one else does not resolve a contextual issue. Such a counterexample shows that the last sentence of (2c) is not licensed by the context, which makes it impertinent.

Again, we can also put the Relatedness Test to work: the *yes/no*-question $?\exists x(Rax \wedge x \neq b)$ is inquisitive after $?x\, Rxb;\ Rab$. This means that $\neg\exists x(Rax \wedge x \neq b)$ is not licensed by the context. In the context of $?x\, Rxb;\ Rab$, it addresses an issue which was not raised by that context.

What the discussion of these examples suggests is the following. One way of accounting for the resolution of the ambiguity in (1a), in the contexts (2a) and (3a), is that we cooperatively interpret (2a) and (3a) in such a way that our interpretation gives rise to a pertinent discourse, where each sentence is licensed by the preceding context. That is how we arrive at (2b) and (3c), and not at (2c) and (3b), as appropriate interpretations for (2a) and (3a).

2.11.2 Presupposing an Issue

If we swap the interrogatives in (2a) and (3a), leaving the intonational contour of the utterances the same, the resulting interrogations are not appropriate, e.g., compare (2a) with (4a):

(4) a. *Whom did Alf rescue? <u>Alf</u> rescued Bea. And no-one else.
b. $?x\, Rax;\ \ll ?x\, Rxb \gg Rab;\ \neg\exists x(Rxb \wedge x \neq a)$

The intuition is that with the intonation contour as indicated in (4a), the first indicative simply does not fit the interrogative. It fits the interrogative we originally had in (2a), not this one in (4a). A natural conclusion to draw is that the intonation contour as such has some semantic impact, because otherwise, we are (semantically) out of business in explaining what is wrong with (4a).

Along not unusual lines, we might account for the unacceptability of (4a), in a presuppositional setting, by assuming that the intonation contour of the first indicatives in (2a) and (3a), presuppose the issue raised by the interrogatives in (2a) and (3a). We can look upon the sequences in (2b-c) and (3b-c) as the result of presupposition accommodation. In (4b), I indicated that by fronting the first utterance of the witness, with the corresponding presupposed question between double angled brackets.[15]

[15] This is only a bit of suggestive notation. The semantics presented in Section 6 does not take presuppositions into account. It would declare $C[\ll \phi \gg \psi] = C[\psi]$,

Now we are back in business. If anything may be assumed, then it is that, leaving accommodation aside, if a question is presupposed, it is to be non-inquisitive in the context. Just as, leaving accommodation aside, a presupposed indicative should be non-informative in the context. Then we are quickly ready with explaining what is wrong with (4a): $?x\, Rxb$ is inquisitive after $?x\, Rax$, the unacceptability of (4a) is due to presupposition failure.

A general feature of presuppositions is that they are preserved under negation. As we noted above, contextual relatedness is of a presuppositional nature. An utterance of an indicative ϕ always presupposes the corresponding *yes/no*-question. Returning to the type of examples we are discussing here, where we take intonational contour into consideration, if we think along these presuppositional lines, then we can represent (3a) out of context, but with the intonation contour as indicated in (5a), as (5b):

(5) a. Alf rescued Bea. And no-one else.
    b. $\ll ?x\, Rxb \gg Rab;\ \neg\exists x(Rxb \wedge x \neq a)$

Just concentrating on the first sentence, we see that as compared to the general presupposition of indicatives we just noted, that ϕ presupposes the *yes/no*-question $?\phi$, the effect of the intonation contour in the first sentence of (5a), according to the representation in (5b), leads to a *stronger* presupposed *who*-question. The stronger presupposition is also preserved under negation:

(6) a. Alf did not rescue Bea. And, also, no-one else.
    b. $\ll ?x\, Rxb \gg \neg Rab;\ \neg\exists x(Rxb \wedge x \neq a)$

Observe that if we consider the first sentence in (6a) with a neutral intonation contour, we get back the same kind of ambiguity we found in (1a), where the second reading is the only one which (7a) has:

(7) a. Alf did not rescue Bea. And, also, no-one else.
    b. $\ll ?x\, Rax \gg \neg Rab;\ \neg\exists x(Rax \wedge x \neq b)$

Next to preservation under negation, the possibility to be cancelled is another characteristic feature of presuppositional phenomena. Compare (2a) with (8a):

(8) a. (Who rescued Bea?) Alf rescued Bea. And, actually, no-one else.
    b. ??(Who rescued Bea?) Alf rescued Bea. And he rescued no-one else.

---

if $C[\phi] = C$, else undefined. Note that indicative and interrogative presuppositions are uniformly dealt with in this way.

Unlike in (2a), in (8a) the ambiguity of (1a) turns up again. Actually, I tend to believe that for (8a) the reading in (2c), which was excluded for (2a), is more salient than the reading in (2b), the only acceptable reading of (2a). The word *actually* crucially seems to give rise to the availability of both readings. Apparently, the conversational effect of *actually*, is an indication of the fact that the issue at hand is being overruled.

Unlike in the artificial language game of interrogation, in real discourse we may invent the issues we want to address ourselves. As (8a) shows, although we are not asked for that, we may provide the additional piece of information that rescuing Bea was Alf's only heroic act. Does this get in the way of the role of our strict notion of relatedness in steering discourse, and determining its appropriateness? I don't think so. The relevant observation is, that if one overrules relatedness to a contextually given issue, and addresses a new issue, as happens in (8a), then one explicitly marks one's utterance for having this effect. If relatedness did not operate, there would be no need for that. So, my hypothesis is, that (8b) is not an appropriate sequence, that is, unless one way or the other, for example, by adding special intonation contour to the utterance (AAANNNDDD!...), the utterance is marked for providing extra unsolicited information.

2.11.3 How Accommodating Can One Get?

The two sentence sequence in (9a) is just as alright as the three sentence sequence in (2a); and from the unavailability of the reading (2c) for (2a), we may expect that (10a) is hardly acceptable:

(9) a. Who rescued Bea? Only Alf rescued Bea.
b. $?xRxb;\ Rab \wedge \neg\exists x(Rxb \wedge x \neq a)$

(10) a. ??Who rescued Bea? Alf rescued only Bea.
b. $?xRxb;\ Rab \wedge \neg\exists x(Rax \wedge x \neq b)$

The following examples also give an illustration of that:

(11) Did Alf rescue Bea? Yes he did. And, in fact, he rescued only Bea.

(12) ??Did Alf rescue Bea? Alf rescued only Bea.

The last two sentences of (11), and the last sentence in (12), provide the same information. Still, the discourse in (11), where we first just resolve the issue raised by the interrogative, and then go on to provide some extra information that is not asked for as such, is alright. But if we make the answer as such over-informative, as in (12), by putting the extra information already in it, the acceptability of the resulting discourse is questionable.

Although the examples discussed above support the idea that the strict notion of contextual relatedness embodied in the notion of licensing is operative in a structural way, it is hard to believe that just being a bit over-informative is always punished so harshly. The following example is a case in point:

(13) a. Did someone rescue Bea? Alf rescued Bea.
b. $?\exists xRxb$; Rab

The indicative in (13), is impertinent after the *yes/no*-question. Only $\exists xRxb$ and $\neg\exists xRxb$ are pertinent in the context of the question $?\exists xRxb$. The sentence Rab properly entails $\exists xRxb$, and hence counts as over-informative. However, intuitively, the information that Rab is such a natural elaboration of $\exists xRxb$, anticipating the further question: *Who?*, that it seems wrong to deem it impertinent in the context. Rather than blaming her for being uncooperative, the witness deserves praise for her accommodating attitude.

Note, first of all, that the indicative in (13a) really needs the intonation contour indicated in (14a):

(14) a. Did someone rescue Bea? <u>Alf</u> rescued Bea.
b. $?\exists xRxb$; $\ll ?x\ Rxb \gg Rab$

In line with the observations made above, this means that the indicative presupposes the issue who rescued Bea, and should be represented as in (14b), and not as in (13b). However, this does not yet explain why the sequence feels alright. The issue $?x\,Rxb$ is not implied by $?\exists xRxb$, but rather the other way around: $?x\,Rxb \models\ ?\exists xRxb$. The issue presupposed by the indicative in (14), is stronger than the issue posed by the question, and hence is inquisitive in the context.

Note, secondly, that although it is perhaps a more standard way to react to the question, it seems not really obligatory to first say: *Yes*, as in (15a):

(15) a. Did someone rescue Bea? Yes, <u>Alf</u> rescued Bea.
b. $?\exists xRxb$; $\exists xRxb$; $\ll ?x\,Rxb \gg Rab$

If this were the case, we would arrive at (15b), and the present examples would fit in with the observation made above, that providing extra information is allowed only after the contextual issue has been resolved.

However, if, as I assume, (14a) as such is fully appropriate, then, as it stands, the logic of interrogation does not give us the means to account for this. One way to approach the matter might be to add a notion of contextual relatedness for questions, which explains why the issue presupposed by the last utterance in (14a) is so closely related to the opening *yes/no*-question, that its accommodation takes no effort.

Another way to address this issue might be to interpret the effect of focussing in the indicative utterance in (14a) in such a way, that it involves existential quantification, and amounts to the same thing as we find in (15b). But further investigations along these lines have to be left to another occasion.

2.12 Summary and Conclusion

In this paper, we investigated the prospects of basing logic on cooperative information exchange instead of valid reasoning. To this end, we introduced a simple dialogue game of interrogation. Relative to a minimal logical query-language suitable for the game, and a semantic interpretation for that language in terms of context change potentials, we defined a logical notion of pertinence, which enables us to arbitrate whether the game is played according to the rules. The elements of pertinence —contextual consistency, non-entailment, and licensing— were seen to correspond to elements of the Gricean Cooperation Principle. The main novelty is the notion of licensing, by which we can judge whether an utterance is logically related to the context. We illustrated the use of the logic of interrogation in natural language semantics by considering some linguistic examples, which exhibit phenomena which are inherently related to the communicative function of language.

We hope to have shown that a reorientation of logic towards raising and resolving issues is a feasible enterprise, which is interesting both from a logical and from a linguistic perspective. It leads to a new notion of meaning as cognitive content, which treats data and issues as equal citizens. In doing so, logical semantics invades the territory of pragmatics. Instead of viewing semantics and pragmatics as constituting two separate components within a theory of meaning, we make a move towards an integrated theory by shifting the logical perspective from valid argumentation to cooperative communication.

3

Axiomatizing Groenendijk's Logic of Interrogation

Balder ten Cate and Chung-chieh Shan

Jeroen Groenendijk (1999, reprinted in this book) introduced a logic, which he called the *Logic of Interrogation* (henceforth LoI), that can be used to analyze which linguistic answers are appropriate in response to a given question. Groenendijk gave only a semantic definition of his logic. For practical applications like building question-answering systems, however, we also need to understand the *proof theory* of this logic (Monz, 2003b, Section 2.4). A better understanding of the proof theory of LoI also enables us to better grasp the empirical predictions made by the model.

In this chapter, we bridge this gap, by providing a sound and complete axiomatization for LoI. Furthermore, we will show that the entailment relation of LoI is closely related to the model-theoretic notion of *definability*. Roughly speaking, the question *Who came to the party?* entails the question *Did anybody come to the party?* in LoI because the proposition that someone came to the party is definable in terms of the property of having come to the party (in the same way that the first-order sentence $\exists x.Px$ is definable in terms of the property P). This connection between question entailment and definability also shows up in the fact that an answer to a natural-language question is typically built up from instances of the question.

Organization of this chapter Section 3.1 briefly recalls the definition of the logic LoI. Section 3.2 presents our main technical result,

Questions in Dynamic Semantics.
Maria Aloni, Alastair Butler and Paul Dekker (eds.).
Current Research in the Semantics/Pragmatics Interface, Vol. 17.

namely a connection between entailment in LoI and Beth's definability theorem for first-order logic. This result is subsequently put to use in Section 3.3, where we provide a sound and complete axiomatization of LoI.

In Section 3.4, we explain how LoI can be seen not only as a logic for reasoning about linguistic questions and answers, but also with natural interpretations in mathematics, database theory, and philosophical logic. With the application of question answering in mind, we also mention a link between optimal answers and uniform interpolation, in Section 3.5.

Unifying these investigations is our view that LoI is a logic about equivalence relations between models. Different types of equivalence relations (isomorphisms, homomorphisms, bisimulations, etc.) give rise to different notions of definability and different logics of interrogation. To illustrate this, in Section 3.6 we consider a variation of LoI, in which possible worlds may have *varying domains*, and extend our results to that setting, giving again a sound and complete axiomatization.

We conclude in Section 3.7.

3.1 The Logic of Interrogation

The Logic of Interrogation was introduced by Groenendijk (1999). Its logical language, called *QL*, is an extension of first-order logic with questions. We define it as follows.[1]

Definition 3.1 (Syntax of LoI) *QL* is the set containing $!\phi$ for every sentence ϕ of first-order logic (the *assertions* or *indicatives*), and $?\psi$ for every formula ψ of first-order logic (the *questions* or *interrogatives*).

For convenience, we will assume there are no function symbols of positive arity. (Such function symbols may be replaced by relation symbols if needed.) Notice that questions can contain free variables, whereas assertions cannot. In what follows, lowercase Greek letters $\theta, \eta, \ldots$ will denote elements of *QL* (that is, questions or assertions), and uppercase Greek letters $\Sigma, \Gamma, \ldots$ will denote finite (possibly empty) sequences of elements of *QL*.

Groenendijk defines an entailment relation $\Gamma \models \theta$ between finite sequences Γ of elements of *QL* and elements θ of *QL*. An example of

[1]Our notation slightly differs from that of Groenendijk. In Groenendijk's notation, questions are of the form $?x_1 \ldots x_n.\phi$, where $x_1 \ldots x_n$ is an enumeration of the free variables of ϕ. The advantage of our notation is that it avoids having to introduce axioms such as $?\vec{x}\phi \vdash ?\vec{y}\phi$, where $\vec{x}$ is a permutation of $\vec{y}$.

a valid entailment in Groenendijk's logic is $?Px \models ?Pj$; in words, the question *Who is going to the party?* entails the question *Is John going to the party?*.

Definition 3.2 (Semantics of LoI) A *possible worlds structure* is a triple $\mathrm{A} = (W, D, I)$, where W is a set of worlds, D is a set of individuals, and I interprets the constants and relation symbols in each world. It is required that constants are interpreted *rigidly*, that is, $I_w(c) = I_v(c)$ for all $w, v \in W$. The extension of a formula ϕ at a world w, denoted by $[[\phi]]^w$, is the set of assignments g satisfying ϕ:

$$[[\phi]]^w = \{\, g \in D^{\mathrm{FV}(\phi)} \mid w, g \models \phi \,\}.$$

Given a possible worlds structure $\mathrm{A} = (W, D, I)$, a *context* is a transitive symmetric relation $C \subseteq W^2$ (think: partitioned subset). Contexts can be *updated* with assertions or questions in the following way.

$$C[!\phi] = \{\, (w, v) \in C \mid w \models \phi \text{ and } v \models \phi \,\}$$
$$C[?\phi] = \{\, (w, v) \in C \mid [[\phi]]^w = [[\phi]]^v \,\}$$

Finally, entailment is defined in terms of context update, as is usual in update semantics: The entailment $\theta_1, \ldots, \theta_n \models \eta$ is valid iff, for all possible worlds structures A and contexts C, $C[\theta_1] \cdots [\theta_n][\eta] = C[\theta_1] \cdots [\theta_n]$.

Groenendijk (1999) explains the intuition behind this semantics.

Definition 3.2 is arguably more complicated than it needs to be. In particular, we will see in Section 3.2 that the use of possible worlds can be avoided: the semantics can be reformulated purely in terms of classical first-order models. Also, the fact that the left-hand side of the entailment relation is a *sequence* of formulas rather than a *set* is not essential, as the following proposition shows.

Proposition 3.1 Let Γ and Γ' enumerate the same finite set of *QL* formulas, and let θ be any *QL* formula. Then $\Gamma \models \theta$ iff $\Gamma' \models \theta$.

Proof. As context update is defined as intersection with the update potential, the commutativity and idempotence of set intersection imply that $C[\theta][\eta] = C[\eta][\theta]$ and $C[\theta][\theta] = C[\theta]$ for all C, θ, η. The result follows by the definition of entailment. □

In other words, whenever two sequences Γ and Γ' are enumerations of the same set, they entail exactly the same elements of *QL*. For this reason, we will be a bit sloppy in what follows by identifying such Γ and Γ'.

The following proposition provides many examples of entailments that are valid in LoI.

Definition 3.3 (Developments) A *development* of a set of first-order formulas Σ is a first-order formula that is built up from elements of Σ and formulas of the form $(x = y)$ using the Boolean connectives and quantifiers. In other words, the developments of Σ are given by

$$\phi ::= \chi \mid (x = y) \mid \top \mid \neg\phi \mid \phi_1 \wedge \phi_2 \mid \phi_1 \vee \phi_2 \mid \exists x.\phi \mid \forall x.\phi,$$

where x and y are variables and $\chi \in \Sigma$.

Proposition 3.2 If ψ is a development of $\{\, \phi_1, \ldots, \phi_n \} \cup \{\, x = c \mid c \text{ is a constant} \,\}$, then $?\phi_1, \ldots, ?\phi_n \models ?\psi$.

3.2 The Relation with Beth's Definability Theorem

In this section we establish a precise connection between LoI and Beth's Definability Theorem for first-order logic. This connection will be used later to prove our axiomatization of LoI complete.

Definition 3.4 (Isomorphisms) Given a set Γ of first-order formulas, a Γ-*isomorphism* between two first-order models M and N is a bijection $f : \mathrm{M} \to \mathrm{N}$ between the domains of M and N such that for each formula $\phi(x_1, \ldots, x_n) \in \Gamma$, and for any sequence of individuals $d_1, \ldots d_n$ in the domain of M, we have $\mathrm{M} \models \phi[d_1, \ldots, d_n]$ iff $\mathrm{N} \models \phi[fd_1, \ldots, fd_n]$.

Definition 3.5 (Implicit Definitions) Let Σ be a first-order theory, let Γ be a set of first-order formulas, and let ψ be a first-order formula. The theory Σ *implicitly defines* the formula ψ in terms of the formulas in Γ iff every Γ-isomorphism between two models of Σ is a $\{\psi\}$-isomorphism as well.

Intuitively, a theory implicitly defines ψ in terms of Γ if the denotation of ψ is completely determined by that of Γ—in other words, if, whenever two models completely agree (are isomorphic) with respect to Γ, they completely agree (are isomorphic) with respect to ψ.

If a formula ψ is a development of some set of formulas Γ, then a simple induction over ψ shows that every theory (including the empty theory) implicitly defines ψ in terms of Γ. In a sense, Beth's Definability

Theorem tells us that the converse holds, modulo logical equivalence. (In what follows, we will write $\models_{\text{fol}}$ for classical first-order entailment, in order to distinguish it from entailment in LoI.)

Theorem 3.1 (Beth Definability) Σ implicitly defines ψ in terms of Γ iff there is a development χ of Γ, with the same free variables $\vec{x}$ as ψ, so that $\Sigma \models_{\text{fol}} \forall\vec{x}(\psi \leftrightarrow \chi)$.

We can think of this theorem as a syntactic characterization of implicit definability in first-order logic.

Some comments should be made concerning this formulation of Beth's Definability Theorem. First, this formulation is slightly stronger than Beth's original version. In the above shape, the result is sometimes referred to as the *Projective Beth Theorem*, and it was first proved by William Craig (1957). Second, in the more usual expositions, Beth's Definability Theorem is formulated in terms of atomic relation symbols and constants rather than formulas with free variables (in other words, ψ and the elements of Γ would be predicate symbols or constants rather than formulas). Our apparent generalization of the theorem can easily be obtained from this more classical version by introducing for each $\gamma(x_1, \ldots, x_n) \in \Gamma$ a new n-ary predicate P_γ and by extending Σ with formulas of the form $\forall\vec{x}(P\vec{x} \leftrightarrow \gamma(\vec{x}))$.

Here comes the connection between LoI and the Beth Definability Theorem.

Theorem 3.2 The LoI entailment $!\phi_1, \ldots, !\phi_n, ?\chi_1, \ldots, ?\chi_m \models ?\psi$ holds iff the set of asserted formulas $\{\phi_1, \ldots, \phi_n\}$ implicitly defines ψ in terms of $\Gamma = \{\chi_1, \ldots, \chi_m\} \cup \{\, x = c \mid c \text{ is a constant}\,\}$.

Proof. [$\Rightarrow$] Suppose $!\phi_1, \ldots, !\phi_n, ?\chi_1, \ldots, ?\chi_m \models ?\psi$. Let $f : \mathrm{M} \to \mathrm{N}$ be a Γ-isomorphism between $\mathrm{M} = (D, I)$ and $\mathrm{N} = (D', I')$, both models of $\{\phi_1, \ldots, \phi_n\}$. We will show that f is a $\{\psi\}$-isomorphism as well. Define the possible worlds structure $\mathrm{A} = (\{w, v\}, D, I'')$, where $I''_w = I$ and $I''_v = f^{-1} \circ I' \circ f$. (The construction of Γ guarantees that all constants have a rigid interpretation in A.) Furthermore, let C be the ("trivial") context $\{(w, w), (w, v), (v, w), (v, v)\}$. A simple inductive argument shows that $C[!\phi_1] \cdots [!\phi_n][?\chi_1] \cdots [?\chi_m] = C$. From the LoI entailment assumed at the start, it follows that $C[?\psi] = C$, from which we can conclude that $[[\psi]]^w = [[\psi]]^v$. Therefore, f must be a $\{\psi\}$-isomorphism.

[$\Leftarrow$] Suppose $\{\phi_1, \ldots, \phi_n\}$ implicitly defines ψ in terms of Γ, and consider any possible worlds structure $\mathrm{A} = (W, D, I)$ and context C. Let C' be the updated context $C[!\phi_1]\cdots[!\phi_n][?\chi_1]\cdots[?\chi_m]$. We will show that $C'[?\psi] = C'$. Consider any $(w, v) \in C'$. A simple inductive argument shows that $w \models \phi_i$ and $v \models \phi_i$ for all $i \leq n$. Similarly, $[[\chi_i]]^w = [[\chi_i]]^v$ for all $i \leq m$. It follows that the identity relation on D is a Γ-isomorphism between A_w and A_v. By the definition of implicit definition, the identity relation on D is a $\{\psi\}$-isomorphism between A_w and A_v. In other words, $[[\psi]]^w = [[\psi]]^v$. Therefore, $(w, v) \in C'[?\psi]$. $\square$

By combining Theorem 3.1 and Theorem 3.2, we obtain a syntactic characterization of the LoI entailment relation when the consequent is a question.

Corollary 3.1 The LoI entailment $!\phi_1, \ldots, !\phi_n, ?\chi_1, \ldots, ?\chi_m \models ?\psi$ holds iff there is a development ψ' of $\{\chi_1, \ldots, \chi_m\} \cup \{\, x = c \mid c \text{ is a constant}\,\}$, with the same free variables $\vec{x}$ as ψ, so that $\phi_1, \ldots, \phi_n \models_{\text{fol}} \forall\vec{x}(\psi \leftrightarrow \psi')$.

Corollary 3.1 characterizes LoI validity in the case where the consequent is a question. As it turns out, the validity of entailments with an assertion as the consequent can be characterized in even simpler terms.

Theorem 3.3 $!\phi_1, \ldots, !\phi_n, ?\chi_1, \ldots, ?\chi_m \models !\psi$ iff $\phi_1, \ldots, \phi_n \models_{\text{fol}} \psi$.

Proof. [$\Rightarrow$] Suppose $!\phi_1, \ldots, !\phi_n, ?\chi_1, \ldots, ?\chi_m \models !\psi$, and let $\mathrm{M} = (D, I)$ be a first-order model that verifies ϕ_i for all $i \leq n$. We will show that M verifies ψ as well. Construct the possible worlds structure $\mathrm{A} = (\{w\}, D, I')$, where $I'_w = I$. Furthermore, let C be the context $\{(w, w)\}$. A simple inductive argument shows that $C[!\phi_1]\cdots[!\phi_n][?\chi_1]\cdots[?\chi_m] = C$. From the LoI entailment assumed at the start, it follows that $C[!\psi] = C$, from which we can conclude that $w \models \psi$. Therefore, $\mathrm{M} \models \psi$.

[$\Leftarrow$] Suppose $\phi_1, \ldots, \phi_n \models_{\text{fol}} \psi$, and let $\mathrm{A} = (W, D, I)$ be any possible worlds structure and C any context. Let C' be the updated context $C[!\phi_1]\cdots[!\phi_n][?\chi_1]\cdots[?\chi_m]$. We will show that $C'[!\psi] = C'$. Consider any $(w, v) \in C'$. A simple inductive argument shows that $w \models \phi_i$ and $v \models \phi_i$ for all $i \leq n$. From the first-order entailment assumed at the start, it follows that $w \models \psi$ and $v \models \psi$. Therefore, $(w, v) \in C'[!\psi]$. $\square$

In other words, if the conclusion is an assertion, then validity in LoI reduces to classical first-order validity. This means that LoI is a conservative extension of classical first-order logic: if one restricts attention to assertions, validity in LoI and classical validity coincide.

Theorems 3.2 and 3.3 give us an alternative semantics for LoI that makes no reference to possible worlds. Intuitively, the reason that such a semantics exists is that, to test an LoI entailment, it suffices to consider structures with only two possible worlds.

3.3 Axiomatization

Table 1 lists a sound and complete axiomatization of LoI. When axiomatizing *classical* first-order logic, it suffices to axiomatize the first-order *tautologies*: by *compactness* and the *deduction theorem*, an entailment $\Sigma \models_{\text{fol}} \phi$ holds just in case there are $\psi_1, \ldots, \psi_n \in \Sigma$ such that $\models_{\text{fol}} \psi_1 \wedge \cdots \wedge \psi_n \rightarrow \phi$. In LoI, on the other hand, there is no easy way to reduce the entailment problem to the problem of validity of formulas, due to the absence of a suitable analogue of the deduction theorem. For this reason, Table 1 axiomatizes the entailment relation rather than just the tautologies.[2]

The axiom scheme [CT] expresses that LoI is an extension of first-order logic; in other words, every valid first-order sentence is still valid in LoI. In fact, we know already from Theorem 3.3 that LoI is a conservative extension of first-order logic. Interestingly, there is a second way in which LoI is conservative over first-order logic, namely with regards to *structural rules*. Johan van Benthem (1996, Chapter 7) has shown that the [Ref], [Cut], [Monotonicity], [Permutation] and [Contraction] completely characterize the structural properties of classical entailment. Table 1 shows that LoI is conservative over first-order logic, in the sense that these structural properties are still valid.

Theorem 3.4 The axiomatization in Table 1 is sound and complete for entailment in LoI. That is, for all Γ and θ, $\Gamma \vdash \theta$ iff $\Gamma \models \theta$.

Proof. Soundness is straightforward. As for completeness, suppose $\Gamma \models \theta$, where Γ is some sequence $!\phi_1, \ldots, !\phi_n, ?\chi_1, \ldots, ?\chi_m$. We can distinguish two cases.

[2] One could consider introducing an explicit implication sign $\Longrightarrow$ that operates on questions and assertions. With the help of such a connective, $!\phi \models ?\psi$ could for instance be reduced to $\models (!\phi \Longrightarrow ?\psi)$. The proper semantics of this connective is not clear, but it might be worth investigating the intuitive connection with *conditional questions*, such as *If we go for dinner tonight, will Mary join us?* (Velissaratou, 2000).

TABLE 1 Axiomatization of LoI

	[CT]	$!\phi_1, \ldots, !\phi_n \vdash !\psi$	whenever $\phi_1, \ldots, \phi_n \models_{\text{fol}} \psi$
+	[$\top$]	$\vdash ?\top$	
	[$\neg$]	$?\phi \vdash ?\neg\phi$	
	[$\wedge$]	$?\phi, ?\psi \vdash ?(\phi \wedge \psi)$	
+	[$\vee$]	$?\phi, ?\psi \vdash ?(\phi \vee \psi)$	
	[$\exists$]	$?\phi \vdash ?\exists x\phi$	
+	[$\forall$]	$?\phi \vdash ?\forall x\phi$	
+	[Subst]	$?\phi \vdash ?\phi[x/t]$	where t is substitutable for x in ϕ
	[Equality]	$\vdash ?(x = y)$	
	[Const]	$\vdash ?(x = c)$	
	[Equiv]	$!\forall\vec{x}(\phi \leftrightarrow \psi), ?\phi \vdash ?\psi$	where $\mathrm{FV}(\phi) \cup \mathrm{FV}(\psi) = \{\vec{x}\}$
+	[Ref]	$\theta \vdash \theta$	
	[Cut]	If $\Gamma \vdash \theta$ and $\Gamma, \theta \vdash \eta$ then $\Gamma \vdash \eta$	
	[Monotonicity]	If $\Gamma \vdash \theta$ then $\Gamma, \Gamma' \vdash \theta$	
	[Permutation]	If $\Gamma, \theta, \eta, \Gamma' \vdash \zeta$ then $\Gamma, \eta, \theta, \Gamma' \vdash \zeta$	
+	[Contraction]	If $\Gamma, \theta, \theta \vdash \eta$ then $\Gamma, \theta \vdash \eta$	

Axioms marked with + are derivable

- θ is of the form $!\psi$. By Theorem 3.3, $\phi_1, \ldots, \phi_n \models_{\text{fol}} \psi$. By the axiom [CT], $!\phi_1, \ldots, !\phi_n \vdash !\psi$. By the structural rule [Weakening], it follows that $\Gamma \vdash !\psi$.
- θ is of the form $?\psi$. By Corollary 3.1, there is a formula ψ' such that (1) $\phi_1, \ldots, \phi_n \models_{\text{fol}} \forall\vec{x}(\psi \leftrightarrow \psi')$ and (2) ψ' is a development of $\{\chi_1, \ldots, \chi_n\} \cup \{\, x = c \mid c \text{ is a constant}\,\}$. From (1), the axiom [CT] and the structural rule [Weakening], it follows that $\Gamma \vdash !\forall\vec{x}(\phi \leftrightarrow \phi')$. From (2), it follows that $\Gamma \vdash ?\phi'$ (by induction on ϕ'). Therefore, $\Gamma \vdash ?\phi$.

$\square$

3.4 Four Perspectives on LoI

LoI was introduced as a logic for reasoning about the relevance of linguistic utterances. However, besides this linguistic view on the logic, there are alternative perspectives. LoI has a natural mathematical interpretation (as a logic describing equivalence relations between models), a computational interpretation (describing reductions among database queries), and a philosophical interpretation (describing logicality of operations). We survey the different perspectives on LoI in this section.

LoI provides not only a unifying perspective on these different topics, but also a common starting point for exploring variations on them: different notions of utterance relevance, model equivalence, query reduction, and logicality correspond to different variants of LoI. These in turn give rise to variations of Beth's Definability Theorem. Section 3.6 presents one such variation: a variant of LoI defined in terms of possible worlds with varying domains.

3.4.1 Linguistic

Groenendijk (1999) introduced LoI as a logic for reasoning about relevance (*aboutness*) of linguistic utterances. For instance, that *John is going to the party* is a relevant response to the question *Who is going to the party?* is reflected by the validity of $?Px \models ?Pj$. In general, it is claimed, an assertion $!\phi$ is relevant after a sequence of utterances Γ (Γ *licenses* $!\phi$, to use Groenendijk's terminology) if and only if $\Gamma \models ?\phi$. This claim has several empirical problems, and consequently, slight variations of the semantics have been proposed that arguably make better predictions.

For instance, Groenendijk and Stokhof (1997) discuss an alternative semantics for LoI in terms of possible worlds structures with *varying domains*. This more liberal semantics allows each possible world to have a different domain. Consequently, the question $?Px$ no longer entails $?\neg Px$, thus invalidating the axiom [$\neg$] in Table 1. We will study this alternative semantics in more detail, and give a sound and complete axiomatization, in Section 3.6.

Another parameter of variation concerns the interpretation of terms. Following Groenendijk (1999), we treat constants as rigid designators. Consequently, the question $?Px$ entails the question $?Pj$; it is reflected in Table 1 as the axiom [Const]. The logic would be quite different if some or all constants were non-rigid. An even more fine-grained semantics, introduced by Aloni (2001), interprets constants as elements of *conceptual covers*. Again, this change of semantics crucially affects the validities.

One important feature of sound and complete axiomatizations like the one provided in Section 3.3 is that they provide further insight in the precise implications of the different "design choices".

3.4.2 Mathematical

From a more mathematical point of view, LoI can be seen as a logic of isomorphisms. For instance, the entailment $?Px, ?Qx \models ?(Px \wedge Qx)$ (which can be proved using Proposition 3.2 or Theorem 3.2) roughly says that every $\{Px, Qx\}$-isomorphism is a $\{Px \wedge Qx\}$-isomorphism. Likewise, the entailment $?Px, !\forall x(Px \leftrightarrow Qx) \models ?Qx$ means that every $\{Px\}$-isomorphism between models satisfying $\forall x(Px \leftrightarrow Qx)$ is a $\{Qx\}$-isomorphism. Continuing on this observation, we can see LoI as a logic for describing isomorphisms.

If isomorphisms play such a central part in this logic, what happens if we replace them by *homomorphisms* or *bisimulations*? We will come back to this question.

3.4.3 Computational

A third perspective on the LoI is as a logic for reasoning about database queries. In database research, there is much interest in reasoning about query equivalence. For example, the two queries $?Px$ and $?(Px \wedge Qx) \vee (Px \wedge \neg Qx)$ give identical outcomes, but the former is easier to process than the latter. A less trivial example is the following: if we know that $\forall x(Px \rightarrow Qx)$ holds in our database, then the queries $?(Px \wedge Qx)$ and $?Px$ are equivalent. This is reflected in the two LoI entailments

$$!\forall x(Px \rightarrow Qx), ?Px \models ?(Px \wedge Qx),$$
$$!\forall x(Px \rightarrow Qx), ?(Px \wedge Qx) \models ?Px.$$

Thus, LoI is a logic of database queries—albeit one that builds on a rather crude notion of query equivalence, since it considers $?Px$ and $?\neg Px$ equivalent. In fact, Theorem 3.2 suggests that we should interpret $!\phi_1, \ldots, !\phi_n, ?\chi_1, \ldots, ?\chi_m \models ?\psi$ roughly as *The answer to* $?\psi$ *can be computed from the answers to* $?\chi_1, \ldots, ?\chi_m$*, given that* $\phi_1, \ldots, \phi_n$ *are true*. This computational intuition behind LoI can be made more explicit.

Proposition 3.3 Suppose $!\phi_1, \ldots, !\phi_n, ?\chi_1, \ldots, ?\chi_m \models ?\psi$. Then the extension of ψ in a finite model satisfying $\phi_1, \ldots, \phi_n$ can be effectively computed from the extension of $\chi_1, \ldots, \chi_m$, the domain of the model, and the interpretation of all constants. In fact, the computation can be performed in PSPACE.

Proof. By Corollary 3.1, there is a development ψ' of $\chi_1, \ldots, \chi_n$ such that

$$\phi_1, \ldots, \phi_n \models_{\text{fol}} \forall \vec{x}(\psi \leftrightarrow \psi').$$

Since ψ' is built up from instances of $\chi_1, \ldots, \chi_n$, we can apply any PSPACE model checking algorithm for first-order logic to compute the extension of ψ' (hence of ψ) from the extension of $\chi_1, \ldots, \chi_n$, the domain, and the interpretation of the constants. □

The converse does not hold, due to the restriction to finite models. For instance, let ψ be a first-order sentence that states that some binary relation $<$ is an unbounded strict order. Because ψ only has infinite models, there is trivially an efficient algorithm that computes the truth value of ψ in any given finite model—just report *False* right away. Nevertheless, $\not\models ?\psi$, since there are models of equal (infinite) cardinality such that ψ is true in one and false in the other. Thus, one could say that LoI is sound but not complete for this "computational" or "finite-domain" semantics.

3.4.4 Philosophical

Tarski (1986) asks the important philosophical question: *What counts as a logical operation?* Our intuitions say that predicate intersection is a logical operation, whereas intersection-if-it-rains-and-union-otherwise is not a logical operation. The question, then, is: *what relevant feature of the former operation does the latter lack?* Tarski gives an answer in terms of bijections: predicate intersection is logical because for any bijection f between the domains of two models, and for any two predicates P, Q, if f respects membership of P and Q, then it also respects membership of their intersection. The operation intersection-if-it-rains-and-union-otherwise does not satisfy this property, and hence is not logical according to Tarski. Tarski's solution is not undisputed. For instance, Feferman (1999) argues that in order for an operation to be truly logical, the above criterion should hold not only for bijections but for any surjective function.

Tarski's criterion is closely connected to the notion of implicit definitions, as given in Definition 3.5. To make this connection precise, consider any first-order formula ϕ with free variables $x_1, \ldots, x_n$ and containing predicate symbols $P_1, \ldots, P_m$ (with $n, m \geq 0$). For convenience, assume that ϕ contains no constants. Each such formula defines an operation on relations, namely

$$\lambda P_1 \ldots P_m. (\lambda x_1 \ldots x_n. \phi).$$

This operation takes as input m relations of appropriate arity, and outputs a single n-ary relation. Now, it follows from Definition 3.5 and Theorem 3.2 that this operation is logical in Tarski's sense iff the LoI entailment

$$?P_1\vec{x}_1, \ldots, ?P_n\vec{x}_n \models ?\phi$$

holds (where each $\vec{x}_i$ is a sequence of as many variables as the arity of P_i).

On the one hand, this connection gives us a further motivation for the current definition of LoI: it seems plausible that all and only the *logical* operations may be used to compose (develop) complex questions and answers out of simple ones. On the other hand, variants of LoI may be obtained by considering alternative notions of logicality such as the one proposed by Feferman. These variants of LoI will have different predictions as to what constitutes an appropriate answer to a question.

3.5 Interlude: Optimal Answers and Uniform Interpolation

Recall from Section 3.4.1 that an assertion $!\psi$ is a relevant response to (*is licensed by*) a question $?\phi$ in case $?\phi \models ?\psi$. Suppose we are given a question $?\phi$ and a certain amount of knowledge, represented by a finite set of assertions Σ. One would like to find an assertion $!\psi$, called an *optimal answer to* $?\phi$ *given* Σ, satisfying

1. $\Sigma \models !\psi$. ("$!\psi$ follows from Σ")
2. $?\phi \models ?\psi$. ("$!\psi$ is a relevant response to $?\phi$")
3. For all assertions $!\psi'$ satisfying 1 and 2, $!\psi \models !\psi'$. ("$!\psi$ is most informative")

Is there always an optimal answer to $?\phi$ given the information in Σ? The answer is *No.* Let Σ be any satisfiable theory (that is, any set of assertions) that has only infinite models, and set the question $?\phi$ to simply $?\top$. Let ψ_n (for each $n \in \mathbb{N}$) be a sentence that says that there are at least n different objects. Then the entailments $\Sigma \models \psi_n$ and $?\phi \models ?\psi_n$ hold for all $n \in \mathbb{N}$. (The latter entailment holds because the domain of individuals is fixed across possible worlds in the semantics of LoI.) In other words, the potential answers ψ_n all satisfy conditions 1 and 2 above. Any optimal answer ψ, then, must entail each ψ_n and furthermore be equivalent to a formula that contains no non-logical symbols. It follows (e.g., using the invariance of first-order formulas for potential isomorphisms) that $\neg\psi$ defines the class of finite models, which is known not to be first-order definable.

The reader might have noticed that this proof is almost identical to Henkin's proof that first-order logic does not have *uniform interpolation* (Henkin 1963). Indeed, these two properties—uniform interpolation and there being always a unique most informative answer—are intimately related. Making the connection precise may require a fair amount of abstract model theory, so we avoid it here.

3.6 A Variation on LoI: Varying Domains

We now turn to a variation of LoI that was more or less proposed by Groenendijk and Stokhof (1997). The only difference from LoI as defined in Section 3.1 is that we drop the restriction to possible worlds structures with *constant domains*. We will show that this variant of LoI admits an analysis analogous to the one already given.

Definition 3.6 (LoI semantics, varying domains) A *varying domain structure* is a quadruple $\mathrm{A} = (W, Dom, D, I)$, where W is a set of worlds, Dom is a set of entities, $D : W \to \wp(Dom)$ assigns a domain to each world, and I interprets the constants and relations in each world, such that

- For each constant c and world w, $I_w(c) \in D_w$.
- For each n-ary relation R and world w, $I_w(R) \subseteq D_w^n$.
- All constants are rigid: for all constants c and worlds w, v, $I_w(c) = I_v(c)$.

(This implies that the intersection of the domains is non-empty.) The extension of a formula ϕ at a world w, denoted by $[[\phi]]^w$, is

$$[[\phi]]^w = \{\, g \in D_w^{\mathrm{FV}(\phi)} \mid w, g \models \phi \,\}.$$

Contexts, updates and entailment are defined as before, with the single difference that varying domain structures replace constant domain structures.

We use the notation $\models_{\mathrm{vd}}$ for LoI entailment under the varying domain semantics. Note that every constant domain structure is a varying domain structure, so $\Gamma \models \theta$ whenever $\Gamma \models_{\mathrm{vd}} \theta$. In order to axiomatize this variant of LoI, we need to find an appropriate analogue of Beth's Definability Theorem. In order to do so, we need to introduce a new kind of model equivalence relation.

Definition 3.7 (Full Partial Isomorphisms) Given a set of first-order formulas Γ, a *partial* Γ*-isomorphism* between two first-order models M and N is an injective partial function $f : \mathrm{M} \to \mathrm{N}$ such that for each formula $\phi(x_1, \ldots, x_n) \in \Gamma$, where $x_1, \ldots, x_n$ are the free variables of ϕ, and for any individuals $d_1, \ldots, d_n$ in the domain of f, we have $\mathrm{M} \models \phi[d_1, \ldots, d_n]$ iff $\mathrm{N} \models \phi[fd_1, \ldots, fd_n]$. In addition, f is a *full* partial Γ-isomorphism (FPI) if the following conditions hold:

- For any formula $\phi(x_1, \ldots, x_n)$ in Γ and individuals $d_1, \ldots, d_n$ in the domain of M, if $\mathrm{M} \models \phi[d_1, \ldots, d_n]$ then $d_1, \ldots, d_n$ are in the domain of f.
- For any formula $\phi(x_1, \ldots, x_n)$ in Γ and individuals $d'_1, \ldots, d'_n$ in the domain of N, if $\mathrm{N} \models \phi[d'_1, \ldots, d'_n]$ then $d'_1, \ldots, d'_n$ are in the range of f.

Definition 3.8 (Implicit Definitions over FPIs) Let Σ be a first-order theory, let Γ be a set of first-order formulas, and let ψ be a first-order formula. The theory Σ *implicitly defines* the formula ψ in terms of the formulas in Γ over full partial isomorphisms iff every full partial Γ-isomorphism between two models of Σ is a full partial $\{\psi\}$-isomorphism as well.

Definition 3.9 (Strict Developments) The *strict development* of a set of first-order formulas Γ are the first-order formulas given by

$$\phi ::= \chi \mid (x = y) \wedge \psi \mid \top \mid \neg\phi_1 \wedge \phi_2 \mid \phi_1 \wedge \phi_2 \mid \phi_1 \vee \phi_2 \mid \exists y.\phi,$$

where $\chi \in \Gamma$, $x \in \mathrm{FV}(\psi)$ in the case of equality, $\mathrm{FV}(\phi_1) \subseteq \mathrm{FV}(\phi_2)$ in the case of negation, and $\mathrm{FV}(\phi_1) = \mathrm{FV}(\phi_2)$ in the case of disjunction.

If a formula ψ is a strict development of some set of formulas Γ, then a simple induction over ψ shows that the trivial theory implicitly defines ψ in terms of Γ over full partial isomorphisms. In a sense, the following variation on Beth's Definability Theorem tells us that the converse holds, modulo logical equivalence as before.

Theorem 3.5 (Beth Definability for FPIs) Σ implicitly defines ψ in terms of Γ over full partial isomorphisms iff there is a strict development χ of Γ, with the same free variables $\vec{x}$ as ψ, so that $\Sigma \models_{\text{fol}} \forall\vec{x}(\psi \leftrightarrow \chi)$.

The Beth definability theorem is usually proved as a corollary of the Craig interpolation theorem. For the proof of Theorem 3.5, we will need the following more refined version of interpolation Otto (2000):

Lemma 3.1 (Relativized interpolation) Let $\mathcal{U} = \{U_1, \ldots, U_n\}$ be a collection of unary predicates, and let ϕ, ψ be $\mathcal{U}$-relativized formulas (i.e., formulas in which all quantification is of the form $\exists x.(Ux \wedge \cdots)$ or $\forall x.(Ux \rightarrow \cdots)$, with $U \in \mathcal{U}$). Furthermore, suppose that $\models \phi \rightarrow \psi$. Then there is a $\mathcal{U}$-relativized formula ξ such that:

1. $\models \phi \rightarrow \xi$ and $\models \xi \rightarrow \psi$.
2. All free variables of ξ are free variables of ϕ and of ψ.
3. All relation symbols occurring in ξ occur both in ϕ and in ψ.

Proof of Theorem 3.5. We prove only the hard direction ($\Rightarrow$). We discuss only the simplified case where Γ consists of atomic relation symbols: the general result can be derived by introducing a new atomic relation symbol R_χ for each $\chi \in \Gamma$ and extending Σ with $\forall\vec{x}(R_\chi\vec{x} \leftrightarrow \chi(\vec{x}))$. Let

$$\theta_\Gamma(y) = \bigvee_{\substack{R\in\Gamma\\ k\leq \text{arity}(R)}} \exists x_1 \ldots x_{\text{arity}(R)}.(R(\vec{x}) \wedge x_k = y)$$

which expresses that y belongs to a tuple in the denotation of some $R \in \Gamma$. Two straightforward inductive arguments, one in each direction, verify the following fact:

> *Fact 1.* Up to logical equivalence, the strict developments of Γ are precisely the first-order formulas of the form $\zeta(x_1, \ldots, x_n) \wedge \theta_\Gamma(x_1) \wedge \cdots \wedge \theta_\Gamma(x_n)$, where ζ is built up from atomic relation symbols in Γ using the Boolean connectives and θ_Γ-relativized quantification.

Now, suppose Σ implicitly defines ψ in terms of $\Gamma = \{R_1, \ldots, R_n\}$ over FPIs. For a start, it follows quite easily from the definition of implicit definability for FPIs (in particular, from the requirements on the domain and range of FPIs) that

> *Fact 2.* $\Sigma \models \forall\vec{x}(\psi(\vec{x}) \rightarrow \bigwedge_k \theta_\Gamma(x_k))$

Next, let Σ' be a copy of Σ in which each relation symbol $R \notin \Gamma$ is uniformly replaced by a new relation symbol R' of the same arity. Furthermore, pick new unary predicates P_1, P_2, U. Let Σ^{P_1} and Σ'^{P_2} be obtained from Σ and Σ' by relativizing all quantifiers by P_1 or P_2, respectively. Consider the theory

$$\Sigma^* = \Sigma^{P_1} \cup \Sigma'^{P_2} \cup \{\forall x.(Ux \to P_1 x)\} \cup \{\forall x.(Ux \to P_2 x)\} \\ \cup \{\forall \vec{x}((\bigwedge_k P_i x_k) \wedge R\vec{x} \to \bigwedge_k U x_k) \mid R \in \Gamma; i = 1, 2\}$$

This theory Σ^* describes a situation where there are two models of Σ and a full partial Γ-isomorphism between them: P_1 and P_2 define the domains of the two models, and the full partial isomorphism is the identity function on U. That the FPI need not preserve relations $R \notin \Gamma$ is reflected in the fact that the submodel defined by P_1 satisfies Σ whereas the submodel defined by P_2 satisfies Σ'.

Since Σ implicitly defines ψ in terms of Γ, it follows that

$$\Sigma^* \models (\psi^{P_1}(\vec{x}) \wedge \bigwedge_k P_1 x_k) \to (\psi^{P_2}(\vec{x}) \wedge \bigwedge_k P_2 x_k),$$

where ϕ^{P_i} is the result of relativizing all quantifiers in ϕ by P_i. By compactness, this holds already for a finite subset of Σ. Hence, in what follows, we will assume that Σ (and hence also Σ') is finite. By writing Σ^{P_1} and Σ'^{P_2} as large conjunctions and rearranging the formulas in the above entailment, we obtain

$$\models (\bigwedge \Sigma^{P_1}) \wedge \forall x.(Ux \to P_1 x) \wedge \forall \vec{x}((\bigwedge_k P_1 x_k) \to \bigwedge_{R\in\Gamma}(R\vec{x} \to \bigwedge_k U x_k)) \wedge \\ (\psi^{P_1}(\vec{x}) \wedge \bigwedge_k P_1 x_k) \\ \to \\ \Big(((\bigwedge \Sigma'^{P_2}) \wedge \forall x.(Ux \to P_2 x) \wedge \forall \vec{x}((\bigwedge_k P_2 x_k) \to \bigwedge_{R\in\Gamma}(R\vec{x} \to \bigwedge_k U x_k))) \\ \to \quad (\psi^{P_2}(\vec{x}) \wedge \bigwedge_k P_2 x_k)\Big)$$

We now apply the relativized interpolation theorem (Lemma 3.1) to obtain a $\{P_1, P_2, U\}$-relativized interpolant ξ for this implication. Interpolation guarantees that only U and the relation symbols in Γ can occur in ξ. Therefore, neither P_1 nor P_2 occurs in ξ, so all quantifiers in ξ are relativized by U. As a final step, we replace all occurrences of U in ξ by θ_Γ. The resulting formula ξ' satisfies the following property:

Fact 3. $\Sigma \models \forall \vec{x}(\psi(\vec{x}) \leftrightarrow \xi'(\vec{x}))$

(This follows from the fact that ξ is entailed by the interpolation antecedent above, and entails the interpolation consequent above, by replacing P_1, P_2, and U by $\top$, $\top$, and θ_Γ, respectively).

Finally, $\xi'(\vec{x}) \wedge \bigwedge_k \theta_\Gamma(x_k)$ is the strict development of Γ that we are looking for: By Facts 2 and 3 together, $\Sigma \models \forall\vec{x}(\psi(\vec{x}) \leftrightarrow (\xi'(\vec{x}) \wedge \bigwedge_k \theta_\Gamma(x_k)))$. By Fact 1, $\xi'(\vec{x}) \wedge \bigwedge_k \theta_\Gamma(x_k)$ is (logically equivalent to) a strict development of Γ. □

Proposition 3.4 An alternative semantics for LoI with varying domains that does not use possible worlds structures is as follows.

1. $!\phi_1, \ldots, !\phi_n, ?\chi_1, \ldots, ?\chi_m \models_{\mathrm{vd}} !\psi$ iff $\phi_1, \ldots, \phi_n \models_{\mathrm{fol}} \psi$.
2. $!\phi_1, \ldots, !\phi_n, ?\chi_1, \ldots, ?\chi_m \models_{\mathrm{vd}} ?\psi$ iff $\{\phi_1, \ldots, \phi_n\}$ implicitly defines ψ in terms of $\{\chi_1, \ldots, \chi_m\} \cup \{\, x = c \mid c \text{ is a constant} \,\}$ over full partial isomorphisms.

Proof. Analogous to Theorems 3.2 and 3.3. □

Corollary 3.2 $!\phi_1, \ldots, !\phi_n, ?\chi_1, \ldots, ?\chi_m \models_{\mathrm{vd}} ?\psi$ iff there is a strict development ψ' of $\{\chi_1, \ldots, \chi_m\} \cup \{\, x = c \mid c \text{ is a constant} \,\}$ with the same free variables $\vec{x}$ as ψ such that $\phi_1, \ldots, \phi_n \models_{\mathrm{fol}} \forall\vec{x}(\psi \leftrightarrow \psi')$.

The difference between developments and strict developments is reflected in different LoI entailments with constant and varying domains. For instance, the LoI entailment $?Px \models ?\forall x.Px$ (the axiom [$\forall$] in Table 1) no longer holds under the varying domain semantics. The counterexample is illustrative: let M be a first-order model with domain $\{a\}$ in which the unary predicate P has the extension $\{a\}$. Let N be a model with domain $\{a, b\}$ in which P also has the extension $\{a\}$. Furthermore, suppose all constants denote a in both M and N. Then P has the same extension in M and N, but $\forall x.Px$ does not: it is true in M and false in N.

Table 2 contains a sound and complete axiomatization of $\models_{\mathrm{vd}}$. Completeness follows in the same way as before.

3.6.1 Four Perspectives on LoI Revisited

We saw earlier that there are four natural perspectives on LoI, namely linguistic (in terms of aboutness), mathematical (in terms of isomorphisms), computational (in terms of database queries), and philosophical (in terms of logical operations). We now consider the varying domain version of LoI from the same four perspectives.

Linguistic Table 2 shows that the varying domain version of LoI makes counter-intuitive linguistic predictions. Intuitively, *Everybody is going to the party* is a very natural answer to *Who is going to the party?*, and *Somebody is going to the party* is less natural an answer.

TABLE 2 Axiomatization of the varying domain version of LoI

	[CT]	$!\phi_1, \ldots, !\phi_n \vdash !\psi$	whenever $\phi_1, \ldots, \phi_n \models_{\text{fol}} \psi$
+	[$\top$]	$\vdash ?\top$	
	[$\neg'$]	$?\phi, ?\psi \vdash ?(\phi \wedge \neg\psi)$	where $\mathrm{FV}(\psi) \subseteq \mathrm{FV}(\phi)$
	[$\wedge$]	$?\phi, ?\psi \vdash ?(\phi \wedge \psi)$	
	[$\vee$]	$?\phi, ?\psi \vdash ?(\phi \vee \psi)$	where $\mathrm{FV}(\phi) = \mathrm{FV}(\psi)$
	[$\exists$]	$?\phi \vdash ?\exists x\phi$	
+	[$\forall'$]	$?\phi, ?\psi \vdash ?\forall\vec{x}(\phi \to \psi)$	where $\mathrm{FV}(\phi) = \{\vec{x}\}$
+	[Subst]	$?\phi \vdash ?\phi[x/t]$	where t is substitutable for x in ϕ
	[Equality$'$]	$?\phi \vdash ?((x = y) \wedge \phi)$	where $x \in \mathrm{FV}(\phi)$
	[Const]	$\vdash ?(x = c)$	
	[Equiv]	$!\forall\vec{x}(\phi \leftrightarrow \psi), ?\phi \vdash ?\psi$	where $\mathrm{FV}(\phi) \cup \mathrm{FV}(\psi) = \{\vec{x}\}$
+	[Ref]	$\theta \vdash \theta$	
	[Cut]	If $\Gamma \vdash \theta$ and $\Gamma, \theta \vdash \eta$ then $\Gamma \vdash \eta$	
	[Monotonicity]	If $\Gamma \vdash \theta$ then $\Gamma, \Gamma' \vdash \theta$	
	[Permutation]	If $\Gamma, \theta, \eta, \Gamma' \vdash \theta$ then $\Gamma, \eta, \theta, \Gamma' \vdash \theta$	
+	[Contraction]	If $\Gamma, \theta, \theta \vdash \eta$ then $\Gamma, \theta \vdash \eta$	

Axioms marked with + are derivable

LoI with varying domains predicts the opposite: $?Px \models_{\mathrm{vd}} ?\exists x.Px$ yet $?Px \not\models_{\mathrm{vd}} ?\forall x.Px$, because only a restricted form of universal quantification is allowed. Indeed, once we allow the domains of our first-order models to vary, $\forall x.Px$ does not provide information about the extension of the predicate P, only about the complement of its extension! We could of course dualize the semantics of LoI by consistently interpreting $?\phi$ as asking about the *complement* of the extension of ϕ. In this way, we get the correct empirical predictions, but it remains mysterious why this is the case.

Mathematical Just as LoI can be seen as a logic of isomorphisms, the varying domains version of LoI can be seen as a logic of full partial isomorphisms. Are full partial isomorphisms interesting in their own right? There is at least one reason to believe so: Andréka et al. (1998) introduce a number of fragments of first-order logic, one of which (Fragment F3) can be shown to be the fragment of first order logic invariant under full partial isomorphisms.

Computational The computational perspective provided by Proposition 3.3 becomes even more natural for the varying domain semantics, since it reduces down to the following.

Proposition 3.5 Suppose $!\phi_1, \ldots, !\phi_n, ?\chi_1, \ldots, ?\chi_m \models ?\psi$. Then the extension of ψ in a finite model satisfying $\phi_1, \ldots, \phi_n$ can be effectively computed from the extension of $\chi_1, \ldots, \chi_m$, given the interpretation of all constants. In fact, the computation can be performed in PSPACE.

Note that, unlike in the constant domain case, the domain of the model is not required for the computation. Unfortunately, just as explained for the constant domain case in Section 3.4.3, the converse of Proposition 3.5 does not hold.

Philosophical In response to Tarski's question *What are logical operations?*, the notion of strict developments embodies the view that negation and universal quantification are only logical operations when the body formula is guarded by a restrictor predicate. Semantically speaking, this view submits that the extension of the entire domain itself is not a logical notion. For instance, according to Definition 3.9, bounded (three-part) universal quantification is an acceptable way to build up a strict development, but unbounded (two-part) universal quantification is not. This restriction on the use of universal quantification is reminiscent of the restriction on set comprehension used to avoid Russell's paradox. However, the precise relationship between restricted comprehension and varying domains remains to be worked out.

3.7 Conclusion

We axiomatized Groenendijk's logic of interrogation, and showed that it not only has a natural linguistic interpretation, but also describes equivalence relations between models, reductions among database queries, and logicality of operations. Thus these topics are all related to each other. For example, if we allow the domains of possible worlds to differ, then fewer statements will count as answer to a question, fewer database queries reductions are possible, and fewer operations are logical.

Other interesting variations on LoI may be obtained by replacing rigid individuals by *conceptual covers*, or replacing isomorphisms by *homomorphisms* or *bisimulations*. Using homomorphisms excludes negative answers such as *Britney Spears won't be coming to the party.* Using bisimulations excludes quantitative answers such as *More than 27 people will come to the party.* We leave it as future work to find sound and complete axiomatizations for these cases.

Acknowledgements

Thanks to Johan van Benthem, Paul Dekker and Jeroen Groenendijk for valuable input. The first author is supported by NWO grant 612.069.006. The second author is supported by NSF grants IRI-9712068 and BCS-0236592.

4

Optimal Inquisitive Discourse

Paul Dekker

Abstract

In this paper I combine the major results of three of the main theories of interpretation which are concerned with inquisitive discourse and I overcome their obvious limitations. Grice's cooperative principles are given a rational reformulation, with the formal rigour of a Groenendijk, Stokhof and Krifka style semantics of questions and answers. The scope of these paradigms is extended with the global perspective on discourse interpretation convincingly argued for in relevance theoretic accounts like that of Sperber and Wilson.

Keywords: semantics and pragmatics of natural language, dynamic interpretation, game and decision theory, epistemic logic, questions and answers.

4.1 Introduction

The theory of discourse, and that of discourse interpretation in particular, is still far from formal implementation. The syntax and semantics of sentences is theoretically highly sophisticated, and there is a huge amount of literature on the formal pragmatics of specific indicative assertions. Nevertheless, no general, unified formal account has been offered sofar, despite numerous attempts over the last twenty years.

In this paper I want to contribute to such an account. I take my clue from a Montagovian perspective on semantics and a Gricean perspective on conversation, agreeing that rational principles of conver-

Questions in Dynamic Semantics.
Maria Aloni, Alastair Butler and Paul Dekker (eds.).
Current Research in the Semantics/Pragmatics Interface, Vol. 17.

sation motivate a cooperative matrix. Actual interpretation, however, goes much beyond that. Interlocutors cannot always be assumed to be unconditionally cooperative and perfectly rational, and there are rules about how decent conversations ought to go by. Some theories of discourse structure focus on such rules, but they either focus on structural formal relationships between sentences, or they invoke informal principles of relevance. I want to generalize this picture, and offer an intuitively motivated and formally generalized notion of an optimal inquisitive discourse, which covers the examples discussed in the literature, and many more besides.

This paper proceeds as follows. Section 2 gives an introduction to my own implementation of the standard formal view on the semantics of questions and answers. It is based upon the basic insights of Hamblin and Karttunen which are intuitively motivated and formally worked out well by Groenendijk and Stokhof and Krifka. Section 3 discusses the logical and pragmatic merits of this type of framework and it presents my own account of how questions and answers in discourse update the common ground in discourse. This will serve to set the ground for giving us a formal paradigm to actually define a notion of an optimal inquiry. This will be done in section 4, where it is also put to test and used to explain 'mention some'-interpretations of questions. Section 5 summarizes the results.

4.2 Semantic Satisfaction of Questions and Assertions

Questions (interrogative utterances) have been studied from both a semantic and a pragmatic perspective, more than indicative sentences (assertions) have been, and for good reasons. While the interpretation of questions depends on context as much as the interpretation of assertions does, their effects upon the context are more obvious. A question normally wants to be answered. Even so, indicative utterances have also been studied from a combined semantic/pragmatic perspective in recent systems of dynamic semantics and discourse representation theory. Clearly, this motivates a treatment of both types of utterances in tandem.

According to a very old and standard picture, dating back to Frege and Wittgenstein, the meaning of an indicative sentence can be spelled out in terms of its truth-conditions. The idea is that you know the meaning of such a sentence if you know what the world should be like in order for the sentence to be true. Putting it the other way around, you grasp what information an assertion of such a sentence conveys, if you understand what the world will be like if the assertion is true, so that you can act accordingly.

According to a not so old, but equally standard picture, dating back to Hamblin and Karttunen, the meaning of an interrogative sentence can be spelled out in terms of its answerhood conditions. You know the meaning of an interrogative sentence if you know what counts as a full answer to the question. You grasp what information is queried by the use of an interrogative sentence, if you know what, given how the world is like, would count as an answer fully resolving the question. You may fail to know the answer, and you may have information only partly resolving the question, what counts is that, if you knew what the world were like, what would be the true and complete answer.

The intuitions about indicative and interrogative sentences can be spelled out in terms of a simple satisfaction relation. Such a satisfaction relation $\models$ relates sentences or formulas ϕ of a formal language representing the idealized meanings of natural language sentences, with the conditions under which they are satisfied. In case ϕ is a purely indicative sentence, this satisfaction relation boils down to a simple Tarskian truth relation; in case ϕ is interrogative, it is satisfied by the true and full answer to the question involved. In general this is formalized as $M, g, \vec{\alpha} \models \phi$, where M is a formal model representing a possible world or situation, g is an assignment of individuals as values for variables or indices, formally required to interpret (sub-)formulas quantified over, and $\vec{\alpha}$ is a possibly empty sequence $\vec{\alpha}_1, \ldots \vec{\alpha}_n$ of answers to questions posed.

The formal language I emply is a rudimentary language of predicate logic extended with a question operator ?. It is built around atomic formulas consisting of n-place relational constants R^n plus a sequence of n arguments t_i, which are either individual constants or variables. The language can be defined as follows in Backus-Naur form (BNF):

Definition 4.1 (Language of LQA)

- $\phi ::= \ R^n t_1 \ldots t_n \mid {\sim}\phi \mid \phi \wedge \phi \mid ?\vec{x}\phi$

Besides atomic formulas we have the elementary tools of negation $\sim$, conjunction $\wedge$, and questioning ?. The question operator $?\vec{x}$ queries the possible values of the variables $\vec{x}$ under which the embedded formula ϕ can be satisfied. I use $\vec{x}$ to indicate a possibly empty sequence of variables $x_1, \ldots, x_i$. In case $\vec{x}$ is empty, $?\vec{x}\phi$ is a polar question, also known as a *yes/no* question. I could have added first and second order quantifiers to the language, but they are not pertinent to the purposes of this paper.

As indicated above, the basic semantics of our language LQA is stated in terms of a satisfaction relation $M, g, \vec{\alpha} \models \phi$. The models which I use are standard first order models $M = \langle D, I \rangle$ where D is a domain of individuals under discussion, and I an interpretation function for the constants of our language. For any individual constant c, $I(c) \in D$ is the extension of c in M, the member of D denoted by c in M. A relational constant R^n denotes the set $I(R^n)$ of tuples of individuals $d_1, \ldots, d_n$ which are supposed to stand in the R^n relation in M. A variable assignment g assigns individuals from D to the variables which our syntax requires us to use. These assignments are regulated by variable binding operators, $?\vec{x}$ in our basic system, and by variable binding quantifiers in (regular) extensions of it.

The sequence $\vec{\alpha}$ is short for any Tarskian or Kaplanian sequence of parameters relevant for the satisfaction of a formula which is being evaluated. Since I focus on a semantics for a language with questions, this sequence will be understood as a sequence of answers to the questions posed in a formula ϕ to be satisfied. Our system elaborates upon the classical insight (Hamblin (1958), Karttunen (1977), Groenendijk and Stokhof (1984)) that the meaning of a question is its full and complete answer. A question $?\vec{x}\phi$ gets satisfied by the answer to the question under which valuations of the variables $\vec{x}$ the formula ϕ gets satisfied. If $\vec{x}$ consists of one variable x only, as in $?xCx$ ("Who come?"), it asks for the extension of C; if $\vec{x} = xy$ consists of two variables, as in $?xy(Bx \wedge (Gy \wedge Sxy))$ ("Which boys saw which girls?"), it asks for the set of pairs consisting of a boy and a girl the boy saw; if $\vec{x}$ is the empty sequence, as in $?p$ ("Does it rain?") it asks for the truth value of p: it denotes the set $\{\lambda\}$ consisting of the empty sequence $\lambda = \langle \ \rangle$ only, which is the truth value *true* (**1**) by definition, or the empty set $\{ \ \}$, the truth value *false* (**0**).

Questions can also be conjoined. For instance, $?OKy \wedge ?x(Bx \wedge Ryx)$, can be used to query whether your are OK (OKy) and which x are books (B) you read (Ry). Such a conjunction has to be satisfied by a pair of answers, a specification of books, and an acknowledgement about your well-being. In case a formula does not raise any question at all, it can only be satisfied by an empty sequence of answers, which I abbreviate by means of capital Λ. Such an empty sequence satisfies the formula if and only if it is satisfied in a classical, Fregean / Tarskian sense.

A boring, but pertinent, note on notation is crucial here. Since a formula ϕ may raise a number of questions $Q_1, \ldots Q_n$, a satisfying sequence $\vec{\alpha} = \vec{\alpha}_1, \ldots, \vec{\alpha}_n$ must answer all of these, so the numbers of the two sequences must be the same. Besides, a question Q_j can be of any type, because it may question the values of any sequence of i variables, so $\vec{\alpha}_j$ must be an i-ary relation as well. In what follows I will assume that these sequences and the arities of their members simply match, without further discussion. I will not discuss, here, the occurrence of the question operator under other operators like that of negation, or the question operator itself. I also assume the usual interpretation of (individual and relational) constants c and variables x:

- $[c]_{M,g} = I(c)$ and $[x]_{M,g} = g(x)$

The reader should by now be able to digest the following definition of my satisfaction semantics.

Definition 4.2 (Satisfaction Semantics for LQA)

- $M, g, \Lambda \models Rt_1 \dots t_n$ iff $\langle [t_1]_{M,g}, \dots, [t_n]_{M,g} \rangle \in [R]_{M,g}$
  $M, g, \Lambda \models {\sim}\phi$ iff $M, g, \Lambda \not\models \phi$
  $M, g, \vec{\alpha}\vec{\epsilon} \models \phi \wedge \psi$ iff $M, g, \vec{\epsilon} \models \phi$ and $M, g, \vec{\alpha} \models \psi$
  $M, g, \alpha \models ?\vec{x}\phi$ iff $\alpha = \{\vec{e} \mid : M, g[\vec{x}/\vec{e}], \Lambda \models \phi\}$

Let me briefly comment. It must be obvious that atomic formulas are satisfied in a completely standard way by an empty sequence of answers Λ and it is relatively easily established that the same goes for compound formulas which do not contain any occurrences of the question operator ?. I will call these indicative formulas, and they are henceforth abbreviated as $!\phi$. For any such formula $!\phi$ (and $!\psi$):

Observation 4.1 (Satisfaction of Indicatives)

- $M, g, \Lambda \models !\phi \wedge !\psi$ iff $M, g, \Lambda \models !\phi$ and $M, g, \Lambda \models !\psi$

Conjunction is relatively simple. When we conjoin two formulas we want each of them to be satisfied. If any one of them is indicative, it must be true in the classical sense, and if it is interrogative, a satisfying sequence of answers for the conjunction must supply the answer for that conjunct as well. If two interrogatives are conjoined, the satisfying (sequences of) answers are stacked, in such a way that the last question raised must be the first to be answered.

The most simple example of a question is a polar one, $?\vec{x}!\phi$ where $\vec{x}$ is an empty sequence of variables and $!\phi$ is indicative:

(1) Does it rain? ($?p$)

Given that $\vec{x}$ is the empty sequence, this queries whether the empty sequence of individuals satisfies p, which it does in case p is actually true. Formally:

Observation 4.2 (Satisfaction of Simple Polar Questions)

- $M, g, \alpha \models ?p$ iff $\alpha = \{\lambda\} = \mathbf{1}$ if $M, g, \Lambda \models p$ and
  $\alpha = \{\ \} = \mathbf{0}$ otherwise

Questions associated with non-empty sequences of variables constitute a generalization of the polar case. Consider:

(2) Which boys come?
$?x(Bx \wedge Cx)$

(3) Which professors failed which students?
$?xy(Px \wedge Sy \wedge Fxy)$

In these examples the possible values of x (and y) are being queried, so that the embedded formula $(Bx \wedge Cx)$ (and $(Px \wedge Sy \wedge Fxy)$, respectively) are satisfied. Formally:

Observation 4.3 (Satisfaction of Simple *Wh*-Questions)

- $M, g, \alpha \models ?x(Bx \wedge Cx)$ iff
  $\alpha = \{d \mid d \in I(B)\ \&\ d \in I(C)\}$
- $M, g, \alpha \models ?xy(Px \wedge Sy \wedge Fxy)$ iff
  $\alpha = \{dd' \mid d \in I(P)\ \&\ d' \in I(S)\ \&\ \langle d, d'\rangle \in I(F)\}$

As in standard treatments of questions, *Wh*-interrogatives denote their true and complete answers. The full answer to the question which boys come consists of a specification of the whole set of boys who come; the full answer to question (3) consists of a full specification of the set of pairs consisting of a professor and a student which the professor failed. Like indicatives, simple interrogatives, thus are also treated in the standard way.

4.3 Logic and Pragmatics of Questions and Answers

Our satisfaction semantics incorporates the basic insights of standard theories of indicatives and interrogatives, and it inherits the accomplishments and results from standard formal frameworks like those presented in, e.g., (Groenendijk and Stokhof (1984), von Stechow (1991), Krifka (1991), van Rooij (2003)). The standard theory is built on the idea that contents of assertions and information states can be characterized by means of sets of possibilities, those possibilities compatible with these assertions or states, and that questions can be taken to partition these states. The elements of such partitions indicate what are the relevant distinctions. Agents are interested in knowing which of the elements of a partition correspond to the real world, and they are supposed to be insensitive to differences between possibilities which reside in one block.

This however does require us to generalize the extensional models we used above to intensional models $\mathcal{M} = \langle W, D, I\rangle$ consisting of a set of worlds W, a domain of individuals D, and an interpretation function I for the constants of our language, and such that for any world $w \in W$: $\mathcal{M}_w = \langle D, I_w\rangle$ is an extensional model like we had above. This is a totally standard lift from extensional to intensional.

In terms of such intensional models we can account for the contents of (mixed) indicative and interrogative sentences. As indicated above, the content of any formula can be spelled out in terms of its satisfaction conditions, so it can be equated with the set of parameters in a model which satisfy it. In the definition below these are satisfaction sets S which consist of sequences of answers $\vec{\alpha}$ plus worlds w such that w is not excluded to be the actual world and $\vec{\alpha}$, in w, provides the complete answers to outstanding questions. In terms of these satisfaction sets we can derive standard notions of data, answerhood and indifference:

Definition 4.3 (Content, Answerhood, and Indifference)

- $[\![\phi]\!]_{\mathcal{M},g} = \{\vec{\alpha}w \mid \mathcal{M}_w, g, \vec{\alpha} \models \phi\}$ (content of ϕ)
  $D(S) = \{w \mid \exists\vec{\alpha}\colon \vec{\alpha}w \in S\}$ (data of S)
  $A(S) = \{\ \{w \mid \vec{\alpha}w \in S\}\ \mid \exists v\colon \vec{\alpha}v \in S\}$ (possible answers)
  $I(S) = \{\langle v, w\rangle \mid \exists\vec{\alpha}\colon \vec{\alpha}v \in S\ \&\ \vec{\alpha}w \in S\}$ (indifference)

A satisfaction set for a simple indicatives utterance p ("It rains.") consists of the worlds in $\mathcal{M}$ in which p is true, i.e. where it rains. A satisfaction set for a simple interrogative $?q$ ("Does it rain?") consists of pairs αw where α is the true answer to the question whether q in w. A satisfaction set for a mixed sentence: $p \wedge ?q$ ("It rains. Will John come?"), consists of those worlds in $\mathcal{M}$ in which it rains, after they have been paired with the answer **1** ("Yes.") or **0** ("No.") in worlds where John does come, and in those where he doesn't, respectively. The idea is that we deem the actual world to be one of those considered possible, and not like one of those excluded, and that we want to know which of the two types of worlds we inhabit, the type where John comes or the type where he doesn't.

The data (S) provided by a satisfaction set S simply consists of the set of worlds not excluded by S. The data thus model the information which S conveys in a standard, indicative, sense, and they neglect all the issues raised by S. As in the classical theory of questions, $A(S)$ provides the set of propositional answers to the question(s) modelled by S. That is, for any possibility $\vec{\alpha}v \in S$, the worlds w which agree with v on the full answers $\vec{\alpha}$ are collected together in a separate proposition, as a matter of fact the proposition true in exactly those worlds (which are not excluded!) in which $\vec{\alpha}$ provides the (sequence of) answers to the (sequence of) questions raised by S. In simple cases these generated sets of propositions are partitions of the sets of worlds conceived possible in S, which is to say that every world consistent with S participates in exactly one proposition in $A(S)$ (thus fleshing out the intuition that in every world there can be only one true and full answer to a particular question). Thus, the question $?xCx$ ("Who come?") can be modeled by a set of propositions: the proposition that (which is the set of worlds in which) nobody comes; the proposition that (set of worlds in which) Anja comes, and nobody else; the proposition that Boris and only he comes; the proposition that both come and nobody else; etc.

Indifference is another, and insightful, way of looking at these partitions, or at propositional answerhood. Partitions of any space can be characterized by an equivalence relation (a reflexive, transitive and symmetric relation on the points in that space). If we think of the questions in a satisfaction set S as those that are relevant, then S is indifferent about distinctions not made by the possible answers to the questions raised. That is to say, if S only raises the question whether the sun shines, then it is immaterial whether my brother visits Mexico. In that case S is concerned with the issue whether the world is like one in which the sun shines or like one in which it doesn't, and not with the issue whether the world is like one in which the sun shines and my brother visits Mexico, or like one in which the sun shines and my brother doesn't visit Mexico.

As Groenendijk and Jäger have shown, indifference looks like the most logical notion. If there are no questions involved, we are totally indifferent so that $I(S) = S^2 = \{\langle v, w\rangle \mid v, w \in W\}$, which means that we are insensitive for the difference between any two worlds v and w. If we add questions, we get a more involved look at the world, and our indifference $I(S)$ decreases. If we are just concerned with the question whether the sun shines, then we are indifferent between any two possibilities in which the state of the sun is the same, but we are sensitive to being in the type of world in which the sun does, and in one in which it does not shine. If we want to know everything, that is, if we want to know exactly what the world is like, then $I(S)$ has shrunk into the smallest indifference relation $\{\langle v, v\rangle \mid v \in W\}$. In the introduction these observation about indifference are illustrated in a more pictorial fashion, so we refer the reader here to that part of the present volume.

The semantics of questions in terms of partitions and indifference has two major benefits and one main limitation. Such a semantics combines a fully straightforward logic (Groenendijk and Stokhof (1984)) with an intuitive decision-theoretic interpretation (van Rooij (2003)). (See also the introduction to this volume.) However, it fails a straightforward account of constituent questions (Krifka (1991)). The semantics proposed in this paper, which is based on the satisfaction semantics from the previous section, retains the goodies, and overcomes the limitations of these approaches, as it has incorporated, right from the start, some (empirical) insights from the structured meaning approaches to questions (von Stechow (1991), Krifka (1991)). The remainder of this section gives a concise sketch of these three issues, but space restrictions do not allow me to go in full detail here.

The notion of indifference allows one to define a notion of entailment or support for interrogatives and indicatives in one gloss (cf. Jäger (1996), Groenendijk (1999)):

Definition 4.4 (Support)

- $\phi \models \psi$ iff $I([\![\phi]\!]_{\mathcal{M},g}) \subseteq I([\![\psi]\!]_{\mathcal{M},g})$ (for all $\mathcal{M}$ and g)

With the help of the notion of indifference, support boils down to simple inclusion ($\subseteq$), which is standard. For an expression ϕ to support ψ it effectively requires ϕ to provide more data and pose more questions. For two indicative expressions this boils down to classical entailment, and for two inquisitive expressions ϕ and ψ we find that the former entails the latter iff every complete answer to the first also completely answers the second. Moreover, an indicative expression $!\phi$ entails an inquisitive expression $?\vec{x}\psi$ iff it fully answers the question.

When we turn to the use of questions and answers in discourse it is expedient, if not necessary, to use a tool to keep track of what has happened in the discourse sofar. A system of update semantics provides precisely this tool when we are interested in the information which has been exchanged and the questions that have been raised, because this enables a formal account of the process of raising and resolving issues (Ginzburg (1996), Hulstijn (2000), Roberts (1996)).

Satisfaction sets are very well suited to model the required type of information obtained at a certain stage in a discourse, because they can serve to account for the data and questions agreed upon in one set-theoretical construct. Updating satisfaction sets proceeds as follows. Let S be the satisfaction set of the discourse at some point, so that it both contains the information provided by previous indicative utterances as well as the questions raised so far. Then the update of S with (an utterance of) ϕ consists of adding to S both the information and the questions provided by ϕ. Moreover, ϕ may contain information answering questions in S, which therefore can be wiped out. The definition runs as follows:

Definition 4.5 (Update Semantics)

- $S[\![\phi]\!]_{\mathcal{M},g} = \{\vec{\alpha}\vec{\epsilon}w \mid \vec{\epsilon}w \in S \ \& \ \mathcal{M}_w, g, \vec{\alpha} \models \phi\}^*$ with
- $T^* = \{\vec{\epsilon}w \mid \vec{\alpha}\vec{\epsilon}w \in T\}$ for the longest $\vec{\alpha}$ such that: $D(T) = D(T^*)$

According to the first clause an update of S with ϕ consists of *eliminating* sequences $\vec{\epsilon}w$ incompatible with the information provided by ϕ and *adding* sequences $\vec{\alpha}$ to the remaining sequences $\vec{\epsilon}w$ provided these sequences $\vec{\alpha}$ satisfy the questions of ϕ in w. The star on the satisfaction set that results from this update makes sure that resolved questions are popped. This operation removes answers from the top of the sequence if it is the same in all remaining possibilities. For instance, suppose the last interrogative has been $?p$ and the last (subsequent) indicative has been that p. The initial result of the update of initial set S is the set:

- $T = \{i\vec{\epsilon}w \mid \vec{\epsilon}w \in S \ \& \ i = I_w(p) \ \& \ I_w(p) = \mathbf{1}\}$

(Where i figures as a meta-variable for truth values.) Since all sequences in this set provide the same answer $\mathbf{1}$ to the last question, it can figure as the sequence $\vec{\alpha}$ in the definition above, so that

- $T^* = \{\vec{\epsilon}w \mid \mathbf{1}\vec{\epsilon}w \in T\} = \{\vec{\epsilon}w \mid \vec{\epsilon}w \in S \ \& \ I_w(p) = \mathbf{1}\}$

and clearly $D(T) = D(T^*)$.

4.4 Strategic Inquiry with Questions and Answers

We now have a satisfaction semantics for a language with indicatives and interrogatives, as well as an update semantics defined in terms of it. Not only does such an enterprise serve the purpose of giving an account of the interpretation of discourse, but it may also serve to define what constitutes a good, or structured, or coherent, or optimal discourse. And here comes the main point of the paper. I do not believe one can say much about this issue of optimality if one adopts a local perspective, that is by focusing on sentence pairs and discourse relations only, and ruling some ‘coherent’, or ‘felicitous’, or ‘congruent’, and others not. A whole series of authors has studied such pairs, and made very interesting observations about them, e.g., (Mann and Thompson (1988), Lascarides and Asher (1993), Groenendijk (1999)). Of course, asserting “John comes to the party, and no other students do.” can be relevant in response to a question “Who will come to the party?”, but almost any other utterance (indicative or inquisitive) can be relevant as well. We are perfectly able to make sense of other replies such as “Mary goes to the movies.”, “There’s a basketball match on TV tonight.”, “Will you come?”, “Is there beer in the fridge?”, and I don’t see why a response like “Patty will come to the PARTY!!??” should be deemed ungrammatical, incoherent, infelicitous, incongruous, or whatever, except, maybe, for the sake of defining one’s own notion of felicity, congruence, or what.

I believe a pragmatic, or global, perspective should be the one to be adopted. This observation is definitely not new, as Grice has already initiated it, as a strong defense of it is given in relevance theory (Sperber and Wilson (1986)), as it has been adopted by many other authors and as indeed also Asher and Lascarides advocated it. However, as Sperber and Wilson observe, Grice’s own perspective is still quite limited, being based on cooperativity and rationality assumptions with the interlocutors; besides, the ideas of Grice and the work done in relevance theory is very informal; theories of information structure like that of (Büring (1999), Ginzburg (1996), Hulstijn (2000), Roberts (1996)) are indeed theories of information *structure*, but they do not supply a (too) unrestrictive notion of an optimal discourse; finally, a global and formal account is offered by (van Rooij (2003)) in a very innovative way, but it requires us to adopt the apparatus of decision theory. I believe that a global and formally well-defined notion of an optimal inquiry can be defined, which can be motivated by rationality and cooperativity, but which does not presuppose interlocutors to be rational and cooperative, and which does not require them to calculate probability and utility measures. In fact, I will offer such a notion here.

One of Grice’s aims was to show that certain general principles constrain and guide the intention and interpretation of utterances of (linguistic) agents which are deemed rational and cooperative. The assumption of rational cooperative behaviour advances the agents involved in a conservation to obey, or to pretend to obey, the maxims of quality, quantity, relation and manner. These maxims require a speaker not to say things for which she lacks adequate evidence, not to say more nor less than is required for the purposes of the conversation, to advance relevant propositions, and to be well-behaved.

These maxims can be understood and formalized in the following way without adopting rigid rationality and cooperativity assumptions. It is important, as will also become clear from examples discussed below, that we do not try to characterize specific utterances as more or less felicitous, but that we indeed adopt a global perspective, which can be used to render whole discourses more or less optimal. So think of a game of information exchange as consisting in getting one's questions answered in a reliable and preferably pleasant way. Interlocutors engage in a multi-speaker dialogue Φ which can be deemed optimal if Φ answers their questions, while its contents are supported by the information the interlocutors have, and the communication is smooth:

Definition 4.6 (Optimal Inquiry) Given a set of interlocutors A with states $(\sigma)_{i \in A}$ a discourse $\Phi = \phi_1, \ldots, \phi_n$ is optimal iff:

- $\forall i \in A$: $D([\![\Phi]\!]) \cap D(\sigma_i) \models \sigma_i$ (relation)
$\bigcap_{i \in A} D(\sigma_i) \models D([\![\Phi]\!])$ (quality)
Φ is minimal (quantity)
Φ is well-behaved (manner)

An optimal discourse is one in which all questions of all interlocutors get answered in the first place (relation). For each agent $i \in A$, it requires that the data provided by the discourse $D([\![\Phi]\!])$ together with the data the agent had in the first place $D(\sigma_i)$, resolve ($\models$) all the initial questions the agent had. Of course, we are not satisfied with any arbitrary answer, we want *true* answers, and since we cannot be absolutely certain about the truth, we have to live with the data our interlocutors have. This is what the second line (quality) requires: the data provided by the discourse $D([\![\Phi]\!])$ must be supported by the combined initial information of the interlocutors, given as $\bigcap_{i \in A} D(\sigma_i)$.

When agents engage in a cooperative conversation, it is reasonable that they make clear what questions they have, and that they provide information which they have support for. The above notion of an optimal inquiry accounts for this. Here is a simple example of an optimal exchange. Suppose A wishes to know whether Sue comes to the party ($?s$), and B wants to know whether Tim comes to the party ($?t$), and assume that each of them knows the answer to the other one's question. The two information states can be defined as follows, σ being A's state, τ being that of B:

- $\sigma = \{\ [\![s]\!] \cap [\![\neg t]\!]\ ,\ [\![\neg s]\!] \cap [\![\neg t]\!]\ \}$
$\tau = \{\ [\![s]\!] \cap [\![\ \ t]\!]\ ,\ [\![\ \ s]\!] \cap [\![\neg t]\!]\ \}$
$CG_0 = W$

Indeed we see that no worlds are considered possible in which t is true according to σ and that this state distinguishes between the worlds in which s is true or false. Similarly, τ only calculates with worlds in which s is true, and distinguishes between those among them in which t is true or false. The following dialogue is optimal then:

(4) *A:* Will Sue come?
B: Yes.
Will Tim come?
A: No.

Both questions are answered, by information which was initially there distributed over the two initial information states. The exchange is, intuitively, also minimal, and well-behaved except maybe for the fact that there are no ceremonies, greetings, or the like. The update of the common ground proceeds as follows:

(5) *A:* Does Sue come? $CG_1 = \{iw \mid w \in W \ \&\ i = I_w(s)\}$
B: Yes. $CG_2 = \{iw \mid w \in W \ \&\ i = I_w(s) = \mathbf{1}\}^* = [\![s]\!]$
Does Tim come? $CG_3 = \{iw \mid w \in [\![s]\!] \ \&\ i = I_w(t)\}$
A: No. $CG_4 = \{iw \mid w \in [\![s]\!] \ \&\ i = I_w(t) = \mathbf{0}\}^* = [\![s]\!] \cap [\![\neg t]\!] = \sigma' = \tau'$

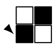
Formally, the requirements in definition (4.6) are satisfied. Example (4) can also be used to show that some standard felicity requirements (like informativity, non-redundancy, consistency, and congruence of answers with questions) can be derived from the requirements we have stated above, and I leave it to the reader to check this out. Most importantly, however, as has already been indicated, they are no absolute requirements.

Definition (4.6) may serve as a guideline for things to work out well in ideal circumstances. However, the guidelines do not presuppose participants to be cooperative and reliable in general. That is to say, even though we have sketched a model in which example (4) is produced in an ideal case, of course the interlocutors may be wrong, may lie, or may know or just think they are unreliable or lying. Thus, as a result of the very same example, A might very well conclude that B wants her to know that Tim is not coming, for instance, if A happens to know that B is a pathological liar. Such fancy complications of the ideal Gricean case of course draw from a lot of epistemic logic reasoning. It suffices here to observe that these considerations and conclusions are based upon a Gricean model of the ideal case, and upon the interlocutors' understanding of what would count as an ideal case, that is, if the formulated guidelines are not understood in a categorially imperative sense.

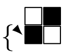
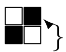
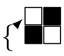
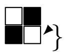
Apart from delusions and deliberate betrayal, there are also apparent deviations from the strict Gricean schemes which do remain cooperative. Quite surprisingly, it can be useful to ask for more information than one actually needs. In the next section I discuss two such cases, one more formal, and one more intuitive, and will then show how these cases can be used to explain some phenomena that have plagued the literature on the semantics of questions.

4.5 Superquestions and 'Mention Some'

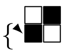
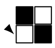
Here is a formal example of a useful superquestion. Let the actual world be a simple 2×2 chessboard with agent A at position $a1$, as in:

- 

A knows she is on the chessboard, but she does not care at which position she is, although she does care whether she is at a black or a white square. Her epistemic state can be characterized as follows:

- $\sigma = \{\ \{$  ,  $\}$, $\{$  ,  $\}\ \}$

A has no idea, and doesn't care, which of the four positions she occupies, but she indeed cares about being on a black or a white square. Her addressee B does know on which position A is, but she does not know what the chessboard looks like. Given that B does not have any questions himself, his state can be characterized as:

- $\tau = \{\ \{$  ,  $\}\ \}$

Now the following discourse unfolds:

(6) *A:* Am I on a black square?
B: I don't know.
A: On which square am I?
B: You're on $a1$.
A: Then I am on a black square.

This discourse is perfectly reasonable because A first asks what she wants to know, and B indicates he doesn't know the answer and then A asks something more specific than she wants to know, any answer to which also answers her question. B has a motivated reply to that question, and A's original question is resolved.

The previous example is a bit artificial, and it could be amended. For, as we already remarked above, A's 'real' question is whether, given that she is right, she is on a black square, or more precisely whether she is on $a1$ or $b2$, if these are the black fields indeed. By the same token B

could have directly solved A's question by replying that "Yes, if $a1$ is black." or with the counterquestion "What colour is $a1$, which is your current position?" But in practice it is not always obvious to see what is the optimal reply or question and the following example is meant to show this in some more detail.

Consider the following situation. There is a party which may be visited, apart from the speaker S (Sonja), by the professors Arms A, Baker B, Charms C, and Dipple D, which gives $2^4 = 16$ configurations. S's decision to go or not will be based on the question whether it is useful to do so, and it is going to be useful if S can speak to professor A or C. So A or C must be there, but there are some further complications. If, besides A, B is there as well B will absorb A if B doesn't absorb C, that is, if C is not absorbed by D; furthermore, if neither B and C are present, D will absorb A. The following table lists the configurations under which it is useful for Sonja to go:

•

	C & D	C & $\neg D$	$\neg C$ & D	$\neg C$ & $\neg D$
A & B	-	+	-	-
A & $\neg B$	+	+	-	+
$\neg A$ & B	-	-	-	-
$\neg A$ & $\neg B$	-	+	-	-

Of course, Sonja could ask: "Will I go there?", but this is normally not up to her interlocutor to decide. Given her requirements and expectations, Sonja wants to know if she is in a + or - situation, and that will help her enough to make here decision. Normally this corresponds to a polar question, a positive answer to which would mean that she is in a + type world, and a negative answer the opposite, which would indeed help her to decide whether to go or not. But without any further assumptions it seems she can hardly do better than asking:

(7) $(A\ AND\ [(B\ AND\ C\ AND\ \neg D)\ OR\ (\neg B\ AND\ (D \rightarrow C))])\ OR$ $(C\ AND\ \neg B\ AND\ \neg D)$?

Apparently, this is a somewhat cumbersome question. Alternatively it would also do to simply ask:

(8) Who come?

Any full answer to this question would answer S's main question, but notice that (8) asks for more specific information than she actually needs. Nevertheless (8) is a much more efficient means than (7) for S to solve her decision problem whether to go or not.

Once we realize that the requested information can be more specific than the information actually needed, we can react accordingly. For instance, if I happen to know more about Sonja's preferences, I might reply:

(9) Arms will not come, but Baker does.

Formally, this is only a partial answer to Sonja's question in (8), since it does not mention Charms and Dipple, but it does tell her enough: the party is going to be of the **-** type, so she can safely stay home.

In cases like this it is important to distinguish the decision problem which an agent faces, which is inherently indexical and subjective, and the objective question which she actually asks. Of course, Sonja might have asked "Will I be at the party tonight?", and this makes sense if, for instance, she wants to go there and it depends on the help of others whether she can make it. In the current situation, however, it is her own decision problem whether she will go, and then it seems up to irrational to ask others to decide it. So while it normally does not make sense that people directly express their decision problem ("Will I be at the party or not?"), we may realize that the objective questions they actually do ask ("Who will be at the party?") can originate from such subjective decision problems. I believe this distinction between subjective decision problems and factual questions, and their relation, together with some pragmatic reasoning, also throws light on the so-called "mention some" problem. To finish this section I will elaborate a bit on this point.

The following are relatively standard examples from the literature:

(10) Who's got a light?

(11) How can / do I open a gzip file?

(12) Where do they serve Thai food?

(13) How can / do I get to the station?

Normally, when such examples are used, they do not ask for an exhaustive answer. If the reply to (10) is that Peter can give me a light, that suffices for me and I do not need to know about others who could give me a light. It is also enough to know one method to open a gzip file, if it is a good one, and one does not need to know all alternatives. Similarly, a reply to (12) does not need to list all Thai restaurants out here, and hardly anybody would use (13) to ask for all possible routes to the station—which may be infinitely many.

Since these examples can be used with the intention of soliciting only one instance of the queried predicate, if that belongs to their meaning, and the meaning of a question resides in its answerhood conditions, then, as has been argued, the meaning of a question is not its full exhaustive answer, but rather a kind of disjunction of its possible instances. These examples thus cast doubt on the notion of the meaning of a question as it has been elaborated by, e.g., Groenendijk and Stokhof. I cannot discuss, here, all of the relevant literature on the subject, but I stick to a discussion of how these examples fit in the Groenendijk and Stokhof-style picture developed in this paper.

First, it should be noticed that the above examples in principle can be used with the intention to solicit an exhaustive reply anyway. For instance, a salesman might be interested in all Thai places where he can sell his own Taro root. And example (13) can be used if somebody is interested, given a suitable restriction of the domain of quantification, in all possible ways to reach the station, by car, bicycle, tram, bus or by foot. Acknowledging that the above examples can be used for both 'mention all' and for 'mention some' requests, should we therefore conclude that they are ambiguous between these two interpretations? Grice has taught us not to multiply meanings beyond necessity, so, if we can derive one of the interpretations from the other by pragmatic means, then we should do so.

Secondly, it should be noticed that any 'mention all' reply entails any 'mention some' reply. If we know all places where they serve Thai food, then we also know some places where we can go, provided that there are any. Thus, semantically there is nothing wrong with an exhaustive reply, since it satisfies the question on its 'mention some' interpretation, except that it can be boring, and too long-winded. Moreover, even though the meaning of a question is spelled out, above, as it is in Groenendijk and Stokhof, in terms of exhaustive answerhood, the analysis of actual replies is not. As I have shown more in detail in my other contribution to this volume, in reply to the question "Who gave what to whom?", a constituent answer "John a book to Mary." is only taken to assert that John gave a book to Mary, and it requires a (possibly implicit) indication like "Nobody anything to anything else." that the full answer is supposed to be given now.

So, thirdly, the only thing we need is an explanation why the examples (10–13) can be reasonably understood as requiring a 'mention some' reply only. Now our distinction between what is an agent's decision problem, and what she actually asks about the world to actually solve it becomes highly relevant. If a hearer understands that what somebody actually asks, semantically, is more specific than what she needs to know, as in example (9), if he can dig what it might be that she actually needs to know, and if the speaker can be confident that the hearer will understand all this, then there is nothing left to explain.

Let me briefly comment on some situations where a 'mention some' reading of the examples (10) and (12) is appropriate. A typical 'mention some' understanding of example (10) obtains in a situation where our agent Sonja has gone to the party, where we find Arms, Baker and Charms (amongst a lot of other irrelevant people), she lifts a cigar out of her pocket and utters (10). It is easy to decide what Sonja wants then (a light), but it is not so easy to describe what her 'decision problem' is. She has to step forward to some participant and get a light from him or her, but whom? If she doesn't ask anything in public, she can try and ask each of the participants until she has got a light, but in which order to ask these participants? So maybe her decision problem is: "Shall I ask Arms first, Baker next, etc., or shall I ask Baker first, Charms next, etc., etc." Obviously, this is an even more cumbersome question than the one in (7). A reply to her actual question (10) need not resolve this problem, but it can make life much easier. If the answer is "Charms, and also Erdvik." she can try and get a light from Charms first, and if Charms'a lighter happens to be out of gas, she can try Erdvik. In any case, if the respondent(s) understand what the situation is like, if they understand that the question actually posed is different from, but much more easily formulated than, the underlying decision problem, and if they also realize that the order of lighter-owners is practically immaterial, then they know a fully exhaustive reply is unnecessary, and as a matter of fact Sonja can expect that they realize this.

A 'mention some' use of (12) is similar. Suppose Tim is on a junction where he can go North, East, South or West. He can only go one way, so that is partly his decision problem: which of the four ways to go? He does, however, want to go a way where he will find a Thai restaurant. Indeed, if he gets a full specification of all directions in which he can find a Thai restaurant, he can make up his mind, so an exhaustive reply to (12) will definitely help him. That is good about using (12).

In the same situation, a direct formulation of his decision problem must be really something like the conjunction of the following four or five questions: "Will I go North and find a Thai restaurant?", "Will I go East and find a Thai restaurant?", . . . , "Or will I go nowhere?". Not only is this a cumbersome question, it is also hard to answer. I might know that he can find a nice Thai restaurant if he goes North and West, but of course I don't know which of the two ways he will go. Understanding what the motivation for Tim's question (12) can be, however, I can simply reply "North and West." and with this reply I don't exclude he could go South and find a nice Thai restaurant, but, if I got his question right, it ought to be helpful. The notion of an optimal inquisitive discourse, and assumptions about the knowledge and reasoning capacities of the interlocutors thus may serve to explain when exhaustive questions are used to elicit partial answers.

Conclusion

In formal theories of conversation and question-answering the focus is often on either rigid principles of behaviour (like Grice's conversational maxims) or structural answerhood relations (discourse relations from Thompson and Mann and Asher and Lascarides, Krifka's congruence, Groenendijk's notion of pertinence), or quantitative (decision theoretic) reasoning (Merin, van Rooy).

In this paper I have argued for a more liberal perspective, which is based upon but does not presuppose Gricean or decision theoretic rationality and cooperativity assumptions, and which can be used to give a formal account of what can be called "optimal discourses". My account is based on the interests of the discourse participants, and sticks to the usual qualitative type of reasoning. It is not regulative, and does not presuppose cooperativity.

The main conclusion is, in the first place, that utterances in dialogues should be apprehended from a global perspective, which takes into account the information and possible intentions of the dialogue participants, rather than from a local perspective, which focuses on local discourse relations only. In the second place, the conclusion is that such an account can be appropriately formalized. Indeed, the discussion in the last section of this paper was by and large programmatic, but if one adds one's own favourite type of epistemic logic, together with some suitable assumptions about the way agents are, all the results ought to be computable.

Acknowledgements

The research for this work is supported by a grant from the Netherlands Organization for Scientific Research (NWO) for the project *Formal Language Games*, which is gratefully acknowledged. I thank Maria Aloni, Robert van Rooij and Henk Zeevat for useful criticisms and comments.

Part II

Topic and Focus

5

Only Updates. On the Dynamics of the Focus Particle *Only*

Gerhard Jäger

Abstract

The article introduces "Update Logic for Questions and Answers" (ULQA). This is a first order logic where both declarative and interrogative sentences are represented as simple formulae of the same type. Formulae receive a dynamic interpretation as updates over static question denotations in the sense of Groenendijk & Stokhof (1984). The paper first discusses some of the meta-logical properties of this system. In the second part, an analysis of constituent questions and the focus particle "only" within ULQA is presented that models the context dependency of these natural language phenomena in a compositional way.

5.1 Introduction

The Montagovian paradigm of natural language semantics relies on the two crucial assumptions that (a) the meaning of a sentence can exhaustively be described by means of its truth conditions, and (b) this meaning can be built up compositionally from its parts. Unfortunately, empirical observations force us to the conclusion that the mentioned assumptions cannot be true at the same time, as soon we shift our attention to discourse phenomena. This is exemplified by the discourses in (1):

Questions in Dynamic Semantics.
Maria Aloni, Alastair Butler and Paul Dekker (eds.).
Current Research in the Semantics/Pragmatics Interface, Vol. 17.

(1) a. Peter came in. He wore a hat.
b. John came in. He wore a hat.

The second sentence in (1a) is true just in case that Peter wore a hat, while the corresponding sentence in (1b) is equivalent to *John wore a hat.* These two sentences are syntactically identical, at least as far as their surface is concerned. Hence they have the same parts, and, *ceteris paribus*, they should have the same meaning. Nevertheless their truth conditions differ.

This and related problems led several authors to the conclusion that we have to give up the principle of compositionality in the strict Montagovian sense. Most influentially, Kamp (1981) and Heim (1982) propose that there is an additional level of representation relating syntactic structure and semantic interpretation. In their systems, syntactic structure has to undergo a process of "DRS-construction" (Kamp) or "LF-construal" (Heim), and it is the output of this process that is interpreted compositionally in terms of truth conditions.

Groenendijk and Stokhof (1990a) and Groenendijk and Stokhof (1991a) choose the other direction. They point out that the principle of compositionality can be maintained as soon as we do without the assumption that sentence meanings coincide with truth conditions. Instead they propose that sentences (and discourses) denote transition functions over information states. These transition functions are connected to truth conditions, but in an indirect way. The advantage of this strategy is a methodological rather than an empirical one, since compositional and non-representational semantic theories are generally more restrictive in their predictive power.

It is the aim of this paper to extend the coverage of the dynamic paradigm to phenomena involving the focus sensitive operator *only*. Constructions involving this item show a dependency on linguistic context reminiscent to the behavior of anaphora. Existing approaches address this phenomenon by weakening the compositionality of interpretation in several respects. Instead we will try to outline a dynamic theory of the semantics of these constructions that preserves compositionality both on the sentence and on the text level.

5.2 The Problem

Consider the following contrast:

(2) Who is wise? Only [$_{+F}$ SOCRATES] is wise.

(3) Which Athenians are wise? Only [$_{+F}$ SOCRATES] is wise.

Although the answers in (2) and (3) are identical at the surface, they have different truth conditions. The answer in (2) forms a blasphemy since it entails that Zeus is unwise, while the corresponding sentence in (3) is much weaker in the sense that only the wisdom of all Athenians except Socrates is denied. Nothing is said about other individuals like, say, gods. More generally, the respective answers are truthconditionally equivalent to the first order formulae in (4a) and (b) respectively.

(4) a. $\forall x(wise(x) \rightarrow x = s)$
b. $\forall x(athenian(x) \wedge wise(x) \rightarrow x = s)$

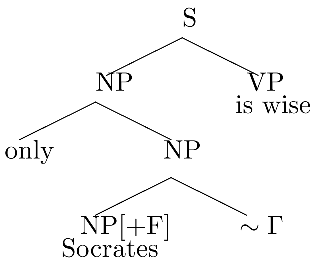
In both cases, the universal quantification is restricted by the non-focused part (the "background") of the sentence (*is wise*). Besides this, there is an additional restrictor in (4b), corresponding to the argument of the *wh*-word in the question (*Athenian*). Hence it is quite obvious that the truth conditions of a sentence involving *only* somehow depend on the question the sentence is an answer to.

We will proceed as follows. In the subsequent section, the proposal made in Rooth (1992) – which can be seen as a kind of paradigmatic approach in a static setting – is briefly presented and discussed. In section 4 we develop a dynamic system that covers both interrogative and declarative sentences. Finally, in section 5 it is shown that this system is able to account for the kind of dependency between questions and answers illustrated above.

5.3 Rooth 1992

In the sense of the discussion above, Rooth's proposal can be seen on a par with Heim (1982). As the feature that matters most for our purposes, he assumes that it is not surface structure that serves as input for semantic interpretation, but that there is an intermediate level of "Logical Form". The proposed LF for the sentence under discussion is roughly as in (5):

(5)



This is not the proper place to discuss the details and merits of Rooth's semantics of focus in general. It is only important that the LF contains – besides the overt material – an additional item "Γ" that is adjoined to the sister constituent of *only* by means of the operator "$\sim$". Γ is interpreted as a restriction of the domain of the universal quantification induced by *only*, such that we end up with an interpretation as it is given in (6).

(6) $\forall x(C(x) \wedge wise(x) \rightarrow x = s)$

"Γ" is considered to be a kind of anaphor that is interpreted as the free variable C above. The value of this variable is – according to Rooth (1992) – determined by a variety of factors that are external to the compositional interpretative machinery. Although he does not address comparable examples directly, it is very much in his spirit to assume that Γ should be coindexed with the *wh*-phrase of the preceding question in (2) and (3) by means of some pragmatic mechanism.

More generally, to achieve the appropriate truth conditions for constructions involving *only* in a static setup, we are forced to assume that (a) there is at least one level of representation distinct from surface structure that serves as input for the compositional interpretation, and (b) truth conditions, i.e. meaning is not completely determined by lexicon and syntax but relies on pragmatic processes. In view of this fact it strikes me a fruitful enterprise to develop a semantical analysis that avoids these stipulations, even if we have to give up the equation $meaning = truthconditions$. More in detail, our aim is

- to get rid of any kind of syntactic placeholders like the anaphor Γ in Rooth's proposal
- to derive the meaning of constructions involving *only* fully compositionally, i.e. without making reference to pragmatics.

5.4 Update Logic for Questions and Answers

5.4.1 A Static Approach to the Semantics of Questions: Groenendijk and Stokhof 1989

It is quite obvious that the different domain restrictions in the answers in (2) and (3) depend on the preceding question. Since we aim at an approach that is purely semantical, we have to assume that it is the semantics of the respective questions that trigger this effect. As basis for further argumentation, I adopt the framework laid down in Groenendijk and Stokhof (1984) without further argumentation.[1] It relies on the

[1] In Groenendijk and Stokhof (1989) it is shown that the propositional accounts to question semantics given in Hamblin (1973), Karttunen (1977), and Groenendijk

assumption that each question determines a unique proposition that constitutes the exhaustive true answer to the question.[2] This is best illustrated by an example. Take some simple yes-no question like

(7) Is it raining?

If it is raining, the unique exhaustive true answer is the proposition *It is raining*, and in case it is not raining, this answer is constituted by *It is not raining*. This can easily be expressed in a two-sorted extensional type theory:

(8) $\lambda w.(rain\prime(w) \leftrightarrow rain\prime(w_0))$

This expression denotes a proposition in every possible world, although it is not necessarily the same proposition in different worlds. To get a fixed semantic object, we have to λ-abstract over the world of evaluation w_0. According to Groenendijk and Stokhof (1984), the meaning of a question is just this new object – the "concept of the true answer".

(9) *Is it raining?* $\leadsto \lambda v \lambda w(rain\prime(v) \leftrightarrow rain\prime(w))$

It is obvious that this denotes an equivalence relation on the set of possible worlds. Hence a question defines an exhaustive partition on this set into a set of mutually exclusive proposition. In the example above, these are just the propositions *It is raining* and *It is not raining*. Generally, the elements of the partition are those propositions that constitute exhaustive – but not necessarily true – answers to the question.

5.4.2 Information States and Updates

The common strategy for the dynamification of a certain static semantics runs roughly as follows: If sentences statically denote objects from some domain α, the corresponding dynamic formulae denote functions $F : \alpha \to \alpha$. Since we want to deal with question-answer sequences in a single dynamic system, we are faced with a serious problem. Declarative sentences statically denote propositions, i.e. sets of possible worlds, while interrogatives denote relations on possible worlds or – equivalently – sets of propositions. Hence there are two candidates for update-denotations: functions from propositions to propositions or functions from relations to relations. By "generalizing to the worst case", we adopt the latter option. Formulae of the dynamic logic to be defined

and Stokhof (1984) are fundamentally equivalent, such that the choice does not matter too much.

[2]Counterexamples to this claim like free-choice questions are ignored throughout this paper.

below denote functions over information states (or simply "states"), where states are equivalence relations on possible worlds.

Let a nonempty set W of possible be given. We define:

Definition 5.1 (Information States) *σ is an information state iff $\sigma \subseteq W \times W$ and σ is an equivalence relation.*

This immediately gives us a partial order on the set of states, corresponding to the intuitive notion of informativity. The minimal and the maximal elements of this order are called **1** (state of ignorance) and **0** (absurd state) respectively.

Definition 5.2 (Informativity)

$$\begin{aligned} \sigma_1 \leq \sigma_2 \quad &\Leftrightarrow_{def} \quad \sigma_1 \supseteq \sigma_2 \\ \mathbf{1} \quad &=_{def} \quad W \times W \\ \mathbf{0} \quad &=_{def} \quad \emptyset \end{aligned}$$

Note that these relations may be partial, i.e. their domains may be proper subsets of W. Hence each state nontrivially determines a certain proposition, which can be thought of as the factual knowledge shared by the conversants.

Definition 5.3 (Domain of a state)

$$D(\sigma) \quad =_{def} \{w | w\sigma w\}$$

Since each equivalence relation uniquely defines a partition on its domain, it is worth considering the structure of the space of partitions determined by the space of states.

Definition 5.4 (Partitions) *Let σ, τ be information states.*

$$\begin{aligned} P_\sigma \quad &=_{def} \quad \{\{v | v\sigma w\} | w \in W\} \setminus \{\emptyset\} \\ P_\sigma \sqsubseteq_d P_\tau \quad &\Leftrightarrow_{def} \quad P_\sigma \supseteq P_\tau \\ P_\sigma \sqsubseteq_i P_\tau \quad &\Leftrightarrow_{def} \quad \bigcup P_\sigma = \bigcup P_\tau \wedge \forall x \in P_\sigma \exists y \in P_\tau : x \supseteq y \end{aligned}$$

Equivalence classes of possible worlds can be thought of as epistemic alternatives in a certain stage of conversation. Information growth can affect these alternatives in two ways. Either some of them are eliminated – this is covered by $\sqsubseteq_d$ – or they are made more fine-grained without changing the domain of the equivalence relation itself ($\sqsubseteq_i$). The latter corresponds to the effect of asking a question, while the former is the purpose of declarative utterances.[3] The notion of informativity given above covers both ways of information growth.

Fact 5.1 *For all states σ and τ, it holds that:*

$$\begin{array}{lcl} P_\sigma \sqsubseteq_d P_\tau & \rightarrow & \sigma \leq \tau \\ P_\sigma \sqsubseteq_i P_\tau & \rightarrow & \sigma \leq \tau \end{array}$$

Furthermore, the notion of informativity is exhausted by $\sqsubseteq_d$ and $\sqsubseteq_i$:

Fact 5.2 *For all states σ and τ, it holds that:*

$$\sigma \leq \tau \quad \leftrightarrow \quad \exists \upsilon : P_\sigma \sqsubseteq_i P_\upsilon \wedge P_\upsilon \sqsubseteq_d P_\tau$$

The intended interpretations of sentences/formulae are updates, i.e. transition functions over states that increase information.

Definition 5.5 (Updates) *Let Σ be the set of information states.*

$$UP \quad =_{def} \quad \Sigma^\Sigma \cap POW(\leq)$$

Updates may be classified according to the way how they increase information.

Definition 5.6 (Interrogative and Declarative Updates)

- An update u is called *declarative* iff $\forall \sigma : P_\sigma \sqsubseteq_d P_{u(\sigma)}$.
- An update u is called *interrogative* iff $\forall \sigma : P_\sigma \sqsubseteq_i P_{u(\sigma)}$.

There are only two updates that are both declarative and interrogative, namely the identity function and the constant function that always gives **0** as output. On the other hand, there are many updates that are neither declarative nor interrogative. Nevertheless, according to Fact 5.2, every update can be decomposed into an interrogative and a declarative one (in this order).

Since interrogative and declarative sentences denote different kinds of objects statically, there are two pairs of operators that switch between static and dynamic meanings.

[3]This is reminiscent to Dekker's EDPL (cf. Dekker, 1993), where information growth either introduces new variables into the state or eliminates possible values of familiar variables.

Definition 5.7 (Up-Arrow and Down-Arrow)
Let σ be an information state, p a proposition, q a static question denotation, and u an update.

$$\begin{aligned}
\downarrow_d u &=_{def} \{w | u(\{\langle w, w\rangle\}) = \{\langle w, w\rangle\}\} \\
(\uparrow_d p)(\sigma) &=_{def} \sigma \cap p \times p \\
\downarrow_i u &=_{def} u(\mathbf{1}) \\
(\uparrow_i q)(\sigma) &=_{def} \sigma \cap q
\end{aligned}$$

Fact 5.3 *For all propositions p and static question denotations q, it holds that:*

$$\begin{aligned}
\downarrow_d \uparrow_d p = p \\
\downarrow_i \uparrow_i q = q
\end{aligned}$$

Please note that the converse neither holds for $\uparrow_d \downarrow_d$ nor for $\uparrow_i \downarrow_i$. The $\uparrow_d$–operator is of particular interest since it enables us to add factual knowledge to a state without destroying the structure of the partition (of course, this holds only to the extend that the alternatives are compatible with this factual knowledge).

Fact 5.4 *For all states σ and propositions p, it holds that:*

$$D(\uparrow_d p(\sigma)) = D(\sigma) \cap p \tag{5.1}$$

$$\forall x (x \in P_\sigma \wedge x \cap p \neq \emptyset \rightarrow x \cap p \in P_{\uparrow_d p(\sigma)}) \tag{5.2}$$

5.4.3 The Semantics of ULQA

Having developed the necessary ontological background, we can start define a simple language that serves to reason about the described kind of updates. The syntax of ULQA is just the syntax of first order logic without functions symbols and with identity, with the single extension that there is a one-place propositional operator "?" that makes formulae out of formulae. For convenience, we take $\wedge, \neg, \rightarrow$, and $\forall$ as logical constants and the other connectives as abbreviations in the usual way.

A model for ULQA consists of an individual domain and a collection of classical interpretation functions (= possible worlds).

Definition 5.8 (Model)
A model M for ULQA is a triple $\langle E, W, F\rangle$, where E is a denumerable infinite set, W is non-empty, and F is a function that assigns a first-order interpretation function based on E to every member of W.

In the definition of the semantics of ULQA, we follow common practise in writing $\sigma[\phi]_g$ instead of $\|\phi\|_g(\sigma)$ in case ϕ denotes an update. By $g[e/x]$ we mean the assignment function $g\prime$ that is exactly like g except that it maps x to e.

Definition 5.9 (The Semantics of ULQA)

$$\begin{array}{rcl}
\|c\|_{w,g} & =_{def} & F(w)(c) \textit{ iff } c \textit{ is an individual constant} \\
\|v\|_{w,g} & =_{def} & g(v) \textit{ iff } v \textit{ is a variable} \\
\sigma[P(t_1, ..., t_n)]_g & =_{def} & \sigma \cap \{\langle v, w\rangle |\ \forall w\prime(v\sigma w\prime \ \rightarrow \\
 & & \langle \|t_1\|_{w\prime,g}, ..., \|t_n\|_{w\prime,g}\rangle \in F(w\prime)(P))\} \\
\sigma[t_1 = t_2]_g & =_{def} & \sigma \cap \{\langle v, w\rangle |\ \forall w\prime(v\sigma w\prime \rightarrow \|t_1\|_{w\prime,g} = \|t_2\|_{w\prime,g})\} \\
\sigma[\phi \wedge \psi]_g & =_{def} & \sigma[\phi]_g[\psi]_g \\
\sigma[\neg\phi]_g & =_{def} & \sigma \setminus \sigma[\phi]_g \\
\sigma[?\phi]_g & =_{def} & \sigma \cap \{\langle v, w\rangle |\ \{\langle v, v\rangle\}[\phi]_g = \emptyset \ \leftrightarrow \\
 & & \{\langle w, w\rangle\}[\phi]_g = \emptyset\} \\
\sigma[\forall x.\phi]_g & =_{def} & \bigcap\limits_{e\in E} \sigma[\phi]_{g[e/x]} \\
\sigma[\phi \rightarrow \psi]_g & =_{def} & \sigma \cap \{\langle v, w\rangle |\ v\sigma[\phi]_g w \rightarrow v\sigma[\phi \wedge \psi]_g w\}
\end{array}$$

The interpretation of atomic formulae is based on the corresponding classical interpretation. Updating a certain state σ with a classical formula ϕ amounts to saying that only those alternatives in P_σ survive that are completely included in the set of possible worlds where ϕ is true under its classical interpretation. If you consider σ as an accessibility relation in a Kripke model, the domain of the output is restricted to those worlds where ϕ is necessarily true in its static interpretation.

The clauses for dynamic conjunction, dynamic negation, and dynamic implication are familiar from other dynamic systems like Veltman's Update Semantics (cf. Veltman, 1996) and do not need much explanation. The semantics of universal quantification is a straightforward extrapolation from its classical counterpart.

The key feature of ULQA is the ?-operator. To explain its impact on a rather intuitive level, each proposition in P_σ is split into those worlds where the formula in the scope of "?" is true and those where it is false. To put it another way, "?ϕ" defines an equivalence relation by its own, and the output of the update is the intersection of σ with this relation.

It does not come as a surprise that atomic formulae denote declarative updates and formulae prefixed with "?" interrogative ones. Both properties are preserved under conjunction and universal quantification. Being a declarative update is also preserved under negation. Negating an interrogative update, on the other hand, returns in all non-trivial cases a relation as output that is reflexive and symmetric but not transitive. Hence the negation of an interrogative update isn't an update at all in the general case.

The definitions of truth and entailment in ULQA are fairly standard from related dynamic calculi. A formula is called *true in a state* if updating the state with the formula does not add information. By abstracting over particular contexts, we get the notion of *truth in a model*, and by abstracting over models, we can define *logical truth*.

Definition 5.10 (Truth)
Let M be a model, σ be an information state and ϕ be a formula.

$$\begin{aligned} M, \sigma \models \phi \quad &\Leftrightarrow_{def} \quad \forall g : \sigma[\phi]_{M,g} = \sigma \\ M \models \phi \quad &\Leftrightarrow_{def} \quad \forall \sigma : M, \sigma \models \phi \\ \models \phi \quad &\Leftrightarrow_{def} \quad \forall M : M \models \phi \end{aligned}$$

The definition of the consequence relation between formulae is straightforwardly derived from this truth definitions. ψ is said to be a consequence of ϕ iff the output of ϕ is always a state where ψ is true.

Definition 5.11 (Entailment)
Let M be a model, σ an information state, and ϕ, ψ formulae.

$$\begin{aligned} \phi \models_{M,\sigma} \psi \quad &\Leftrightarrow_{def} \quad \forall g : \sigma[\phi]_{M,g} = \sigma[\phi \wedge \psi]_{M,g} \\ \phi \models_M \psi \quad &\Leftrightarrow_{def} \quad \forall \sigma : \phi \models_{M,\sigma} \psi \\ \phi \models \psi \quad &\Leftrightarrow_{def} \quad \forall M, \phi \models_M \psi \end{aligned}$$

5.4.4 The Relation of ULQA to First-order Logic

Syntactically speaking, ULQA is a simple extension of first-order logic, and also semantically, there is a close connection between the classical fragment of ULQA and PL1. Recall that the individual domain E of an ULQA-model M together with any possible world w from W forms a first-order model. A ULQA-formula is called *?-free* iff it does not contain any occurrence of "?". Trivially, the ?-free formulae are just the formulae of PL1.

Definition 5.12 *Let ϕ be a ?-free ULQA formula.*

- *By* $\|\phi\|_M^{ULQA}$ *we refer to the ULQA-interpretation of* ϕ *in the ULQA-model* M*.*
- *By* $\|\phi\|_M^{PL1}$ *we refer to the set of worlds* w *from* W *such that* $\|\phi\|$ *is true in* $\langle E, F(w)\rangle$ *under classical first-order interpretation.*

Fact 5.5
Let ϕ *be a ?-free ULQA-formula. It holds in any model* M *that:*

$$\downarrow_d \|\phi\|_M^{ULQA} \quad = \quad \|\phi\|_M^{PL1}$$

Proof : *By induction on the complexity of* ϕ*.*

In a sense, the classical interpretation of some ?-free formula ϕ, i.e. $\downarrow_d \|\phi\|^{ULQA}$, can be seen as the "context-free" truth-conditional or factual impact of that formula. Hence by updating a state σ with $\uparrow_d\downarrow_d \|\phi\|$, we add the factual content of ϕ to σ without affecting the structure of P_σ.

Fact 5.6 *Let* ϕ *be ?-free.*

$$\uparrow_d\downarrow_d \|\phi\|^{ULQA}(\sigma) \quad = \quad \sigma \cap \|\phi\|^{PL1} \times \|\phi\|^{PL1}$$

Proof : *Immediately from the definition of* $\uparrow_d$*.*

Following common practise, we call $\uparrow_d\downarrow_d \|\phi\|$ the *static closure of* ϕ. Fortunately, the operation of static closure can be expressed in the object language, as far as ?-free formulae are concerned.

Fact 5.7 *Let* ϕ *be ?-free.*

$$\uparrow_d\downarrow_d \|\phi\| \quad = \quad \|?\phi \wedge \phi\|$$

Proof : *By* **Fact 5.5** *and induction on the complexity of* ϕ*.*

For convenience, we will henceforth abbreviate "$?\phi \wedge \phi$" with "$\uparrow\downarrow \phi$" and we will also refer to it as the "static closure of ϕ". Context will make clear whether we use the term in its syntactic or its semantic sense.

Remember that the union of the propositions in P_σ (the epistemic alternatives) represents the knowledge that is shared by the conversants. Static closure enables us to make statements about this state of factual knowledge in the object language.

Fact 5.8 *Let ϕ be ?-free.*

$$\begin{array}{lcl} \sigma \models \uparrow\downarrow \phi & \Leftrightarrow & D(\sigma) \subseteq \|\phi\|^{PL1} \\ \psi \models \uparrow\downarrow \phi & \Leftrightarrow & \forall\sigma : D(\sigma[\psi]) \subseteq \|\phi\|^{PL1} \end{array}$$

5.5 Restricted Quantification in ULQA

5.5.1 English $\Longrightarrow$ ULQA

Since ULQA is a first-order language, there cannot be an immediate compositional translation function from English into ULQA. But it is obvious from the definition of the semantics of ULQA that every semantic object that is the interpretation of some ULQA-formula is at the same time the interpretation of some Ty_2-formula. Hence ULQA can be seen as a convenient notation of a fragment of Ty_2. On the other hand, if the translation of a couple of English sentences into Ty_2 are given, it is a technical exercise to develop a Montague-style compositional translation from this fragment of English into Ty_2. This in mind, I will content myself with stipulating the ULQA-translations of the English sentences under debate since the described procedure would take a lot of space without illuminating anything of particular interest.

The translation of simple clauses with names in the argument positions are straightforward and do not need much explanation.

(10) Socrates is wise $\rightsquigarrow wise(s)$

Prima facie, the ?-operator only enables us to form yes-no questions. Nevertheless it is possible to deal with constituent questions appropriately. We start with the observation that a *which*-question is equivalent to a yes-no-question in the scope of a restricted universal quantifier.

(11) a. Which Athenians are wise?
b. For all Athenians: Is he or she wise?

In contrast to other approaches to the semantics of questions, the interpretations of interrogative and declarative sentences belong to the same logical type, namely updates. Hence there is no problem in quantifying into a question. Hence I assume:

(12) Which Athenians are wise? $\rightsquigarrow \forall x(athenian(x) \rightarrow ?wise(x))$

Who-questions can be handled in a similar manner. The only difference lies in the absence of a restriction to the quantifier.

(13) Who is wise $\rightsquigarrow \forall x.?wise(x)$

One of the crucial features of ULQA is the fact that universal quantification is – so to speak – automatically contextually restricted. This fact will be illustrated in some length in the subsequent paragraphs. Therefore the translation of *only*-constructions can be kept pretty simple.

(14) Only Socrates is wise $\rightsquigarrow \forall x(wise(x) \rightarrow x = s)$

This strategy is of course an oversimplification in some respects, but Krifka (1992) shows convincingly that it is possible to derive corresponding translations of more complex construction involving VP-focus and multiple focus fully compositionally.

5.5.2 Some Properties of ULQA

Let us start with a couple of negative results. First of all, the consequence relation defined above is not reflexive.

Fact 5.9 (Non-Identity) *There are formulae ϕ such that*

$$\phi \quad \not\models \quad \phi$$

As it will turn out, this is not an accident but even a quite desirable feature. An example will be given and discussed below. It is worth noting that identity does hold as far as ?-free formulae are concerned.

Fact 5.10 *Let ϕ be ?-free. Then it holds that*

$$\phi \quad \models \quad \phi$$

Sketch of proof: The semantics of ULQA can equivalently be redefined in such a way that formulae denote updates over partitions. Under this perspective, ?-free formulae denote updates that are both eliminative and distributive (cf. Groenendijk and Stokhof, 1990b). Hence there is a static interpretation to this fragment such that updating is just intersecting the state with the static meaning. The fact follows then from the idempotence of set intersection.$\dashv$

For the present discussion, it is more important that we are not entitled to infer from a certain update to its static closure, even if identity holds for this update.

Fact 5.11 *There are formulae ϕ such that*

$$\phi \models \phi \tag{5.1}$$

$$\phi \not\models \uparrow\downarrow \phi \tag{5.2}$$

Proof : Suppose $\phi = \neg\psi$, let ψ be a ?-free closed atomic formula such that $\|\psi\|^{PL1} \neq \emptyset$, $\|\psi\|^{PL1} \subset W$. (1) follows immediately from Fact 5.10. For (2), observe that $\mathbf{1}[\neg\psi] = \mathbf{1}$, $\mathbf{1}[\uparrow\downarrow \neg\psi] = \|\neg\psi\|^{PL1}$. Hence $\mathbf{1}[\neg\psi] \neq \mathbf{1}[\neg\psi][\uparrow\downarrow \neg\psi]$ ⊣

This implies that the context-free meaning of a certain formula may be logically stronger than its context-dependent version. A quite realistic example is

(15) a. Only Socrates is wise.
b. $\forall x.(wise\prime \rightarrow x = s\prime) \not\models \uparrow\downarrow \forall x.(wise\prime \rightarrow x = s\prime)$

The static closure of *Only Socrates is wise* means that Socrates is literally the only wise individual, and this of course cannot be inferred from the utterance of the sentence in a particular context, as (3) shows.

Neither can we infer from a universally quantified formula to the static closure of some instance.[4]

Fact 5.12 *There are formulae ϕ and individual constants a such that*

$$\forall x.\phi \models \phi(a)$$

$$\forall x.\phi \not\models \uparrow\downarrow \phi(a)$$

Proof : Let ϕ be as in the proof of Fact 5.11. Since ϕ is closed, the fact follows immediately from Fact 5.11. ⊣

This is again a desired result, since we don't want to draw the conclusion *Zeus is not wise ($\Leftarrow$ If Zeus is wise, then he is Socrates)* from *Only Socrates is wise* under all circumstances. Nevertheless there is a restricted version of the mentioned kind of universal instantiation.

Fact 5.13 *For all ?-free formulae ϕ, ψ and individual constants a, it holds that if $\psi \models \uparrow\downarrow \psi$*

$$\textit{then } ?\phi(a) \wedge \forall x(\phi \rightarrow \psi) \models \uparrow\downarrow (\phi(a) \rightarrow \psi(a))$$

[4] By $\phi(a)$ we refer to $\phi[a/x]$, provided that, besides x, no variables are free in ϕ.

Sketch of proof: $P_{\sigma[?\phi(a)]}$ contains only propositions that either entail $\|\phi(a)\|^{PL1}$ or $\|\neg\phi(a)\|^{PL1}$. Among those that make $\phi(a)$ classically true, only those can survive in $P_{\sigma[?\phi(a)\wedge\forall x(\phi\rightarrow\psi)]}$ that survive under updating with $\psi(a)$. The premise ensures that these propositions are contained in $\|\psi(a)\|^{PL1}$. Hence if a proposition in $P_{\sigma[?\phi(a)\wedge\forall x(\phi\rightarrow\psi)]}$ classically entails $\phi(a)$, it also entails $\psi(a)$. The conclusion follows by Fact 5.8 (2).$\dashv$.

Applied to the example, it follows that we may infer from the utterance of *Only Socrates is wise* to, say, *Plato is unwise* provided that Plato's wisdom **is under debate** in the present state of conversation.

(16) $?wise(p) \wedge \forall x(wise(x) \rightarrow x = s) \models\uparrow\downarrow (wise(p) \rightarrow p = s)$

To put it another way round, besides the syntactically present restrictor to a universal quantifier, we have the implicit restriction that an individuals being an instance of the restrictor has to be under debate at the current state of conversation. Let me briefly explain why ULQA behaves in this way. A partition corresponding to a state is a collection of sets of worlds, i.e. total first-order interpretation functions. A set of interpretation functions can be identified with a partial function. If all total functions in the set agree about the value of a certain item x, the derived functions assigns this value to x, too. If x receives different values under different functions in the set, its value under the corresponding partial function is undefined. Hence an information state can be seen as a set of situations, i.e. partial first-order models. Asking a question in a certain state extends the domain of the situations in the state. The interpretation of ϕ is defined in any situation in $\sigma[?\phi]$, no matter whether it was defined in σ. Hence $\sigma \models ?\phi$ just if ϕ is completely defined in σ.

This in mind, it becomes clear why identity should not hold in ULQA. Suppose that an atomic formula ϕ is undefined in any situation in a state σ. Then $\sigma[\phi] = \mathbf{0}$ and $\sigma[\neg\phi] = \sigma$. But updating σ with $?\phi$ brings us in a state where ϕ is defined. Now suppose that ϕ expresses a proposition contingent in σ. In this situation, $\sigma[?\phi \wedge \neg\phi] \neq \sigma[?\phi]$. Hence $\neg\phi \wedge ?\phi \not\models \neg\phi \wedge ?\phi$.

A certain individual only falls in the domain of a restricted universal quantifier if it unequivocally either is an instance of the restrictor or it is not. Hence we have an implicit restriction of a quantifier domain given by definedness.

Now let us return to the example. *Only Socrates is wise* makes a statement about those objects whose wisdom is under debate. Asking the question *Which Athenians are wise?* brings you in a state where the wisdom of all individuals that are known to be Athenians is under debate. Let us make this slightly more precise. Firstly, we have a restricted version of Modus Ponens together with universal instantiation in ULQA. To give the restrictions precisely, we firstly need an auxiliary definition.

Definition 5.13 (Persistence) *A formula ϕ is said to be* persistent *iff for all states σ, τ:*

$$\sigma \models \phi,\ \sigma \leq \tau \quad \Rightarrow \quad \tau \models \phi$$

Note that by the definitions, any formula prefixed with "?" is persistent.

Fact 5.14 *For all formulae ϕ, ψ and individual constants a, it holds that if $\phi \models \phi$, $\psi \models \psi$ and $\psi(a)$ is persistent, then*

$$\phi(a) \wedge \forall x(\phi \rightarrow \psi) \models \psi(a)$$

Sketch of proof: Suppose that the premises hold for ϕ and ψ. By the semantics of $\forall$, we have $\sigma[\phi(a) \wedge (\phi(a) \rightarrow \psi(a))] \leq \sigma[\phi(a) \wedge \forall x(\phi \rightarrow \psi)]$. From $\phi \models \phi$, we have $\phi(a) \models \phi(a)$, and together with the definition of dynamic implication, we then have $\sigma[\phi(a) \wedge (\phi(a) \rightarrow \psi(a))] = \sigma[\phi(a) \wedge \psi(a)]$. Hence we have $\sigma[\phi(a) \wedge \psi(a)] \leq \sigma[\phi(a) \wedge \forall x(\phi \rightarrow \psi)]$. From $\psi \models \psi$, we infer $\psi(a) \models \psi(a)$. Hence we have $\sigma[\phi(a) \wedge \psi(a)] \models \psi(a)$. By the persistence of $\psi(a)$, we have $\sigma[\phi(a) \wedge \forall x(\phi \rightarrow \psi)] \models \psi(a)$ ⊣

If we know that a person, say, Plato is an Athenian, after asking the question *Which Athenians are wise?* we are in a state where Plato's wisdom is under debate.

(17) $athenian(p) \wedge \forall x.(athenian(x) \rightarrow ?wise(x)) \models ?wise(p)$

Now from (17) and (16) we may conclude:

(18) a. Which Athenians are wise? Only Socrates is wise.
b. $athenian(p) \wedge \forall x(athenian(x) \rightarrow ?wise(x)) \wedge \forall x(wise(x) \rightarrow x = s)$

$$\models \uparrow\downarrow (wise(p) \rightarrow p = s)$$

Now suppose that a person, for instance Zeus, is neither known to be an Athenian nor to be wise in any of the epistemic alternatives in a certain state σ (formally: $\sigma \models \neg athenian(z)$, $\sigma \models \neg wise(z)$). In this case, there is nothing that can be inferred about Zeus' wisdom from the question-answer pair above. Hence the domain of the universal quantification introduced by *only* is in fact restricted to Athenians in this context.

To analyse *Who is wise?*, please observe that $\forall x.?wise(x)$ is synonymous to $\forall x(x = x \rightarrow ?wise(x))$. Hence after asking that question, anybody's wisdom is under debate, and therefore we do not have any domain restriction at all in the subsequent statement.

(19) $\forall x.?wise(x) \models ?wise(a)$ (where a is an arbitrary individual constant)

From (19) and (16), we may conclude:

(20) a. Who is wise? Only Socrates is wise.
b. $\forall x.?wise(x) \wedge \forall x(wise(x) \rightarrow x = s) \models \uparrow\downarrow (wise(z) \rightarrow z = s)$

5.6 Summary

The implicit universal quantification introduced by *only*-constructions is restricted by contextual information. This fact becomes most obvious in question-answer pairs. According to Rooth (1992), these constructions nevertheless involve classical universal quantification which is restricted by a syntactically present anaphor Γ. The interpretation of Γ is governed by some pragmatic mechanism. It was the aim of this paper to achieve the same result in a purely semantic manner. Firstly, to deal with context dependency semantically, we are forced to use a dynamic setup. Secondly, we changed the semantics of universal quantification in such a way that it is restricted implicitly by the context. Suppose a universal quantifier is syntactically restricted by some predicate P. In this case, the actual domain of quantification is not the entire universe but the set of individuals whose being P is under debate in the current state of conversation, and it is the purpose of questions to bring issues into the debate. Hence the dependency between questions and focus is a rather indirect one under the present approach.

There are plenty of questions left that require further investigations, concerning both the logic developed here and its linguistic application. As I mentioned in the preceding section, the semantics of ULQA makes use of a kind of simulated partiality. It strikes me an interesting issue to see what happens if we replace sets of propositions by sets of situations. Besides this, it is worth investigating whether it is possible to incorporate ULQA in a static logic with program modalities in a similar manner as presented in van Eijck and de Vries (1995) and van Eijck (1993) for Update Logic and Dynamic Predicate Logic. Linguistically, the coverage should be extended to other phenomena like the semantics of indirect questions of *wh*-pronouns.

Acknowledgements

I am particularly indebted to Henk Zeevat for a very inspiring discussion during his stay in Berlin in spring 1995.

6

The Dynamics of Topic and Focus

Maria Aloni, David Beaver, Brady Clark and Robert van Rooij

6.1 Background and Motivations

This article presents a dynamic account of topic and focus. A dynamic view on meanings as context change potentials (e.g. Stalnaker, Kamp, Heim, Groenendijk & Stokhof) will provide us with a substantial account of the dependence of focused answers on the *context* set up by their preceding questions. Questions pose conditions on the focal structure of their answers (see Paul, 1880) and can further restrict the domain of subsequent focusing operators like *only* (e.g. von Stechow, 1991, von Fintel, 1997b, and Jäger's contribution to this volume). As an illustration of these two facts consider the following example:

(1) a. Who did John introduce to Sue?
b. Which gentlemen did John introduce to Sue?
c. John only introduced $[\text{Bill}]_{\text{F}}$ to Sue.
d. # John only introduced Bill to $[\text{Sue}]_{\text{F}}$.

After question (1a) or (1b), only an answer with the focal structure in (1c) is felicitous or *congruent*. The focal structure in (1d) is out. Consider now the meaning of the congruent answer (1c). After question (1a), (1c) means 'The only person John introduced to Sue is Bill'. After (1b), it can mean 'The only gentleman John introduced to Sue is Bill'.

Standard analyses of focus define congruence in terms of identity between the question meaning and the focal alternatives of the answer (e.g. von Stechow, 1991, Roberts, 1996), and identify the domain

Questions in Dynamic Semantics.
Maria Aloni, Alastair Butler and Paul Dekker (eds.).
Current Research in the Semantics/Pragmatics Interface, Vol. 17.

of focusing operators like *only* with the set of focal alternatives (e.g. Rooth, 1985). In our example, the two distinct questions (1a) and (1b) pose the same conditions on the focal structures of their answers but can have different effects on the quantificational domain of subsequent *only.* These two facts constitute a problem for these standard theories unless they come equipped with a smart analysis of the *dynamics* of domain restriction which plays a role in these cases. The main goal of this article is to provide such an analysis.

Most existing dynamic analyses of questions have been developed in the tradition of the *partition theory* of Groenendijk and Stokhof (1984). In the partition theory, the meaning of a question is identified with the set of meanings of all its exhaustive answers. In a dynamic setting, questions partition information states, and answers eliminate blocks of these partitioned contexts (see Groenendijk, 1999, Jäger, 1996, both reprinted in this volume, but also Hulstijn, 1997). These theories in which interrogatives and indicatives update a context, constitute a simple model of how information in discourse is organized by the question-answer relation (e.g. Carlson, 1983, Roberts, 1996). The notion of a partial or complete answer is specified in terms of entailment which is uniformly defined for indicative and interrogative sentences. Although logically very appealing, these theories are, empirically, not completely satisfactory. First of all, partitions seem to be too coarse-grained for a proper treatment of focus, and, thus, for an account of the facts in (1). Constituent answers are hard to tackle in these analyses as well. For example, Groenendijk cannot account for the different content expressed by answer (2c) after (2a) and after (2b), for the two questions, having the same set of complete answers, induce exactly the same partition.

(2) a. Who smokes?
b. Who doesn't smoke?
c. [John]$_{\mathrm{F}}$.

Related difficulties also arise for theories in the Hamblin/Karttunen/Rooth tradition, e.g. problems with multiple foci (see Krifka, 1992) and alternative questions (see von Stechow, 1991, Krifka, 2001). The standard treatment of alternatives as sets of (propositional) answers is not fined-grained enough and, as many people have argued, for a proper account we need the *abstracts* underlying the questions (see Groenendijk and Stokhof, 1984, Ginzburg, 1995, van Rooij, 1997b) and *direct access* to focus, i.e. structured meanings.

In a *structured meaning* account we have fitting analyses of questions and focus: questions denote abstracts, $\lambda\vec{x}\phi$, i.e. functions that when applied to the meaning of the possible constituent answers yield the meaning of the corresponding full sentential answers; and focus leads to a partition of the semantic value of an expression into a background part, also a function, and a focus part: $\langle \lambda \vec{x} \phi, \vec{a} \rangle$. Although structured meanings seem to supply us with the right level of fine-grainedness, this account does not assume interrogatives to belong to a uniform category or semantic type. Therefore, unlike the partition theory, structured meaning accounts lack an elegant analysis of embedding and coordination of questions, as in (3):

(3) Adam knows whether there is a party, who will go and who invited whom.

In what follows we shall present an update semantics of questions and focus. Utilizing the close correspondence between information states in dynamic semantics — sets of world-assignment pairs — and structured propositions, the obtained analysis will combine the positive sides of partitions and structured meanings, solve the discussed difficulties and allow a number of further applications.

6.2 An update semantics of questions and focus

In this section we shall present an update semantics of questions and focus building on Gawron's (1996) dynamic model of domain restriction. In Gawron's analysis, the introduction of a quantificational operator is separated by the introduction of the quantificational domain. The latter is allowed to be fixed non-locally. The intuition is that domains of quantification are constructed by combining constraints that arise from different sources. These constraints are encoded in so called *environments* which map variables to sets of possible assignments encoding information about which values are possible for them. In this article, we propose to interpret the semantic contribution of interrogative sentences in term of extensions of these Gawronian environments. In our formalism, an environment is a sequence of sets of world-assignment pairs. We will take these sets to represent the *topics* under discussion in the current context. Interrogative sentences will be analyzed as setting up new topics, or expanding on previously introduced ones. From a topic in an environment we can easily recover the partition it would induce on the current information state. Therefore, we will be able to define all of the logical notions which are relevant for a theory of questions and answers. Since our topics are as fine-grained as abstracts, we will improve, though, on the partition theory with respect to phenomena like constituent answers or alternative questions. On the other hand, since interrogatives are associated with a uniform semantic type, we will also improve on the structured meaning account with respect to the embedding and coordination of questions. Finally, since, as in Gawron, topics encode domain restrictions, we will be able to account for the impact of questions on subsequent domains of alternatives and account for the 'gentlemen' example discussed in the introductory section of this article.

6.2.1 A closer look

Formulae are associated with context change potentials. A context s_e is a pair consisting of an information state s (a set of world-assignment pairs) and an environment e (a sequence of states). States encode what is known and what antecedents are available for future anaphora; environments encode information about what is merely under discussion. Contexts s_e can be depicted as in (4) where each box stands for an information state.

(4) $\langle s : \Box,\ e : \Box_1, \ldots, \Box_n \rangle$

For example, the empty box in (5a) stands for the state of minimal information, whereas the box in (5b) encodes the information that x is P.

(5) a. $\Box \ \mapsto \{(\emptyset, w) \mid w \in W\}$ (minimal information)
b. $\boxed{\text{x: P(x)}} \ \mapsto \{(g, w) \mid g(x) \in w(P)\}$ (x is P)

Questions Questions set up (or expand on previously introduced) topics. Interrogative sentences are formed by prefixing a question mark and a sequence of variables $x_1, ..., x_n = \vec{x}$ to a formula. The effect of updating with sentence $?\vec{x}\phi$ is that the last element in the output environment is a state that verifies ϕ.

A polar question like (6a), represented as in (6b), extends the environment with a state that entails that Mary smokes (e.g. (6c)).

(6) a. Does Mary smoke?
b. $?S(m)$
c. $\langle \Box \rangle [\![?S(m)]\!] \langle \Box, \boxed{\text{S(m)}} \rangle$

A constituent question like (7a) represented as (7b) extends the environment with a state which encodes the information that x is a smoker (e.g. (7c)). Intuitively we can think of (7b) as introducing the set of smokers as topic under label x.

(7) a. Who smokes?
b. $?xS(x)$
c. $\langle \Box \rangle [\![?xS(x)]\!] \langle \Box, \boxed{\text{x: S(x)}} \rangle$

Topics and sets of propositions From a topic in s_e we can uniquely derive the corresponding 'Hamblin' denotation[1] or Groenendijk and Stokhof's partition both expressed as a(n equivalence) relation over the current state s. As an illustration, consider the topics represented in (8b) and (9b) introduced by the questions (8a) and (9a). The partitions and 'Hamblin' denotations induced by these topics can be depicted as in (8c) and (9c), if we assume that j and m are the only individuals in the domain.

(8) a. $?xS(x)$

b. $\langle \Box, \boxed{\text{x: S(x)}} \rangle$

c. Hamblin: $\begin{array}{|c|}\hline S(m) \\ \hline S(j) \\ \hline \end{array}$ G&S: $\begin{array}{|c|}\hline \forall x \neg S(x) \\ \hline \forall x(S(x) \leftrightarrow x = m) \\ \hline \forall x(S(x) \leftrightarrow x = j) \\ \hline \forall x(S(x) \leftrightarrow (x = j \vee x = m)) \\ \hline \end{array}$

(9) a. $?S(m)$

b. $\langle \Box, \boxed{\text{S(m)}} \rangle$

c. Hamblin: $\begin{array}{|c|}\hline S(m) \\ \hline \end{array}$ G&S: $\begin{array}{|c|}\hline S(m) \\ \hline \neg S(m) \\ \hline \end{array}$

The state-environment pairs in (b) are more fine-grained than the G&S partitioned states in (c). E.g. (9) after (8) does not add anything to the partition (see (10c)), but it extends the environment in a non-trivial way (see (10b)).

(10) a. $?xS(x) \wedge ?S(m)$

b. $\langle \Box, \boxed{\text{x: S(x)}}, \boxed{\text{S(m)}} \rangle$ c. $\begin{array}{|c|}\hline \forall x \neg S(x) \\ \hline \forall x(S(x) \leftrightarrow x = m) \\ \hline \forall x(S(x) \leftrightarrow x = j) \\ \hline \forall x(S(x) \leftrightarrow (x = j \vee x = m)) \\ \hline \end{array}$

In what follows we shall exploit these two levels of fine-grainedness in a crucial way.

Entailment and support We define the logical notion of *entailment*, $\models$, in terms of the partitioned states (exactly as in Groenendijk 1998-99), and the more discourse oriented notion of *support*, $\approx$, in terms

[1]We call the 'Hamblin' denotation of a question not the set of its congruent answers, but the set of its questioned propositions. Therefore we depart from the standard Hamblin-Karttunen approach where polar questions do not denote singleton sets. For the present notion, we do not have to assume that the denotation of polar questions is determined differently from the denotation of (multiple) wh-questions. Standard Hamblin denotations for polar questions can also be derived, but, in our view, are less interesting.

of the more fine-grained state-environment pairs. As for indicative sentences, support and entailment are the same notion. But, they crucially differ with respect to questions.

An interrogative is *entailed* in a context iff its update does not further partition the input state. An interrogative $?\vec{x}\psi$ is entailed after an indicative ϕ iff the indicative is a *complete answer* to $?\vec{x}\psi$. An interrogative $?\vec{x}\psi$ is entailed after another interrogative $?\vec{y}\phi$ iff any complete answer to $?\vec{y}\phi$ is a complete answer to $?\vec{x}\psi$. E.g.

(11) a. $\forall x(S(x) \leftrightarrow x = m) \models\ ?xS(x)$, but $S(m) \not\models\ ?xS(x)$

b. $?xS(x) \models\ ?S(m)$

On the other hand, an interrogative is *supported* in a context iff the topic it introduces is already entailed in the input context, either by the input state or by an old topic in the input environment. After an indicative ϕ, interrogative $?\vec{x}\psi$ is supported iff ϕ entails $\exists\vec{x}\psi$. After another interrogative $?\vec{y}\phi$, sentence $?\vec{x}\psi$ is supported iff $\exists\vec{y}\phi$ entails $\exists\vec{x}\psi$.

(12) a. $S(m) \mid\!\approx\ ?xS(x)$

b. $?S(m) \mid\!\approx\ ?xS(x)$, but $?xS(x) \not\mid\!\approx\ ?S(m)$

Entailment seems to be relevant for *indirect* uses of interrogatives. The sentences (13a-b) are valid implications, but (13c) is not.

(13) a. If John knows that only Mary smokes, then John knows who smokes.

b. If John knows who smokes, then John knows whether Mary smokes.

c. If John knows that Mary smokes, then John knows who smokes.

The new notion of support is relevant for *direct* uses of questions in discourse. Question (14b), although entailed, is not supported after (14a) and indeed it is not a vacuous move: it introduces a *new* topic, it indicates a strategy to answer (14a) (see Roberts, 1996).

(14) a. Who smokes?

b. Does Mary smoke?

As we will see, support will further play a crucial role for our characterization of focus and its pragmatic role.

Relevance In terms of entailment and support we define a generalization of Groenendijk's notion of *relevance* which also applies to questions. In doing so, we propose a formalization of Roberts' (1996) insight that a question is relevant iff it is part of a strategy to answer the immediate question under discussion.[2]

Groenendijk (1999) proposes the following characterization of the notion of a relevant (or pertinent, coherent) move in a discourse:

(15) A move is *relevant* iff it is (i) about the issue under discussion; (ii) non vacuous; and (iii) consistent.

Groenendijk's characterization of (i) in terms of *licensing*[3] and (ii) in terms of entailment prevents a correct application of this notion to questions. According to Groenendijk, questions are always licensed, and are informative iff they are not entailed. Therefore, we obtain the predictions in (16), which are highly counter-intuitive.

(16) a. Who smokes?
b. Well, does Mary smoke? (not relevant)
c. Well, does Mary work? (relevant)

Question (b) is not relevant after (a) because, since it is entailed, it is not informative. Question (c) is relevant because licensed, not entailed and consistent. Intuitively though, both questions are non-vacuous moves after (a), but only (b) is about (a), since it suggests a strategy to answer the question. Entailment does not seem to be the right notion to characterize non-vacuous questions, and Groenendijk's licensing should be modified to capture aboutness of questions, and not only of assertions.

We propose first of all to define vacuity in terms of support rather than entailment. To be relevant a sentence should not be supported. Furthermore we propose to generalize Groenendijk's notion of licensing as follows. An interrogative sentence $?\vec{x}\phi$ is licensed in a context iff $?\vec{x}\phi$ is entailed in the context. An indicative ϕ is licensed in a context iff $?\phi$ is entailed in the context. Intuitively, a sentence is licensed iff it exclusively addresses the question under discussion Q either by giving a partial answer to Q (as in Groenendijk) or by introducing a question the answers of which are partial answers to Q, i.e. an entailed question.

[2] Eventually our characterization of the notion of a strategy of inquiries should take into account the *average informativity* of the possible answers, or borrowing a term from information theory, the *entropy* of the related questions (see van Rooij, 2003). This would allow us to distinguish sub-question (b) from (c) in example (i). The former is intuitively part of a much more efficient strategy to answer (a).

(i) a. Who ate what?
b. What did Fred eat?
c. Did Fred and Mary eat the beans?

[3] Groenendijk's licensing turns out to be equivalent to Lewis's (1988) notion of aboutness.

The obtained notion of relevance gives us the correct predictions in (17).

(17) a. Who smokes?

b. Well, does Mary smoke? (relevant)

c. Mary smokes. (relevant)

d. Well, does Mary work? (not relevant)

Sub-question (17b) is licensed, but not supported (although entailed) after (17a), therefore it is relevant, as well as sentence (17c). Question (17d) is not relevant because it is not licensed.

Topics and quantification A further crucial characteristic of topics in this framework is that they encode domain restrictions (as in Gawron, 1996). As illustrated in (18) an update with a quantified sentence $\exists x\phi$ only modifies the state parameter, but crucially depends on the environment parameter, in particular on the last topic in which the quantified variable is defined, $e(x)$, which encodes all restrictions previously placed on x.

(18) a. $?xS(x) \wedge \exists xP(x)$

b. $\langle \Box \rangle [\![?xS(x)]\!] \langle \Box, \boxed{\text{x: S(x)}} \rangle [\![\exists xP(x)]\!] \left\langle \boxed{\text{x: S(x)} \wedge \text{P(x)}}, \boxed{\text{x: S(x)}} \right\rangle$

The valid entailments in (19) illustrate a crucial feature of our formalism. Questions can restrict subsequent quantification if coindexed.

(19) a. $?\vec{x}\phi_1 \wedge \cdots \wedge\ ?\vec{x}\phi_n \wedge \exists\vec{x}\psi \models \exists\vec{x}((\phi_1 \wedge \cdots \wedge \phi_n) \wedge \psi)$

b. $?\vec{x}\phi_1 \wedge \cdots \wedge\ ?\vec{x}\phi_n \wedge \forall\vec{x}\psi \models \forall\vec{x}((\phi_1 \wedge \cdots \wedge \phi_n) \rightarrow \psi)$

Presupposition Topics can be also presupposed. Presupposition (denoted by Beaver's partial operator ∂) expresses conditions on the input context which must be satisfied for the sentence to be defined (Stalnaker, Heim, Beaver). An update with a presupposition $\partial\phi$ is defined in s_e iff s_e supports ϕ. Please notice that presupposition is defined in terms of support rather than entailment. This means that a presupposed topic like $\partial[?xI(a,x)]$ is defined after $?I(a,b)$, but not after $?xyI(y,x)$. This notion of presupposition will play a crucial role for our treatment of focus.

Focus Focus indicates the presence of a topic in the context. More specifically, as in the structured meaning approach, focus leads to a 'partition' of the sentence into: (i) a presupposed topic (background); and (ii) an existential sentence (focus).[4]

[4]Focused sentences often receive an exhaustive interpretation (see Zeevat's contribution to this volume). An interesting question is whether exhaustivity should be part of the meaning of focus or not (see É. Kiss's (1998) distinction between

A sentence like (20a) represented as (20b) presupposes that the set S of smokers is under discussion and asserts that Mary is part of it.

(20) a. $[\text{Mary}]_{\text{F}}$ smokes.

b. $\partial[?xS(x)] \wedge \exists x(x = m)$

c. $\langle \Box, \boxed{\text{x: S(x)}} \rangle$ $[\![(20\text{b})]\!]$ $\langle \boxed{\text{x: S(x)} \wedge \text{x=m}}, \boxed{\text{x: S(x)}} \rangle$

This analysis covers focus in questions as well, as illustrated in (21). Question (21a) represented in (21b) again presupposes that the set of smokers is under discussion, and asks whether Mary is among them.

(21) a. Does $[\text{Mary}]_{\text{F}}$ smoke?

b. $?(\partial[?xS(x)] \wedge \exists x(x = m))$

c. $\langle \Box, \boxed{\text{x: S(x)}} \rangle [\![(21\text{b})]\!] \langle \Box, \boxed{\text{x: S(x)}}, \boxed{\text{x: S(x)} \wedge \text{x=m}} \rangle$

Note that from the representations in (20b) and (21b) we can recover the ordinary meanings of the sentences.

(22) a. $?xS(x), \partial[?xS(x)] \wedge \exists x(x = m) \models S(m)$

b. $?xS(x), ?(\partial[?xS(x)] \wedge \exists x(x = m)) \models ?S(m)$

In the following sections, we will discuss a number of applications of this formalism. Section 6.3 deals with questions and answers. Section 6.4 with focus and its pragmatic and semantic role.

6.3 Questions and answers

In this part, we will show how the formalism presented in the previous section allows us to solve a number of problems arising for standard analyses of questions and answers. The fine-grainedness of our notion of a topic will be used for a treatment of constituent answers and alternative questions which improves on proposition set analyses of questions and answers (section 6.3.1 and 6.3.2). Section 6.3.3 deals with embedding and coordination of questions showing how the problems typical of a structured meaning account are avoided in the present framework. Finally, section 6.3.4 concludes this part with an analysis of *which*-interrogatives.

---

identificational (exhaustive) and information (non-exhaustive) focus in Hungarian). On the present analysis, we define a non-exhaustive notion of focus, assuming that exhaustive meanings can be derived by other pragmatic means (see van Rooij and Schulz's and Spector's contributions to this volume). An exhaustive notion of focus, however, would not be hard to define in this framework (by means, for example, of the $only_x$ operator introduced in section 6.4.1).

6.3.1 Constituent answers

On the present account, a constituent answer is expressed as an existential sentence, the domain of which is crucially restricted by the preceding question (cf. Dekker, 2002b, reprinted in this volume).

Term answers like *John* are represented as in (23c).

(23) a. Who smokes? $?xS(x)$

b. Who doesn't smoke? $?x\neg S(x)$

c. [John]$_{\mathrm{F}}$. $\exists x(x = j)$

Given these representations, we correctly predict that after (23a), *John* means 'John smokes'; after (23b), instead, it means 'John does not smoke'.

(24) a. $?xS(x)$, $\exists x(x = j) \models S(j)$

b. $?x\neg S(x)$, $\exists x(x = j) \models \neg S(j)$

This analysis can be extended to *yes*-*no* answers. *Yes* and *no* are represented as in (25b):

(25) a. Does Mary smoke? $?S(m)$

b. [Yes]$_{\mathrm{F}}$/[No]$_{\mathrm{F}}$. $\exists\top/\neg\exists\top$

Given these representations we correctly predict that after (25a), *yes* means 'Mary smokes'; and *no* means 'Mary does not smoke'.

(26) a. $?S(m)$, $\exists\top \models S(m)$

b. $?S(m)$, $\neg\exists\top \models \neg S(m)$

6.3.2 Alternative questions

Proposition set theories of questions in both the Groenendijk & Stokhof and Hamblin/Karttunen traditions have been shown to have problems in accounting for alternative readings of disjunctive questions (see von Stechow, 1991, Krifka, 2001). In this section, we would like to show that our analysis is fine-grained enough to express the contrast between polar and alternative question readings, and to account for the disambiguating role of focus in these cases.

Consider example (27).

(27) Do you want coffee or tea?

Example (27) is ambiguous between a polar question reading (expected answers: *yes*/*no*) and an alternative question reading (expected answers: *tea*/*coffe*). Intonation seems to play a disambiguating role. In alternative questions, the alternatives are stressed.

(28) Do you want COFFEE or TEA? a. #Yes/No. b. Coffee/Tea.

If we assume for (27) the focal structure in (29a) and for (28) the focal structure in (30a), the contrast between polar and alternative readings follows directly from our analysis of focus.

(29) a. [Do you want coffee or tea]$_{\mathrm{F}}$? (polar reading)
b. $?(W(c) \vee W(t))$
c. Yes / No.
d. $\exists\top$ / $\neg\exists\top$
e. topic: $\boxed{\mathrm{W(c)}\vee\mathrm{W(t)}}$ $\mapsto$ f. Hamblin: $\boxed{\text{You want coffee or tea}}$

(30) a. Do you want [coffee]$_{\mathrm{F}}$ or [tea]$_{\mathrm{F}}$? (alternative reading)
b. $?(\partial[?xW(x)] \wedge \exists x(x = c \vee x = t))$
c. Coffee / Tea.
d. $\exists x(x = c)$ / $\exists x(x = t)$
e. topic: $\boxed{\mathrm{x{:}\ W(x)\wedge(x{=}c \vee x{=}t)}}$ $\mapsto$ f. Hamblin: $\begin{array}{|c|}\hline \text{You want coffee} \\ \hline \text{You want tea} \\ \hline \end{array}$

The formulae (29b) and (30b) set up different topics, therefore they (i) express different question meanings (compare the Hamblin denotation in (f) induced by the introduced topic in (e)); and (ii) allow different constituent answers.

6.3.3 Embedding and coordination of questions

In the introduction we pointed out that although the fine-grainedness of the structured meaning analysis of questions is needed to account for constituent answers and alternative questions, it is problematic too. By assuming that different types of interrogatives have denotations of different categories, the structured meaning account has problems with the coordination and embedding of questions. This problem disappears once one assumes a propositional set theory as those proposed by Hamblin, Karttunen or Groenendijk & Stokhof. According to these latter theories, polar and (multiple) *wh*-questions all have denotations of the same category, and all these questions can thus be coordinated under *know* and *wonder* as in (31):

(31) Adam *knows/wonders* whether there is a party, who is invited, and who will kiss whom.

Only Groenendijk & Stokhof's analysis, however, correctly predicts that indicatives can also be freely coordinated under *know* with interrogatives:

(32) Adam knows that it's Mary birthday and who is invited to come.

Moreover, by thinking of the denotation of a question as an equivalence relation, the inclusion relation accounts for *entailment* not only in the case of declaratives, but also for interrogatives. Our approach shares with Groenendijk & Stokhof these desirable consequences. First, coordination between indicatives and interrogatives of any 'type' is unproblematic: a context s_e can also be updated with ϕ if ϕ contains both an indicative and an interrogative. This updated context gives rise to a structured state: the partition $P(s_e[\phi])$. As shown in the appendix, entailment can be defined in terms of subsistence between such structured states. Taking $K_a(i)$ to denote the epistemically accessible worlds to Adam in possibility i, and ignoring anaphoric dependencies and presuppositions, we can simply assume that the state-environment pair with respect to which the embedded clause should be interpreted in possibility $i = \langle g, w\rangle$ is $K^*_a(i) = \{\langle h, w\rangle : h = g \wedge v \in K_a(w)\}_{e_0}$, where e_0 is the 'empty' environment which makes $P(K^*_a(i)) = \{\langle j, j'\rangle : j, j' \in K^*_a(i)\}$. Now we can define the update of context s_e with sentence '$know(a, \phi)$' as follows:

(33) $s_e[know(a, \phi)] \quad = \quad \{i \in s : K^*_a(i) \text{ entails } \phi\}_e$

This has the result that sentence (32), for instance, is predicted to be true in possibility $i = \langle g, w\rangle$ iff (i) Adam knows that it's Mary's birthday, and (ii) Adam knows that d is invited to come if and only if d is actually invited in w, for every d.[5]

Groenendijk & Stokhof account for the fact that *to wonder*, in distinction with *to know*, cannot embed indicatives by assuming that the former verb is *intensional* and not *extensional*. We won't make use of this assumption, however. Instead, we will assume that a sentence of the form '$wonder(a, \phi)$' can only be true in i if (i) $K^*_a(i)$ does not entail ϕ, but (ii) ϕ does not eliminate any possibility of $K^*_a(i)$. This has the result that ϕ cannot be an indicative, because that would either eliminate possibilities, or else be entailed by $K^*_a(i)$.

6.3.4 *Which*-questions

To end this section we briefly present an analysis of *which*-interrogatives, which will also play a role later on.

We assume that a *which*-phrase gives rise to the presupposition that the set over which it ranges is already given as a *topic*. Questions (34a) and (35a) are represented as in (34b) and (35b).

(34) a. Which men are bachelors?
b. $\partial[?xM(x)] \;\wedge\; ?xB(x)$

[5]Of course, to account for focus in the embedded clause, we might assume a more interesting interaction between $K_a(i)$ and the environment of the 'main' context.

(35) a. Which bachelors are men?
b. $\partial[?xB(x)] \wedge ?xM(x)$

Question (34) presupposes that the set of men is under discussion and it asks which of them are bachelors. Question (35) presupposes that the set of bachelors is under discussion and it asks which of them are men. In distinction with Groenendijk & Stokhof's (1984) treatment, according to which (34) and (35) are equivalent, this analysis allows us to capture the contrast between these two questions. Although (34b) and (35b) determine the same partition, under the assumption that in all worlds all bachelors are men, (35b) is vacuous whenever defined. In distinction with (34b), which is not a trivial question.

6.4 Pragmatic and semantic role of focus

In this section we turn to a number of applications of the presented analysis of focus. Section 6.4.1 distinguishes between focus and topic sensitivity and sketches a way of implementing this distinction in the present framework. Section 6.4.2 defines a notion of discourse congruence to capture which focal structures are felicitous in which contexts. Finally, section 6.4.3 discusses how the present theory can be extended to an analysis of contrastive topics.

6.4.1 Focus and topic sensitivity: *only* and *always*

Sentences such as (36a) and (36b) are commonly analyzed as involving a dependency between the position of focus and the interpretation of *focus sensitive expressions* like *only*. In a situation where Kim serves Pat and Sandy Courvoisier, and serves nobody anything else, (36a) is true while (36b) is false. An expression is focus sensitive if its interpretation involves essential reference to the information structure of the sentence containing it.

(36) a. Kim only serves Sandy [Courvoisier]$_{\mathrm{F}}$.
b. Kim only serves [Sandy]$_{\mathrm{F}}$ Courvoisier.

Analysts (e.g. Rooth, 1985) typically refer to a single mechanism, so-called *association with focus*, to explain the meaning difference between (36a) and (36b).

However, focus sensitive expressions do not constitute a uniform class (see Beaver and Clark, 2003). In this section, we focus on the expressions *only* and *always*, and summarize evidence suggesting that sentences involving these two expressions seem to gain their interpretation in different ways. From this evidence, we argue that some focus sensitive expressions (e.g. *only*) are directly sensitive to focus, whereas others (e.g. *always*) are not. We then sketch an analysis of these two types of focus sensitive expressions in the framework presented in this paper.

The first piece of evidence comes from the interaction of focus sensitive expressions and reduced pronouns. *Only* and its cross-linguistic counterparts systematically fail to associate with reduced pronouns such as '*im* 'him'; see Hoeksema and Zwarts (1991:67) and Bayer (1999:59). In contrast, *always* and its cross-linguistic counterparts can.

Consider the context below. (37), with *always*, is a felicitous response, whereas (38), with *only*, is not. (38) cannot mean 'I only discussed Fred and no one else with Sandy'.

> **Context**: You had many discussions with Sandy, but what I want to know is the extent to which you talked about Fred. Of all the times you talked with Sandy, how often was Fred the person you talked about?

(37) I $[\text{always}]_{\text{F}}$ discussed'im with Sandy
Can mean: "Whenever I discussed someone with Sandy, I discussed Fred."

(38) # I $[\text{only}]_{\text{F}}$ discussed'im with Sandy
Cannot mean: "I only discussed Fred (and no one else) with Sandy."

We find the same split between *always* and *only* in extraction contexts, as illustrated by (39a) and (39b) (see Krifka, 1992). (39a), with *always*, can mean 'We should thank the man such that, if Mary took someone to the movies, it was him', where *always* apparently associates with a gap in the *wh*-relative. In contrast, with *only*, (39b) cannot mean 'We should thank the man such that Mary took only HIM to the movies'. The extraction of the focus associate of *only* is impossible, but the extraction of the focus of *always* is possible.

(39) a. We should thank the man whom Mary always took ___ to the movies.
b. We should thank the man whom Mary only took ___ to the movies.

This data from reduction and extraction suggests that *only* has compulsory association with focus in its syntactic scope. In contrast, reduction or extraction of material does not affect the interpretation of *always*. Similar patterns emerge cross-linguistically (see Beaver and Clark, 2002b). Other phenomena not discussed here that give further evidence of the split between *always* and *only* include negative polarity items and ellipsis.[6] A formal framework which treated focus sensitive expressions as a homogeneous class would fail to capture these differences. In the remainder of this section, we sketch how the framework discussed in this paper accounts for the distribution of focus sensitive expressions. In particular, our analysis hinges on the claim that the focus sensitivity of *only* is derived from a grammatical mechanism, whereas the interpretation of *always* is determined by the discourse topic.

Adverbs of quantification such as *always* are analyzed here as in the Lewis-Heim-Kamp tradition, schematized in (40). They form tripartite structures where *if*/*when*-clauses, if present, provide the restriction. In contexts in which an *if*/*when*-clause is not present, the discourse topic determines what is actually quantified over by the adverb.

(40) $\text{Quantifier}_{\text{topics}}(\text{Restriction})(\text{Scope})$

An utterance of the sentence in (41), with focus on *Bill*, would be felicitous in a context in which the topic $?xI(j,x,s)$ 'Who does John introduce to Sue?' has already been introduced. The sentence in (41) is represented as in (42). Since the sentence in (41) is defined only in contexts in which the topic $?xI(j,x,s)$ has been introduced, the context makes salient an interpretation in which the variable quantified over by *always* is x and, consequently, the domain of quantification of *always* is restricted to individuals John introduces to Sue. However, there could be other contexts in which (41) is felicitous. The crucial component of our analysis is that the restrictor of *always* is contextually identified, rather than being tied to the position of focus.

(41) John always introduces $[\text{Bill}]_{\text{F}}$ to Sue.

(42) $\text{always}(\emptyset)(\partial[?xI(j,x,s)] \wedge \exists x(x=b))$

We treat the focus sensitive expression *only* as an indexed sentential operator $only_{\mathrm{x}_1,\ldots,\mathrm{x}_n}$, where $\mathrm{x}_1, \ldots, \mathrm{x}_\mathrm{n}$ are focus variables. The interpretation of $only_{\mathrm{x}}$ involves a universal quantification over the focused variable x which is automatically restricted by the presupposition expressed by focus. This analysis predicts that *only* obligatorily associates with focus. In contrast, in the analysis sketched above *always* is predicted to only optionally associate with focus.

The sentence in (43) receives the analysis in (44). As in standard analyses of (un)selective binding, only_{x} changes the quantification force

[6] For discussion, see Beaver and Clark (2002a,b, 2003).

of the quantifier binding x from existential to universal.[7] Given the presupposition triggered by focus in (43), the universal quantification is automatically restricted to individuals John introduced to Sue. In a neutral context, (43) means 'The only person John introduced to Sue is Bill'.

(43) John only introduced $[\text{Bill}]_{\text{F}}$ to Sue.

(44) $\text{only}_{\text{x}}(\partial[?xI(j,x,s)] \wedge \exists x(x=b)) \models \forall y(I(j,y,s) \leftrightarrow y=b)$

The domain of *only* can be further restricted by a preceding question. After the question in (45a), the response in (45c) means 'The only gentleman John introduced to Sue is Bill', as in (46).

(45) a. Which gentleman did John introduce to Sue?
b. $\partial[?xG(x)] \;\wedge\; ?xI(j,x,s))$
c. John only introduced $[\text{Bill}]_{\text{F}}$ to Sue.
d. $\text{only}_{\text{x}}(\partial[?xI(j,x,s)] \wedge \exists x(x=b))$

(46) $?xG(x)$, $?xI(j,x,s)$, (45d) $\models \forall y((G(y) \wedge I(j,y,s)) \leftrightarrow y=b)$

6.4.2 Discourse congruence

In this section we show how our dynamic analysis enables us to give an interesting characterization of the notion of discourse congruence which covers contextual restrictions while avoiding problems of over- and under-focus, and which uniformly applies to answers, denials , questions and questions strategies.

In our proposal a sentence ϕ is *congruent* after ψ iff (i) the presupposition of ϕ is defined after ψ, and (ii) no more material is in focus than needed to satisfy (i).

Our conditions (i) and (ii) are closely related to Schwarzschild's (1999) *givenness* and *avoid focus* constraints. As Schwarzschild's *givenness*, condition (i) is a formalization of the traditional idea that non-focused material must be old. In distinction with Schwarzschild, however, our analysis of givenness is of a rather *global* nature: the existential closure of the non-focused parts of a whole clause has to be 'given' in the context, not the individual words themselves.[8] Condition (ii) corresponds to Schwarzschild's optimality theoretic constraint to avoid unnecessary focus: in our framework it will prevent us from placing more material in focus than is strictly necessary to allow the context to support the focal presupposition of the sentence.

[7] More precisely, *only* is analyzed as a selective or asymmetric quantifier; see Dekker (1993). See the appendix.

[8] Our analysis also has nothing to say about embedded F-marking and deaccenting. For an account of the latter phenomenon see Aloni, Butler and Hindsill in this volume.

Focus presupposes a question, and presupposition is defined in terms of support. Therefore in order to understand condition (i) it is important to recall after which sentences a question is supported. As noted above, and explained more formally in the appendix, a question $?\vec{x}\psi$ is supported after an indicative ϕ or an interrogative $?\vec{x}\phi$ iff ϕ or $\exists\vec{x}\phi$ entails $\exists\vec{x}\psi$. By this notion of support, we can account for the intuition that a sentence is congruent if it *either* 'matches' the question the sentence addresses (example (47)), *or* it stands in *contrast* with an earlier made assertion (example (48)).

(47) a. Who voted for Mary? $?xV(x,m)$
b. $[\text{John}]_\text{F}$ voted for Mary. $\partial[?xV(x,m)] \wedge \exists x(x=j)$

(48) a. Bill voted for Mary. $V(b,m)$
b. No, $[\text{John}]_\text{F}$ voted for Mary. $\partial[?xV(x,m)] \wedge \exists x(x=j)$

Sentences (47b) and (48b) are congruent after (47a) or (48a), because they are minimally focused to be defined after the respective antecedents. In the same contexts, the alternative focus structures in (49) are predicted to be infelicitous.

(49) a. # John voted for $[\text{Mary}]_\text{F}$. $\partial[?xV(j,x)] \wedge \exists x(x=m)$
b. # $[\text{John}]_\text{F}$ voted for $[\text{Mary}]_\text{F}$. $\partial[?xyV(x,y)] \wedge \exists x(x=j)$ $\wedge\exists y(y=m)$

Sentence (49a) is undefined after (47a) or (48a), and, therefore, violates condition (i). Sentence (49b) instead violates condition (ii). Had *John* not been in focus there, then the presupposition of the sentence would already be supported after (47a) or (48a).

Just like Roberts (1996), our notion of congruence applies to questions and question strategies as well. Also in these cases, *under*focused questions will be undefined and *over*focused ones will violate our minimality constraint.

Finally, our dynamic analysis also immediately predicts correctly for sequences in which contextual restrictions play a crucial role. Since question (50) supports question (47a), in our analysis the two questions pose the same condition on the focal structure of their answers.

(50) Which Democrats voted for Mary? $\partial[?xD(x)] \;\wedge\; ?xV(x,m)$

6.4.3 Contrastive Topics

In the literature, there exist two popular views on what a sentence is *about*. According to a tradition starting with Paul (1880), the topic of a sentence is the *question* the sentence is addressing. According to another tradition going back at least to Goodman (1961), the topic of a sentence is the *referent* the sentence is about. In more recent analyses along the second tradition, e.g. Reinhart (1981) and Vallduví (1992), this referent need not be a particular real entity, but is thought of rather as a *discourse referent*. By representing questions *as* discourse referents in an environment, we suggest that these two views are two sides of the same coin.

What a sentence is about is linguistically *marked*, in English, by the use of accent. Jackendoff (1972a) distinguishes between A and B accent. The rising A accent marks *dependent* focus, while the falling B accent marks *independent* focus.

(51) (Who ate what? What about Fred?) Fred$_B$ ate the beans$_A$.

According to our analysis, focus presupposes a topic: it indicates that it addresses a certain question. Because two foci are used, (51) presupposes at least the multiple *wh*-question (52a) as in Roberts (1996). However, as in Büring (1999), we will also assume that (51) presupposes (52b).

(52) a. Who ate what? $?xy\ A(x, y)$
b. What did Fred eat? $?y\ A(f, y)$

According to Roberts (1996), the two questions form part of a questioning *strategy*. Our notion of *relevance* between questions shows that the question (52b) can be part of a strategy to answer (52a), but not the other way around. Thus, we can determine that the presupposition and assertion of (51) should be represented as follows:

(53) a. Fred$_B$ ate the beans$_A$.
b. $\partial[?xyA(x, y)] \wedge \partial[?yA(f, y)] \wedge \exists y[y = b]$ or equivalently
c. $\partial[?xyA(x, y)] \wedge \partial[?x(x = f)] \wedge \exists y[y = b]$

The ordinary meaning of the sentence is entailed: (53c) $\models A(f, b)$.

What Jackendoff called A and B accent is called *focal* and *topical* accent respectively by Büring (1999). Büring proposes that a sentence like (51) not only has a focal-value, but also a *topic-value*. The former corresponds with our question (52b), but the latter is not a question, but rather a *set* of questions: for each relevant individual d the question what d ate. To account for the intuition that (51) is only a *partial* answer to question (52a), he states an extra *disputability* condition. If we denote the topic-value of A by $[[A]]^t$, the condition says that if in A a topical accent is used, at least one question in $[[A]]^t$ must still be open. This disputability condition, however, gives rise to the so-called *last answer problem*.

(54) a. Who ate what?

b. Mary$_B$ ate sprouts$_A$, and

c. Fred$_B$ ate the beans$_A$.

After (54b) is given, answer (54c) might resolve the whole question (54a), which is in conflict with Büring's disputability condition. We have taken over Roberts' (1996) suggestion that 'topic'-accent indicates, or presupposes, the use of a certain questioning strategy: (51) presupposes both (52a) and (52b), and congruence demands that the former must have been asked before the latter. But note that from our relevance condition we can still *derive* Büring's disputability in case (51) is used out of context without making use of non-ordinary semantic values. The reason is that the assertion presupposes questions (52a) and (52b), and that our relevance condition on questions demands that (52b) can only be part of a strategy to answer (52a) in case there is at least one individual different from Fred whose eating behavior is still in question.

Büring (1999) makes crucial use of his disputability condition to explain why sentence (55a) only has a $\neg\forall$ reading, i.e., that (55a) cannot mean (55b):

(55) a. All$_B$ politicians are not$_A$ corrupt.

b. $\forall x[Pol(x) \rightarrow \neg Crpt(x)]$

However, this much follows already from our assumption that sentences with independent and dependent focus presuppose two questions, and the general condition that question Q' cannot be part of a strategy to answer Q if they denote the same partition. Notice that it follows from our reasoning above that (55a) presupposes either $\partial[?xPol(x)] \wedge ?xCrpt(x)$ and (56a), or $\partial[?xPol(x)] \wedge ?xCrpt(x)$ and (56b):

(56) a.

$\forall x[Pol(x) \rightarrow Crpt(x)]$
$\neg\forall x[Pol(x) \rightarrow Crpt(x)]$

b.

$\forall x[Pol(x) \rightarrow Crpt(x)]$
$\forall x[Pol(x) \rightarrow \neg Crpt(x)]$

Now suppose that (55a) actually presupposed (56b). Assuming that the presupposition of a question is the union of its possible answers, it follows that (55a) must presuppose that *either* all politicians are corrupt, *or* no politician is corrupt. Assuming that question Q' can only be part of a strategy to resolve 'goal'-question Q if Q' and Q do not denote the same partition, we demand that partition (56b) is not the same partition as the one denoted by $\partial[?xPol(x)] \wedge ?xCrpt(x)$. This means that there must be at least more than one politician, and that it is *not* presupposed that either all politicians are corrupt, or that none of them is corrupt. So, our conditions demand that the partition due to $\partial[?xPol(x)] \wedge ?xCrpt(x)$ denotes a cell where some but not all politicians are corrupt. But this is inconsistent with the presupposition of (56b), which rules out the possibility that (55a) presupposes (56b). The sequence consisting of $\partial[?xPol(x)] \wedge ?xCrpt(x)$ and (56a), on the other hand, is predicted to be appropriate, and will thus be chosen. But this means that (55a) can be given only as answer to (56a), and thus can receive the $\neg\forall$ reading only.

6.5 Conclusion

We have analyzed within dynamic semantics how questions can restrict the domain of quantificational sentences used later in a discourse. We have done this by extending Gawron's (1996) dynamic analysis of domain restriction with an explicit treatment of questions and focus. Our analysis of questions incorporates Groenendijk's logic of interrogation, but improves on it by introducing (basically) the abstracts underlying the questions to the discourse. In this way we were able to account for constituent answers, alternative questions and (multiple) focus while maintaining a uniform category for interrogative sentences. We have further modeled the distinction, put forward in Beaver and Clark (2003), between focus and topic sensitivity. Focus sensitivity derives from a grammatical mechanism, whereas the interpretation of topic sensitive operators is a purely pragmatic matter.

Appendix

Formal Definitions

The vocabulary of our language is like that of standard first-order predicate logic with identity, but with a polyadic existential quantifier $\exists x_1, \ldots, x_n$, and with the addition of a sentential operator only$_{x_1,..,x_n}$, a presupposition operator ∂ and a question operator $?x_1, \ldots, x_n$. We do not have compound interrogatives or quantification into questions, but we have presupposed questions and can form sequences of questions (and assertions). As for the semantics, formulae are associated with context change potentials. A context s_e is a pair consisting of an environment e and an information state s. An information state consists of a set of world-assignment pairs. An environments is a sequence of information states. If $c = s_e$ is a context, then $S(c) = s$ and $E(c) = e$.

Elements of a state are called *possibilities*, given a possibility $i = \langle w, g\rangle$, we write $i(\alpha)$ to refer to the denotation of α with respect to g_i and w_i. As in Dekker (1993), possibilities are ordered by an extension relation $\prec$: j *extends* i, $i \prec j$ iff $w_i = w_j$ & $g_i \subseteq g_j$. This extension relation carries over to an ordering relation between information states: s is a *substate* of t, $s \prec t$ iff $\forall i \in s: \ i \prec t$, where $i \prec t$ iff $\exists j \in t : i \prec j$.

Now we can give a recursive definition of the context-change potential of the formulae of the language. The basic formulae are defined as expected: they can only influence the state parameter s and eliminate possibilities in s in which the formulae are false:

1. $s_e[Pt_1, ..., t_n] = \{i \in s \mid \langle i(t_1), ..., i(t_n)\rangle \in i(P)\}_e$

In the interpretation rule of *negation*, we make crucial use of the ordering relation $\prec$. Just like atomic formulae, negation influences only the state parameter:

2. $s_e[\neg\phi] = \{i \in s \mid i \not\prec S(s_e[\phi])\}_e$

Conjunction is defined as standard in dynamic semantics as sequential update:

3. $s_e[\phi \wedge \psi] = s_e[\phi]\ [\psi]$

Until now the environments played virtually no role. They are crucial, however, for the semantic analysis of *quantified* sentences. The update of context s_e with an existential sentence $\exists x_1, ..., x_n\phi$ is defined in terms of the merge of two information states. The *merging* of information state s with information state t, $s \wedge t$, is defined as the 'least upper bound' of s and t (see again Dekker, 1993):

$$s \wedge t = \{i \mid \exists j \in s : \exists j' \in t : dom(i) = dom(j) \cup dom(j')\ \&\ j \prec i\ \&\ j' \prec i\}$$

If we define random assignment, $s[x]$, as $\{\langle w, g[x/d]\rangle : \ \langle w, g\rangle \in s\ \&\ d \in D\}$, we can define the update of s_e with an existential sentence in terms of this merge-operator as follows. Assume $x_1, ..., x_n = \vec{x}$ are not defined in s.[9]

4. $s_e[\exists\vec{x}\phi] = (S((s[x_1], ..., [x_n])_e[\phi])\ \wedge e(\vec{x}))_e$

where $e(x_1, ..., x_n)$ is the last state in e in which the variables $x_1, ..., x_n$ are defined. More formally, if $e = \langle e_1, ..., e_m\rangle$, then (i) $e(x_1, ..., x_n) = e_m$, if $n = 0$; (ii) $e(x_1, ..., x_n) = e_i$ in e, such that $x_1, ..., x_n \in dom(e_i)$ and $\forall e_j[x_1, ..., x_n \in dom(e_j) \rightarrow j \leq i]$, otherwise.

Quantificational sentences make use of the environment, but have no influence on these environments themselves. Only *questions* have. The effect of updating context s_e with question $?\vec{x}\phi$ is that the last element in the new environment is a set of possibilities that verify ϕ. If

[9] As in Heim (1982), variables cannot be reset. So, in addition to formulae containing free variables, quantified sentences are partial updates as well. Since this issue is not directly relevant to the issues discussed in this article, we have passed over it in what proceeds.

$e = \langle e_1, ..., e_n\rangle$ and $e' = \langle e'_1, ..., e'_m\rangle$ are environments, then $e + e' = \langle e_1, ..., e_n, e'_1, ..., e'_m\rangle$.

5. $s_e[?\vec{x}\phi] = s_{e'}$ where $e' = e + S(s_e[\exists\vec{x}\phi])$.

An update with a quantifier or a question will depend on the last introduced state in the current environment in which the quantified variables are defined. Yes-no questions and answers will depend on the last introduced state.

Finally, we define the operator only$_{\vec{x}}$ which is analyzed as an asymmetric adverb of quantification. Let $j \prec_{\vec{x}} i$ iff $j \prec i$ and $dom(g_i) = dom(g_j) \cup \{\vec{x}\}$. Let ϕ be of the form $\partial[?\vec{x}\psi_1] \wedge \exists\vec{x}\psi_2$

6. $s_e[\text{only}_{\vec{x}}(\phi)] = \{j \in s \mid \{i \mid j \prec_{\vec{x}} i \;\&\; i \prec S(s_e[\exists\vec{x}\psi_1])\} \subseteq \{i \mid i \prec S(s_e[\phi])\}\}_e$

Disjunction, implication and universal quantifier are defined as standard in terms of conjunction, negation and the existential quantifier.

Topics and sets of propositions From a topic e_k of domain $\vec{x}$ of length n in a context s_e we can derive the corresponding 'Hamblin' denotation, $H_k^{s_e}$, or G&S partition, $P_k^{s_e}$, both expressed as a(n equivalence) relation over s.

Definition 1 [Hamblin denotation]

$$H_k^{s_e} = \{\langle i, j\rangle \mid i, j \in s \;\&\; \exists\vec{d} \in D^n : i[\vec{x}/\vec{d}] \prec (s\wedge e_k) \;\&\; j[\vec{x}/\vec{d}] \prec (s\wedge e_k)\}$$

Definition 2 [G&S partition]

$$P_k^{s_e} = \{\langle i, j\rangle \mid i, j \in s \;\&\; \forall\vec{d} \in D^n : i[\vec{x}/\vec{d}] \prec (s\wedge e_k) \;\leftrightarrow\; j[\vec{x}/\vec{d}] \prec (s\wedge e_k)\}$$

Entailment and Support Building on Groenendijk (1998), we define *entailment* in term of subsistence between structured states. By $P(s_e)$ we will denote the partition induced on s by all the topics in e. Let $L(e)$ be the length of e, i.e. if $e = \langle e_1, ..., e_m\rangle$, then $L(e) = m$. Then $P(s_e) = \bigcap_{k\in L(e)}(P_k^{s_e})$. Partitions $P(s_e)$ assigned to contexts s_e are equivalent to the structured states σ defined in Groenendijk 1998. We denote by ι the pair $\langle i, j\rangle$ of world-assignment pairs elements of such a structured state. Groenendijk defines *subsistence* between *structured states* in terms of the notion of $\prec$ between world-assignment pairs defined above. A pair $\langle i, j\rangle$ subsists in $\langle i', j'\rangle$, $\langle i, j\rangle \prec \langle i', j'\rangle$ iff $i \prec i'$ & $j \prec j'$. This relation between pairs of possibilities carries over to a relation between structured states: $\sigma \prec \sigma'$ iff $\forall\iota \in \sigma : \iota \prec \sigma'$, where $\iota \prec \sigma'$ iff $\exists\iota' \in \sigma' : \iota \prec \iota'$.

We can now define entailment. We denote by `min` the context of *minimal* information $\{(\emptyset, w) \mid w \in W\}_\emptyset$.[10]

Definition 3 [Entailment]

(i) $s_e \models \phi$ iff $P(s_e) \prec P(s_e[\phi])$
(ii) $\phi_1, \ldots \phi_n \models \psi$ iff $\texttt{min}[\phi_1]...[\phi_n] \models \psi$

Support is defined in terms of *subsistence* between *contexts*, rather than partitioned states. A context s_e subsists in context t_f, $s_e \prec t_f$ iff $s \prec t$ and $e + s \prec f + t$, where an environment e subsists in f, $e \prec f$, iff $\forall f_j \in f : \exists e_i \in e : e_i \prec f_j$. We can now define support.

Definition 4 [Support]

(i) $s_e \approx\!\!\!\!| \;\phi$ iff $s_e \prec s_e[\phi]$
(ii) $\phi_1, ..., \phi_n \approx\!\!\!\!| \;\psi$ iff min $[\phi_1]...[\phi_n] \approx\!\!\!\!| \;\psi$

In terms of support, we define Beaver's (1995) presupposition operator.

Definition 5 [Presupposition]

$$s_e[\partial\phi] = s'_{e'} \quad \text{iff} \quad s_e[\phi] = s'_{e'} \;\&\; s_e \approx\!\!\!\!| \;\phi, \text{ undefined otherwise.}$$

Acknowledgements

The present article is the result of merging Aloni et al. (1999) presented at the Twelfth Amsterdam Colloquium and Aloni and van Rooij (2002) presented at SALT XII. We would like to thank the audience of those conferences for useful comments. Part of this research has been financially supported by the Dutch Organization for Scientific Research (NWO).

[10] In this semantics, we need the notion of a minimal context. Quantifying over all possible states would lead to a different notion of entailment.

7

Nobody (Anything) Else

Paul Dekker

Abstract

Information structure is the term designating a very lively and active branch of work, which deals with various topics such as anaphora, topical restriction, questions, congruence and exhaustification. This work tends to diverge in many directions which hardly can be seen to be compatible with one another. In this paper we attempt to improve the situation by trying to develop the minimal formal tools required to study the logical properties of the various issues involved and integrate them step by step. We successively deal with anaphoric connections between pronouns and other terms in terms of individual satisfaction by possible witnesses; with questions and topics in terms of sets of possible witnesses; with topical restriction and answerhood in terms of topical satisfaction; we conclude with a compositional deconstruction of Henk Zeevat's exhaustification operation.

Introduction

If we want to put it quite simple, the target of this paper is a compositional analysis of a locution like "else" as it occurs in an example like the following:

(1) Who gave what to whom? John a book to Mary, Jane a funny hat to some hippie, somebody else all her recordings of "Friends" to Denise, and nobody anything to anybody else.

Questions in Dynamic Semantics.
Maria Aloni, Alastair Butler and Paul Dekker (eds.).
Current Research in the Semantics/Pragmatics Interface, Vol. 17.

It may be clear that an adequate interpretation of "else" cannot stand on its own. The term is used in an anaphoric way in (1), it is used in a constituent answer, and it relates to a previously raised issue. In this way "else" participates in quite a number of issues all having to do with information structure. Our tour towards a compositional analysis of "else" will therefore guide us through a number of various topics such as anaphora, topical restriction, constituent answerhood and exhaustification. The approach will be goal-driven though, as we want to lay bare the minimal conceptual tools to deal with these issues.

We take our start from a classical, Tarskian, satisfaction semantics for a language of first order predicate logic. In the first section the system is extended with a treatment of pronouns, which, although it obviously stands in the tradition of systems of discourse representation and dynamic semantics, involves a most minimal and fully conservative extension with witnesses. In the second section we define topically restricted quantification. This is a formalization and generalization of Westerståhl's contextually restricted quantification, and at the same time a minimal reformulation of the type of topically restricted quantification developed by Gawron (1996), Aloni et al. (1999). In section three we use topical restriction to account for constituent answers in a compositional way. Quantifiers are interpreted in a classical way; they are taken to denote sets of sets of individuals, possibly parametric upon witnesses and witness functions. Section four next presents an interpretation of "else" from which a proper interpretation of in particular "somebody else" and "nobody else" can be derived in a compositional fashion. Section five summarizes the results.

Some issues are not discussed in full detail. For an extensive treatment of indefinite noun phrases and anaphoric pronouns we have to refer the reader to Dekker (2002a); an elaborate treatment of the dynamics of presupposition and quantification is offered in Dekker (2003); an update semantic account of the process of raising and resolving issues is presented in (Dekker, this volume). All this work heavily builds upon the seminal Groenendijk (1999), Roberts (1995), Zeevat (1994b).

7.1 Predicate Logic with Anaphora

The system of *PLA* has grown out of the tradition of discourse representation and dynamic interpretation but it deviates from a classical semantics only minimally (cf., Dekker (2002a)). It is inspired by (van Rooij (1997a), Stalnaker (1998)) and formally develops the idea that indefinite noun phrases can be used with referential intentions and that anaphoric pronouns can be coreferential with these indefinites by picking up individuals which may satisfy these intentions.

The language of *PLA* is like that of first order predicate logic except for the fact that it also contains a category of pronouns $P = \{\mathtt{p}_1, \mathtt{p}_2, \ldots\}$. For ease of exposition, we focus on a minimal language which is built up from variables, names, pronouns, and n-ary relation expressions, by means of negation $\neg$, existential quantification $\exists x$ and conjunction $\wedge$. As is usual, we use existentially quantified expressions to model the interpretation of indefinite noun phrases. Conditional sentences can be modeled using implication $\rightarrow$, defined by $(\phi \rightarrow \psi) \equiv \neg(\phi \wedge \neg\psi)$.

The semantics of *PLA* is spelled out in terms of a satisfaction relation $M, g, e \models \phi$, which may hold between an ordinary first order model M, an ordinary variable assignment g, and a sequence of witnesses e on the one hand and a formula ϕ on the other. The sequences of individuals e are the possible referents of terms (indefinite and pronominal) in ϕ. Besides the use of these possible witnesses, the only deviation from a classical semantics is that we also take into account what is referred to as $n(\phi)$, the number of (surface) existentials in ϕ:

- $n(Rt_1 \ldots t_m) = 0 \qquad n(\exists x\phi) \ = 1 + n(\phi)$
  $n(\neg\phi) \qquad\ \ = 0 \qquad n(\phi \wedge \psi) = n(\phi) + n(\psi)$

In the semantics, we use D^n to refer to the set of sequences of n individuals, which correspond to the possible sequences of n individuals which may satisfy referential intentions. Satisfaction is defined as follows:

Definition 7.1 (Satisfaction in PLA)

- $[t]_{M,g,e} = M(c)$ if $t \equiv c$
  $[t]_{M,g,e} = g(x)$ if $t \equiv x$
  $[t]_{M,g,e} = e_i$ if $t \equiv \mathtt{p}_i$
- $M, g,\ e \models Rt_1 \ldots t_m$ iff $\langle [t_1]_{M,g,e}, \ldots, [t_m]_{M,g,e} \rangle \in M(R)$
  $M, g,\ e \models \neg\phi$ iff $M, g, ce \models \phi$ for no $c \in D^{n(\phi)}$
  $M, g, ce \models \phi \wedge \psi$ iff $M, g, e \models \phi$ and $M, g, ce \models \psi$ $(c \in D^{n(\psi)})$
  $M, g, de \models \exists x\phi$ iff $M, g[x/d], e \models \phi$ for $d \in D$
- $M, g, e \models \downarrow\phi$ iff $\exists c \in D^{n(\phi)}$: $M, g, ce \models \phi$

In *PLA* the so-called 'dynamics of interpretation' is located entirely in the dynamics of conjunction, which simply models the fact that if a conjunction is actually used, the first conjunct literally precedes the second. That is, the first conjunct is evaluated before the second conjunct has come up with its possible witnesses and the second after the first has done so.

It is interesting to see out how close indefinites and pronouns are in *PLA*:

Observation 7.1 (Indefinites and Pronouns)

- $M, g, e \models \exists x Fx$ iff $M, g, e \models F\mathtt{p}_1$
  $M, g, e \models \exists x \exists y Rxy$ iff $M, g, e \models R\mathtt{p}_1\mathtt{p}_2$

The difference between the two types of terms resides in the way in which they are used. Pronouns are supposed to be 'old', while indefinites are 'new'. A pronoun can only be coreferential with an indefinite if it is used 'later', in some conjunction. Besides, indefinites are existentially quantified away under a negation, whereas pronouns, of course, are not.

PLA captures the basic results of discourse representation theory and dynamic semantics as can be observed from the following equivalences:

Observation 7.2 (Anaphoric Relations)
$\exists x(Dx \wedge \exists y(Py \wedge Fxy)) \wedge L\mathtt{p}_1\mathtt{p}_2 \;\Leftrightarrow \exists x(Dx \wedge \exists y(Py \wedge Fxy \wedge Lxy))$
$\exists x(Fx \wedge \exists y(Dy \wedge Oxy)) \rightarrow B\mathtt{p}_1\mathtt{p}_2 \;\Leftrightarrow \forall x(Fx \rightarrow \forall y((Dy \wedge Oxy) \rightarrow Bxy))$

These formal equivalences correspond to the intuitive equivalence of the following examples, with our apologies for the worn-out second one:

(2) A diver found a pearl but she lost it again.
A diver lost a pearl she just found.

(3) If a farmer owns a donkey he beats it.
Every farmer beats every donkey he owns.

We will not go into the ins and outs of anaphoric relations between indefinites and pronouns here, as these are not directly relevant to the main issues of this paper. For discussion and further extensions we refer to the papers mentioned earlier.

7.2 Topically Restricted Quantification

In this section we introduce topics and topically restricted quantification. We give a, we think most minimal, reformulation of the rather involved notion put forward in Gawron (1996), Aloni et al. (1999). We employ topics as the meanings of questions, where questions are formed, as is fairly usual, by putting a question marked sequence of variables in front of a formula. Thus, $?\vec{x}\phi$ is a question, where $\vec{x}$ is a (possibly empty) sequence of variables. If $\vec{x}$ is a sequence of i variables, we say that $q(?\vec{x}\phi) = i$. If $q(?\psi) = 0$, then $?\psi$ is a polar question.

In many semantic theories of questions, and in a lot of work on information structure, so-called abstracts are used to model or derive the meanings of questions or topics. We also use such entities as topics here. Just to keep matters simple, we stick to an extensional set up in which topics are sets of sequences of individuals. In case of a polar issue it can only be either $\{\langle\rangle\} = \{\lambda\}$ or $\{\ \} = \emptyset$, which are the truth values 1 and 0, respectively. Formally, the definition runs as follows:

Definition 7.2 (Topics)

- $[\![?\vec{x}\phi]\!]_{M,g,e} = \{c \in D^{q(?\vec{x}\phi)} \mid M, g[\vec{x}/c], e \models \downarrow\phi\}$
  (where $g[\vec{x}/c] = g[x_1/c_1]\ldots[x_n/c_n]$)

It is easily seen that:

Observation 7.3 (Topic Satisfaction)

- $\lambda \in [\![?p]\!]_{M,g,e}$ iff $M(p) = 1$
  $d \in [\![?xPx]\!]_{M,g,e}$ iff $d \in M(P)$
  $cd \in [\![?xyRxy]\!]_{M,g,e}$ iff $\langle c, d\rangle \in M(R)$

So we can also see that:

Observation 7.4 (*Wh*-phrases and Indefinites)

- $a \in [\![?\vec{x}\phi]\!]_{M,g,e}$ iff $\exists c \in D^{n(\phi)}$: $M, g, ace \models \exists\vec{x}\phi$

Thus, also *Wh*-phrases are very much like indefinites and again the two types of terms differ with respect to the different roles they play in discourse. Indefinites are assumed to relate to individuals which are not required to be determinate; *Wh*-phrases relate to individuals which are demanded to be determined.

With our topics on board, we can give a fully general definition of topically restricted quantification. Topical restriction is known from the literature, e.g., (Westerståhl 1984) and (Jäger 1996):

(4) Swedes are funny. All tennis players look like Björn Borg.

(5) Which Athenian is wise? Only Socrates is wise.

In (4) the term "all tennis players" can be taken to be restricted to the *Swedish* tennis players, and the second sentence of (5) can be used to claim that Socrates is the only wise man *among the Athenians*. We offer a generalization of this notion of contextually restricted quantification, since it may concern sequences of quantifiers which are restricted by sets of sequences of individuals, as in Gawron (1996), Aloni et al. (1999). At the same time, it is a vast simplification of the last, because topical information is not hung upon variables which are distributed over various 'information states'.

For the sake of simplicity, we assume that quantifiers respond to one topic only, and that they simultaneously address all arguments of a topic. That is, we will define $M, g, e \models_\alpha \underline{\exists}\vec{x}\phi$, where α is an n-place topic restricting the values of $\vec{x} = x_1 \ldots x_n$ in ϕ.

Definition 7.3 (Topically Restricted Quantification)

- $M, g, ce \models_\alpha \underline{\exists}\vec{x}\phi$ iff $c \in \alpha$ and $M, g[\vec{x}/c], e \models_\alpha \phi$, for $c \in D^{q(\alpha)}$

The definition of $\underline{\exists}\vec{x}$ is like that of $\exists x$ but for the fact that witnesses for $\vec{x}$ must satisfy α.

Observation 7.5 (Topical Restriction)

- $M, g, e \models_{?\vec{x}\phi} \underline{\exists}\vec{y}\psi$ iff $M, g, e \models_{?\vec{x}\phi} \exists\vec{y}(\downarrow[\vec{y}/\vec{x}]\phi \wedge \psi)$
  $M, g, e \models_{?\vec{x}\phi} \underline{\forall}\vec{y}\psi$ iff $M, g, e \models_{?\vec{x}\phi} \forall\vec{y}(\downarrow[\vec{y}/\vec{x}]\phi \rightarrow \psi)$

The following examples show our notion of topical restriction at work. Suppose we are talking about the people at the party P yesterday:

(6) <u>Some</u> girl was absolutely fabulous, and <u>all</u> boys went mad.
$M, g, de \models_{?xPx}$ (6) iff $M, g, de \models \exists x((Px \wedge Gx) \wedge AFx)$ and
$M, g, de \models \forall y((Py \wedge By) \rightarrow WMy)$

(7) <u>Only</u> students drank beer.
$M, g, e \models_{?xPx}$ (7) iff $M, g, e \models \forall z(Sz \leftarrow (Pz \wedge DBz))$

We see that "some girl" comes to mean "some girl who was at the party" and "all boys" "all boys who were at the party." It is important to note that this is not the general pattern though. For "Only students" in (7) does *not*, unconditionally, come to mean "only students who were at the party." In the given context the whole sentence says, rather, that among those who were at the party, only students drank beer. Observe that this is exactly as it should be.

7.3 Quantified Constituent Answers

Before we can give a suitable interpretation of quantified constituent answers, we of course have to introduce generalized quantifiers in the *PLA*-framework in the first place. All by itself, this is a routine enterprise, which, however, is complicated somewhat because we want to preserve the special treatment of indefinites. We will not go into the details here as they have been motivated elsewhere Dekker (2003).

We extend *PLA* with first order abstraction and with generalized quantifiers D (or determiners). Determiners are taken to denote the familiar relations $[\![D]\!]_{M,g,e}$ between pairs of sets of individuals. Determiners $\mathbf{D}$ will also be applied to sets, so that $\mathbf{D}(P)$ is that quantifier $\mathbf{T}$ $= \{Q \mid \langle P, Q\rangle \in \mathbf{D}\}$. In order to treat multiple constituent answer, we will also use (keenian) compositions $\mathbf{T}_1 \circ \mathbf{T}_2$ of quantifiers (cf. Keenan (1992)).

The only thing which is not fully standard is that noun phrases and determiners are associated with (sequences of) witnesses, sometimes witness-sets. Thus, like the existential quantifier in *PLA*, the interpretation of *SOME* requires an associated witness: $[\![SOME]\!]_{M,g,de} = \{\langle P, Q\rangle \mid d \in (P \cap Q)\}$. Proper names $NAME_c$ are true of a set iff it contains the value of the associated individual constant c: $[\![NAME_c]\!]_{M,g,de} = \{Q \mid [\![c]\!]_{M,g,e} = d \in Q\}$. Pronouns presuppose a witness for an antecedent term $[\![PRON_i]\!]_{M,g,de} = \{Q \mid e_i = d \in Q\}$. Besides, genuinely quantifying noun phrases are assumed to come with witness sets Dekker (2003). Using $D^{w(\alpha)}$ for the domain of possible witnesses or witness sequences for an expression α, the interpretation of the new expressions is defined in the following way:

Definition 7.4 (Generalized Quantifiers in QPLA)

$[\![D(\pi)]\!]_{M,g,dce} \quad = [\![D]\!]_{M,g,de}([\![\pi]\!]_{M,g,ce}) \qquad (d \in D^{w(D)};\ c \in D^{w(\pi)})$

$[\![T_1 \circ T_2]\!]_{M,g,dace} \quad = [\![T_1]\!]_{M,g,dce} \circ [\![T_2]\!]_{M,g,ace} \quad (dc \in D^{w(T_1)};\ a \in D^{w(T_2)})$

$M, g, dace \models T(\rho)$ iff $[\![\rho]\!]_{M,g,ace} \in [\![T]\!]_{M,g,dce} \quad (dc \in D^{w(T)};\ a \in D^{w(\rho)})$

It is relatively easily established that indefinites, proper names, and pronouns behave the way they did in *PLA*:

Observation 7.6 (Terms in QPLA)

- $JOHN_j(\lambda x\psi) \Leftrightarrow \exists x(x = j \wedge \psi)$
  $SOME(\lambda x\phi)(\lambda x\psi) \Leftrightarrow \exists x(\phi \wedge \psi)$
  $HE_i(\lambda x\psi) \Leftrightarrow \exists x(x = \mathtt{p}_i \wedge \psi)$

Now we have got our quantifiers on board, we can turn to a definition of a (quantified) constituent answer, using an answerhood operator *ANS*:

Definition 7.5 (Constituent Answerhood)

- $ANS(T_1 \ldots T_n) = (T_1 \circ \ldots \circ T_n)(\lambda\vec{y}\ \underline{\exists}\vec{x}(\vec{x} = \vec{y}))$

The interpretation of *ANS* is not as involved as it may seem. If a sequence of n noun phrases answers an n-ary topic, we take the Keenan composition of the quantifiers and we feed it the n-ary relation which holds between the individuals which satisfy the restriction. Thus, in the absence of further context dependence, we find that:

Observation 7.7 (Topical Constituent Answers)

- $M, g, e \models_{?\vec{x}\phi} ANS(T_1 \ldots T_n)$ iff
  $M, g, e \models (T_1 \circ \ldots \circ T_n)(\lambda\vec{x}\phi)$

Suppose the question is "Who gave what to whom" ($?xyzGxyz$, abbreviated as α). Then consider the following answers:

(8) Mary a picture (to) a boy.
$ANS(MARY\ SOME(PIC)\ SOME(BOY))$
$M, g, mpbe \models_\alpha$ (8) iff
$M, g, mpbe \models \exists x((x = m) \wedge \exists y(Py \wedge \exists z(Bz \wedge Gxyz)))$

(9) Every boy no CD to any girl.
$ANS(ALL(BOY)\ NO(CD)\ SOME(GIRL))$
$M, g, bcge \models_\alpha$ (9) iff
$M, g, bcge \models \forall x(Bx \rightarrow \neg\exists y(CDy \wedge \exists z(Gz \wedge Gxyz)))$

The reader can see that we have indeed provided an adequate compositional interpretation of a constituent answer. Although it is most minimal (because extensional), it is rooted in the uniform, so-called propositional approach to questions advocated by Hamblin, Karttunen and Groenendijk and Stokhof. At the same time it shares the merits of the structured meanings approach by allowing a direct interpretation of constituent answers in response to topics. There is, however, one basic difference with for instance Groenendijk and Stokhof's notion of answerhood.

Groenendijk and Stokhof's notion of an answer has a form of exhaustivity built into it, which is very attractive from a purely logical perspective, as Groenendijk and Stokhof have very well explained over the years, but also from a pragmatic, or decision-theoretic perspective van Rooij (2003), among many other publications by the same author. Our notion of an abstract (which is also used by Groenendijk and Stokhof, by the way) clearly has a form of exhaustivity built into it, but our notion of an answer has not. The reason is that we want to allow for sequences of (partial) constituent answers, which, of themselves, do not come with a claim for exhaustivity. But after all, we also do want to be able to say at some point: "That was it, folks, now we have exhausted the topic." In order to account for this we take our inspiration from Zeevat (1994b), who has proposed such a closure or exhaustification operator in an update semantics. As a matter of fact, as we will show in the final section, Zeevat's exhaustifier can be *derived* from our notion of a constituent answer together with an independently motivated interpretation of a relatively abstract element "else".

7.4 Something Else

We have gone quite a way to arrive at one of the main targets of this paper, the interpretation of "else." Take a look again at our first example, which is repeated here for convenience:

(1) Who gave what to whom? John a book to Mary, Jane a funny hat to some hippie, somebody else all her recordings of "Friends" to Denise, and nobody anything to anybody else.

Inspection of this example reveals, we think, that "somebody else" must denote somebody besides those already listed and that "nobody else" excludes anybody beyond those listed. The common contribution which "else" seems to make is that it is a predicate applying to all not (yet) included. The following definition gives us precisely this:

Definition 7.6 (ELSE)

- $\mathit{ELSE} = \lambda\vec{y}\ \Diamond\underline{\forall}\vec{x}(\vec{x} \neq \vec{y})$

The $\Diamond$ here is an ordinary modal operator with an indexical interpretation. It refers to the current state of discourse, as it has been established publicly and which is easily defined in terms of an update semantics Veltman (1996), Dekker (2002a). Relative to an n-ary topic α, *ELSE* holds of any n-tuple of individuals which, in the current state of the discourse, is not known (asserted, claimed, ...) to satisfy α.

In case of a single constituent issue like, for instance, who will come to the party, *ELSE* holds of any individual which, in the current state of discourse, is not (yet) asserted or implied to go there:

Observation 7.8 (Else)

- $M, g, e \models_{?xPx} \mathit{ELSE}c$ iff $M, g, e \models \Diamond\neg Pc$

Composing $ELSE$ with *SOME* in an answer we get the interpretation sketched above:

Observation 7.9 (Somebody Else)

- $ANS(SOME(ELSE)) \Leftrightarrow \exists y(\Diamond\underline{\forall}x(x \neq y) \wedge \underline{\exists}x(x = y))$

In response to the above question this has the following effect:

- $M, g, de \models_{?xPx} ANS(SOME(ELSE))$ iff $M, g, de \models \exists y(\Diamond\neg Py \wedge Py)$

After a sequence of constituent answers we find that:

(10) John, an undergraduate, and somebody else.
$ANS(JOHN) \wedge ANS(SOME(UNDG)) \wedge ANS(SOME(ELSE))$
$\bullet\, M, g, duje \models_{?xPx}$ (10) iff
$M, g, duje \models \exists x(x = j \wedge Px) \wedge \exists y(Uy \wedge Py) \wedge \exists z(\mathtt{p}_1 \neq z \neq \mathtt{p}_2 \wedge Py)$

Observe that the phrase "somebody else" in example (10) indeed means somebody else besides John *and* the mentioned undergraduate, so it is not an ordinary anaphoric phrase with one antecedent. Notice, too, that in order for this to work out fine, we definitely need a witness for the undergraduate, as indeed is provided in *PLA* and *QPLA*. Notice, finally, that *ELSE* can also be used in answers to multi-constituent topics, like "Who saw whom?" ($?xySxy$):

(11) John Mary, and somebody else somebody else.
$ANS(JOHN\ MARY) \wedge ANS(SOME(ELSE)\ SOME(ELSE))$
$\bullet\, M, g, bdjm \models_{?xySxy}$ (11) iff
$M, g, bdjm \models \exists x(x = j \wedge \exists y(y = m \wedge Sxy)) \wedge \exists x(x \neq \mathtt{p}_1 \wedge \exists y(y \neq \mathtt{p}_2 \wedge Sxy))$

Before we can take a look at "nobody else", one final remark is in order. "Else" does not need to univocally answer one and the same issue under discussion. Consider the following example, which is inspired by one given by Katrin Schulz:

(12) Who ate from the pudding? Well, John was in the garage, and Bertha was in the study, so it must have been somebody else.

Obviously, "somebody else" here relates to a person besides John and Bertha, and, in line with our analysis, it indeed relates to somebody not (yet) listed. But the issue is, of course, that (12) does not serve to list John and Bertha as persons who have eaten from the pudding, quite the opposite! Our analysis works out fine though if we can construe the answers in (12) as answers to the question who (among a relevant set of candidates) is or is not the person who ate from the pudding, which seems to be fairly intuitive.

We have seen that an answer with "somebody else" says that somebody besides those listed satisfies a certain topic, so one with "nobody else" does precisely the opposite:

Observation 7.10 (Nobody Else)

- $ANS(NO(ELSE)) \Leftrightarrow \neg\exists y(\Diamond\underline{\forall}x(x \neq y) \wedge \underline{\exists}x(x = y))$

An answer with "Nobody else" says, in response to the question who comes to the party, that those who are not yet known to come, do not come:

(13) John, an undergraduate, and nobody else.
$ANS(JOHN) \wedge ANS(SOME(UNDG)) \wedge ANS(NO(ELSE))$
$\bullet\, M, g, uje \models_{?xPx}$ (13) iff
$M, g, uje \models \exists x(x = j \wedge Px) \wedge \exists y(Uy \wedge Py) \wedge \neg\exists z(\mathtt{p}_1 \neq z \neq \mathtt{p}_2 \wedge Py)$

Example (13) shows that we get the right exhaustification effects of answers to single constituent issues. Although the interlocutors may be unsure about the identity of the undergraduate, the example, on our analysis, clearly entails that only two persons come, John and an undergraduate. The analysis not only works for single-constituent issues though. For:

Observation 7.11 (Nobody Anybody Else)

$ANS((NO\ SOME)(ELSE)) \Leftrightarrow \neg\exists yz(\Diamond\underline{\forall}uv(uv \neq yz) \wedge \underline{\exists}uv(uv = yz))$

Consider again the question "Who saw whom?" ($?xySxy$), with the following sequence of answers:

(14) John Mary, Pete Greta, and nobody anybody else.
$ANS(JOHN\ MARY) \wedge ANS(PETE\ GRET) \wedge$
$ANS((NO\ SOME)(ELSE))$
$\bullet\, M, g, pgjm \models_{?xySxy}$ (14) iff
$M, g, pgjm \models \exists xy(xy = jm \wedge Sxy) \wedge \exists xy(xy = pg \wedge Sxy) \wedge$
$\neg\exists xy(\mathtt{p}_1\mathtt{p}_2 \neq xy \neq \mathtt{p}_3\mathtt{p}_4 \wedge Sxy)$

This combination of "no" and "else" serves to express that a list of (multiple) constituent answers indeed exhausts the interpretation of a given (multiple) constituent question, in an entirely compositional fashion.

7.5 Conclusion

In this paper we have started out from an independently motivated satisfaction semantics *PLA*, we have added a traditional notion of a topic, we have added generalized quantifiers, and we then have given a direct and compositional definition of constituent answerhood. Armed with these tools, we have formulated a single, polyadic, interpretation of "else" which has been shown to behave as required in constructions like "Somebody else," "Nobody else," and "Nobody somebody else." To conclude this paper, we want to mention one further subject that naturally suggests itself, and add a final observation.

A system of interpretation like the one given here of course calls for an extension which accounts for the earlier mentioned process of raising and resolving issues. But that seems to be a somewhat routine exercise once we have a good idea of the intricate interaction between topical restriction and constituent answerhood as we have given in this paper and the update semantics provided in (Dekker, this volume).

We want to end with an inspiring observation. Since both *ANS* and *ELSE* are defined as polyadic predicates, they have zero-place instances. Interestingly, these correspond to affirm ("Yes.") and deny ("No.") respectively:

Observation 7.12 ($\boldsymbol{ANS_0}$ and $\boldsymbol{ELSE_0}$)

- $ANS_0 \Leftrightarrow (\lambda p\ p)\underline{\exists}\top \Leftrightarrow \underline{\top}$
  $ELSE_0 \Leftrightarrow \Diamond\underline{\forall}\bot \Leftrightarrow \underline{\bot}$

Zero constituent *ANS* and *ELSE* correspond to a topically restricted top- and bottom-element. And indeed they figure as our familiar answers "yes" and "no." Observe:

(15) Is it raining? {Yes. / No.}

$$M, g, e \models_{?p} ANS \text{ iff } M, g, e \models_{?p} \underline{\top}$$
$$\text{iff } M, g, e \models p$$
$$M, g, e \models_{?p} ELSE \text{ iff } M, g, e \models_{?p} \underline{\bot}$$
$$\text{iff } M, g, e \not\models p$$

This is interesting because the proper treatment of "Yes." and "No." has been a matter of struggle and debate in the literature. Here they fall into place as two borderline cases of some much more general notions.

Acknowledgements

I would like to thank Maria Aloni, Kata Balogh, Alastair Butler, Jeroen Groenendijk, Katrin Schulz and Henk Zeevat for useful criticisms and comments. The research for this work is supported by a grant from the Netherlands Organization for Scientific Research (NWO), which is gratefully acknowledged.

Part III

Implicatures and Exhaustiveness

8

Exhaustivity, Questions and Plurals in Update Semantics

HENK ZEEVAT

8.1 Introduction

Update Semantics —more than related dynamic frameworks such as DRT— offers a promise of being able to integrate that part of pragmatics that is rule-governed with semantics. Moreover, it has a very natural interpretation: it tells what is the change in an information state under the influx of linguistic input, i.e. it can be interpreted without any further ado as a theory of what happens to language users when they are exposed to the utterances of a speaker. When the information states are interpreted as the common grounds between participants in a conversation, the theory gives an account of what information is established during a conversation.

This paper presents an exhaustification operator in update semantics and discusses a series of applications of this operator. The exhaustification operator takes an open formula and assigns (if this is possible) values to the free variables such that the formula is true as a result and entails all versions of the formula that can be obtained from the formula by assigning other values to the free variables for which the formula is true.

The first application of the operator is to provide an (update) semantics for questions. The Wh-elements of the question are represented as discourse markers and the discourse markers are exhaustified with respect to the content of the question. Positive answers to the

Questions in Dynamic Semantics.
Maria Aloni, Alastair Butler and Paul Dekker (eds.).
Current Research in the Semantics/Pragmatics Interface, Vol. 17.

question present extra constraints on the same discourse markers. The theory merges semantic and pragmatic questions and can reduce the exhaustivity of answers to the semantics of the question.

Question+answer updates are then used to formalize the theory of topic and focus that equates the topic with a question and the focus with its answer. As we use a standard DRT-like representation of the complete sentence to represent the focus, the semantic effect of the topic-focus division is that certain discourse markers in the sentence receive an interpretation that is exhaustive with respect to the topic. The same assumption also makes it possible for the theory to allow multiple topics for the same sentence. The topic-focus theory also derives scalar implicatures and the Evans-effects. The indeterminate marking of the topic-focus division is exploited to explain the possible "cancellation" of the scalar implicatures and the definiteness effects in certain contexts.

The same mechanism is used to salvage an almost forgotten theory of plural NPs within DRT, in which they are very similar to singular NPs and can be decomposed as a combination of features. Exhaustivity provides the properties that the original theory could not deal with and turns it into a viable alternative. An additional advantage is the reduction of the number of different readings that need to be assumed in the classical view and —where that cannot be avoided— a mechanism for resolving the remaining ambiguities. It moreover provides a very natural analysis of the cumulative readings.

Why use update semantics? It will be clear from the discussion that it is quite possible to define exhaustification operators outside the context of an update semantics. Elsewhere (in Zeevat and Scha, 1992), we have defended the view that update semantics is particularly suited for developing pragmatics and semantics within a single theory. The first instance of that is a successful treatment of presuppositions in update semantics due to Karttunen (1974) with important additions by Heim (1983b). Certain pragmatic implicatures of assertions have been shown by Stalnaker (1978) to be directly expressible as conditions on updates. This paper can be seen as an attempt to do the same for certain implicatures arising from quantity and relevance.

Information states are here conceived as in Stalnaker (1978) to be a representation of the apparent common ground between speaker and hearer(s): that body of information which partners have purported to accept in the conversation. Some have proposed to take the hearer's information or the hearer's picture of the common ground, but that position —like the one where it is the speaker's common ground— does not make much difference from the formal perspective. My aim is to describe the common ground as a parameter that influences the behaviour of the participants in a dialogue. It affects both the way in which they interpret the incoming utterances by others and the way they plan their own utterances. It is not really relevant for this enterprise whether speakers and hearers are right in their picture of the common ground, though that can be useful in analysing communication failures.

8.2 Exhaustification

What is the exhaustive interpretation of a variable in a formula? Intuitively, it is that value for the variable such that taking it to be the value rather than something else makes the formula true and makes it entail all the true formulas that can be obtained by assigning another value to the same variable. If one thinks of the free variable as something that can have many values, it is the strongest true interpretation that the open formula allows. Of course, there need not exist an exhaustive interpretation for a formula. This is indeed a common situation. Suppose five boys are asleep. It is then impossible to have an exhaustive reading for sentences like (1a/b). (I use lower case variables for sets of objects, singular objects are represented by their singleton sets).

(1) a. One boy sleeps.
$x \wedge boy(x) \wedge \#x = 1 \wedge sleep(x)$
b. Less than three boys sleep.
$x \wedge boy(x) \wedge \#x < 3 \wedge sleep(x)$

None of the values we can find for these sentences is exhaustive: if x denotes one sleeping boy, x can also denote another sleeping boy without there being a logical connection between the statement about the one boy and the other. The same holds if x denotes sets with cardinality less than three: there are variants for the denotation of x that are logically unconnected.

Exhaustification is thereby a combination of the statement that exhaustive readings are possible together with the assignment of the exhaustive value to the free variable.[1] When exhaustification is possible, it gives minimal or maximal elements with respect to some order, e.g. the inclusion order on sets or the natural order on natural numbers.

It is not standard to let an open formula entail other versions of it on the same model. Entailment involves quantifying over models and

[1] Classically, we would have to say that exhaustification binds the variable. That the variable is available as a name for the exhaustive value outside the scope of the operator is a non-classical dynamic effect. Unlike systems like DPL, we do not assume that the variable only functions in this way to the right of the scope of the operator.

within a single model, the same formula normally has a single meaning. The following construction is an attempt to make it precise.

Let K be a class of models which contains the expansions to a language L of a given model M_0 for a language $L_0 \subseteq L$. The given model fixes the domain and some privileged relations. For the examples I consider, it suffices to take the basic model M_0 to have a domain which is the powerset of some given non-empty set (without $\emptyset$) together with the natural numbers (without 0), with the privileged relations *inclusion* ($\subseteq$) between the sets, *smaller than* ($<$) between the numbers and the *cardinality* operator ($\#$) relating sets and numbers. Object variables will range over sets of objects, number variables over numbers. (A reasonable extension would be the inclusion of quantities of stuff and reals among the domain entities with the basic relations between the two. Part-whole relationships and measurement are other obvious candidates.) In addition, K must obey a set MP of postulates about the non-privileged relations. $|$ is the restriction operator.

$K = \{M : M \models MP \text{ and } M|L_0 = M_0\}$.

Now let φ be a formula with a free variable x and K a class of models M as described above. The exhaustive value of φ in K with respect to the variable x is that object u in the domain U_M of M such that (1) and (2) hold.

(1) $M \models \varphi\langle u\rangle$ and

(2) $\forall v \in U_M \forall M' \in K(M \models \varphi\langle v\rangle \text{ and } M' \models \varphi\langle u\rangle \Rightarrow M' \models \varphi\langle v\rangle)$.

Example 1.

Let K be as described above. Let MP contain: $Px \wedge y \subseteq x \rightarrow Py$. (Gloss: If John has sheep x then John has sheep y for $y \subset x$.) Let φ be Px. Then an exhaustive value for x in the model M is the set of all P in M. (Gloss: John's sheep.)

Example 2.

The postulates are given by: $Pn \wedge m > n \rightarrow Pm$. (Gloss: If John runs the mile in n minutes then John runs it in m minutes if $m > n$.) Let φ be Pn. The exhaustive value is the smallest number m such that Pm holds in M. (Gloss: John's time for the mile.)

Example 3.

$Pn \wedge n > m > 0 \rightarrow Pm$. (Gloss: If Bill has four chairs then Bill has three chairs.) The exhaustive value is the largest number m such that Pm. (Gloss: the number of Bill's chairs.)

8.2.1 Update Semantics

Update semantics is a general name for any theory of language that explains the semantic properties of its expressions in terms of the information change that they bring about on information states. I am using a formalism that is purely eliminative. If σ is an information state (a set of possibilities) and φ a formula the update of σ with φ, written $\sigma[\varphi]$ is always a subset of σ. In the special case that $\sigma[\varphi] = \sigma$ one can also write $\sigma \models \varphi$.

Both the appearance of new discourse markers and the appearance of new facts will be modelled by elimination. The elimination model for information update is closely related to modelling epistemic operators with a Kripke style semantics. The set of belief alternatives is the set of possible worlds that the belief subject cannot recognise as wrong, by not having a belief that rules out the alternative. Here carriers are eliminated because there is information that rules them out.

Information carriers for a language $L = \langle P, F, C\rangle$ (with P a set of relations, F a set of function symbols, and C a set of constant symbols) will be models for languages $L' = \langle P, F, D\rangle$ with $D \subseteq C$. C is made up of two sorts: sets of objects and natural numbers. There are no variables.

The language for defining updates is a version of the DRT-formalism, where discourse referents are treated as conditions c meaning: c denotes.

(2) Terms:
a. basic terms for numbers and sets.
b. $ft_1,\ldots,t_n$ is a term iff $t_1,\ldots,t_n$ are terms, f is a function symbol and $t_1,\ldots,t_n$ match the signature of f.

Formulas are defined in (3).

(3) Formulas:
a. basic terms are formulas
b. $t_1 = t_2$ is a formula iff t_1 and t_2 are terms of the same sort.
c. $Pt_1,\ldots,t_n$ is a formula iff $t_1,\ldots,t_n$ are terms, P is a predicate symbol and $t_1,\ldots,t_n$ match the signature of P.
d. $\neg\varphi$, $\varphi \wedge \psi$, $\varphi \rightarrow \psi$ are formulas iff φ and ψ are.

The function of the terms as formulas is similar to the discourse markers of Kamp (1981). The definition below is syntactic, but a semantic definition will be used later on.

(4) Discourse Markers:
$DM(x) = \{x\}$ if x is a term

$DM(\varphi) = \emptyset$ if φ is atomic or $\varphi = \neg\psi$ or $\varphi = \psi \rightarrow \chi$
$DM(\varphi \wedge \psi) = DM(\varphi) \cup DM(\psi)$

Information states are sets of information carriers. Number terms will denote natural numbers bigger than 0, and other terms non-empty sets over the domain of the carrier. The update $\sigma[\varphi]$ of an information state σ by a formula φ can be defined as follows.

1. $\sigma[x] = \{i \in \sigma : ix \text{ defined}\}$ if x is a term
2. $\sigma[Pt_1, \ldots, t_n] = \{i \in \sigma : \neg\langle it_1, \ldots it_n\rangle \notin iP\}$
3. $\sigma[t_1 = t_2] = \{i \in \sigma : \neg\exists u \exists v(it_1 = u, it_2 = v \wedge u \neq v)\}$
4. $\sigma[\varphi \wedge \psi] = \sigma[\varphi][\psi]$
5. $\sigma[\neg\varphi] = \mathbf{neg}(\sigma[\varphi], \sigma)$
6. $\sigma[\varphi \rightarrow \psi] = \sigma[\neg(\varphi \wedge \neg\psi)]$

For the negation, it is necessary to define the discourse referents of an information state σ with respect to a (superset) τ: the discourse referents of σ that are proper to it and not inherited from σ.

(5) $dm(\sigma, \tau) = \{c \in C : \sigma \models c \wedge \tau \not\models c\}$

We also define the notion of two carriers being the same except for interpretation for the constants in a given set X.

(6) $i =_X j$ iff i and j have the same domain and $\forall a \in L$ ($a \notin X \Rightarrow$ ($ia = ja$ or ia and ja are both undefined.))

This can be used to define σ^X as in (7).

(7) $\sigma^X = \{j =_X i : i \in \sigma\}$

The negation can now be defined as in (8).

(8) $\mathbf{neg}(\sigma, \tau) = \tau \setminus \sigma^{dm(\sigma,\tau)}$

The first three clauses of the definition of update are set up in such a way that there is a distinction between an atomic formula (with *free* terms) eliminating information carriers and updating the *conjunction* of those free terms with the atomic formula: only in the latter case it is guaranteed that each of the constants will be defined throughout the information state. The atomic formulas only eliminate those carriers that overtly contradict them. This allows a notion of the discourse markers of an information state: the terms that are everywhere defined in that information state and, thereby, of the negation of an information state σ_1 with respect to another information state σ: the subtraction of the closure of the first information state σ_1 with respect to those of its discourse markers that are not markers of σ from σ. This semantic definition allows the development of the semantics as a proper algebra over information states.

The treatment of discourse markers may cause some worries. An update with a term c makes the term into a complete object, but does not add interesting claims about it, other than that it is an object. On arbitrary σ, we can add $square(c)$, then $\neg square(c)$ without causing σ to become the inconsistent information state. Only when c is added as a final update will inconsistency be reached. Natural language names are of course quite different, as their use presupposes their existence. Here, the update with c is the presupposed existence, the other occurrences do not presuppose existence.

The fact that the update c is so uninteresting makes the update $\neg c$ necessarily inconsistent. $\sigma[\neg c] = \sigma \setminus \sigma[c]^c = \emptyset$. $\neg\neg c$ consequently is the trivial update.

Information states can be in three minds about a discourse marker: they can contain it, i.e. $\sigma \models c$, they can reject it ($\sigma[c] = \emptyset$) and they can accept it as possible ($\emptyset \subset \sigma[c] \subset \sigma$).

Accessibility as in Kamp and Reyle (1993) can be faithfully expressed as $\sigma \models c$. This should not be confused with the property of being an old discourse marker which is much weaker. That notion cannot be defined along these lines, since one can be old by being a non-accessible discourse marker or by being constrained without being a discourse marker.

8.2.2 Exhaustive Updates

Exhaustive updates are updates with a formula whose discourse markers in the update are exhaustified with respect to the formula. The marker is just another constant. We eliminate the information carriers in which the formula does not hold and those in which the carrier does not give an exhaustive value to the constant. The first elimination is as always, for the second, a new update needs to be defined.

Information carriers are models. Quantification is dealt with by considering other information carriers in the information state which are exactly the same except for the value assigned to certain constants. For exhaustiveness, another relation OA will be introduced similar to variation with respect to a set of constants, but which allows other things to vary instead.

The relation is necessary for making sure that the interpretation of the relevant constants stays the same, not just formally the same, but also with respect to the place of the object in the ontology. I will call it an ontological alternative (OA) and will use OA_i for the ontological alternatives of i and $OA(i, j)$ to say that i and j are ontological alternatives of one another.

The relation guarantees that the individual constants have the same denotation in i and j and that moreover set membership, cardinality, part of and other basic relations and functions between the objects are preserved. Other relations and functions can change.

(9) 1. $\forall u\ v \in D_i \cap D_j \langle u, v\rangle \in iR$ iff $\langle u, v\rangle \in jR$ for $R \in \{\in$, part_of, cardinality, etc. $\}$
2. $\forall x \in C(ix \in D_i \cap D_j$ and $\forall x \in C(ix = u \Leftrightarrow jx = u)$

Modal accessibility, following the concept of Kripke (1972) is proposed as an alternative in Butler (2001), but that runs into the problem that it does not work for "part of" and other non-necessary relations.

OA is the mirror image of variation with respect to all discourse referents. It guarantees that the discourse referents are really the same but allows the domain, the non-privileged relations and functions to vary at random.

As before, the information state (i.e. every carrier in it) has to satisfy a set of meaning postulates *MP*.

The following is the definition. OA specifies the relevant alternatives for entailment, x-variance gives the range of the other possible values for x.

i is exhaustive for x with respect to σ and φ iff $i \in \sigma[\varphi]$ and whenever i has an x-variant $i_x \in \sigma[\varphi]$ and an OA variant i_o in $\sigma[\varphi]$ then i_o has an x-variant $i_{ox} \in \sigma[\varphi]$ that is OA to i_x.

The following diagram shows the demand of exhaustiveness on the constant x to fail with respect to i in the information state $\sigma[\varphi]$.

$$\begin{tikzcd}
\mathtt{i} \arrow[r, "\mathtt{OA}"] \arrow[d, "\mathtt{x\text{-}variant}"'] & i_o \arrow[d, "\mathtt{x\text{-}variant}"] \\
i_x \arrow[r, "\mathtt{OA}"'] & i_{ox}
\end{tikzcd}$$

$i : sleepers = \{j, b, m\}$
$x = \{j, b\}$
$i_o : sleepers = \{j, b\}$
$x = \{j, b\}$ `(OA` i`)`
$i_x : sleepers = \{j, b, m\}$ `(x-var.` i`)`
$x = \{j, b, m\}$
$i_o x : sleepers = \{j, b\}$ `(x-var.` j`)`
$x = \{j, b, m\}$ `(OA` k`)`
`So,` l `does not satisfy` $sleep(x)$

`Exhaustivity Diagram`

To see that this is correct, consider what we mean by exhaustive values. φ according to i should entail all of the φ-meanings in x-variants i_x of i. When would it not do so? If the carrier i has an x-variant i_x that is not entailed. But then there must be a carrier i_o, in which x

has the same value as in i, but for which there is no corresponding x-variant. It must be possible to choose an ontological alternative i_o of i with this property. If it had the corresponding $x - variant\ i_{ox}$, it should be object identical to i_x.

To go back to our earlier example of John having sheep x. We need the meaning postulate (10):

(10) $z \wedge y \wedge Pz \wedge y \subseteq z \rightarrow Py$

i.e. we assume that (11)

(11) $\sigma[z \wedge y \wedge Pz \wedge y \subseteq z \rightarrow Py] = \sigma$

and $\varphi = Px$. x must be new to the information state, i.e. $\sigma \not\models x$. Suppose i assigns $pow(A) \setminus \emptyset$ to P, and $B \subset A$ to x. Take i_x such that i_x assigns A to x. $i_x \in \sigma[Px]$ since x is new and by the assumption. Consider i_o such that i_o assigns $pow(B) \setminus \emptyset$ to P. $i_x \in \sigma[Px]$ as x is new. Then there is no i_{ox} such that $i_{ox} \in \sigma[Px]$, i_{ox} is an x-variant of i_o and i_{ox} is object-identical to i_x.

By OA: i_{ox} assigns A to x.
By x-variance: i_{ox} assigns $pow(B) \setminus \emptyset$ to P.
But then $i_{ox} \notin \sigma[Px]$
So x must be the maximum if i is exhaustive.

The other examples follow by the same reasoning.

An exhaustification operator q can be defined with the above semantics. The operator will take the discourse referents of a formula and deliver an exhaustive interpretation for all of them if that is possible. By the semantic definition of discourse markers, the discourse markers of the argument of the operator are the same as those of the result.

(12) $\sigma[q(\varphi)] = \{i \in \sigma[\varphi] : \forall j, k \in \sigma[\varphi]\ (j =_{dm(\sigma[\varphi],\sigma)} i \wedge k$ is OA to $i\ \exists l \in \sigma[\varphi]\ (l =_{dm(\sigma[\varphi],\sigma)} k \wedge l$ is OA to $j))\}$

Update semantics —or dynamic semantics— is not the only framework that allows an exhaustivity operator. Butler (2001) gives the purely classical definition:

$$\varphi(x_1, \ldots, x_n) \wedge$$
$$\forall y_1, \ldots y_n(\varphi(y_1, \ldots y_n) \rightarrow \Box(\varphi(x_1, \ldots, x_n) \rightarrow \varphi(y_1, \ldots, y_n)).$$

Provided that the semantics of $\Box$ uses OA, this gives the same result. Other definitions by Szabolcsi or Groenendijk and Stokhof go for the largest values instead of the informationally strongest. It is not difficult to repair these definitions.

8.3 Questions

The aim of this section will be to consider the combination of exhaustivity and update semantics as a tool for formulating a theory of questions.

In the theory of Groenendijk and Stokhof (1984)(GS henceforth), the standard answer to a question is true, exhaustive and rigid. The meaning of the question is the function that assigns to every possible world the appropriate standard answer, i.e. the question is the concept of its standard answer. This is equivalent to a characterisation of the question as a partition: two worlds are equivalent if they give the same standard answer.

The informational perspective and the employment of update semantics precludes taking over the Montague grammar formulation of these concepts. In update semantics, there are only expressions of type t and e, and it is only by information change that meaning can be defined. Within monotonic update semantics, it holds that if questions mean anything at all, this meaning is characterised in terms of the new information they bring to the information state.

The theory of questions I am proposing is simple: it applies the exhaustification operator to the formula representing the question that contains the question's Wh-elements as its discourse markers. A question update is an auxiliary update with the formula so obtained. The answer will determine how to proceed with the auxiliary information state.

An auxiliary update leaves the original information state intact and constructs a second information state. An example is the treatment of negation, in which the information state is updated with the negated formula, to determine the full update in terms of the information state so obtained and the original information state.

For questions, there are three ways in which one can deal with the auxiliary state: it can be negated with respect to the original information state, in case the answer is negative (e.g *no one, no, no animals*), one can replace the original state by the auxiliary state updated by the answer if it is positive and, finally, it can be forgotten, if the interlocutor does not know the answer. The ignorance of the interlocutor will be part of the common ground, which makes it strictly speaking wrong to just obliterate the question update in the last case. But I am not modelling the interlocutors in this paper.

The following two examples illustrate these three cases.

(13) Did John come to the party?
a. Yes.
b. No.

c. I do not know.

(14) Who came to the party?
a. John's friends.
b. Nobody.
c. I do not know.

A positive answer can be reconstructed as a sentence (by some mechanism for ellipsis resolution), or one can assume a mechanism for interpreting sentence fragments. In both cases, only one thing is needed: that the discourse markers for the referents of the expressions in the answer corresponding to the Wh-expressions in the sentence are the same (by unification) or are stated to be identical. A positive answer adds its contents to the auxiliary information state, which then replaces the original information state. In the following tables, we give the sequence of events for a question that is asked and then positively answered, negatively answered or declined.

(15) **Positive answers**
1. σ
2. $\sigma.\sigma$
3. $\sigma[question].\sigma$
4. $\sigma[question][answer].\sigma$
5. $\sigma[question][answer]$

In step (1), the conversation partners have a common ground σ. The fact that a question is asked puts (2) a copy of the common ground to the foreground, keeping the original information state in the background (the dot indicates the stack forming operation). The foreground is now updated (3) with the question and with the positive answer (4). Acceptation of the positive answer makes the foreground into the new common ground (5).

(16) **Negative answers.**
1. σ
2. $\sigma.\sigma$
3. $\sigma[question].\sigma$
4. **neg** $\sigma[question].\sigma$

In (16), steps (1) to (3) are the same. In (4), the new common ground becomes the negation of the foreground with respect to the background.

(17) **Declining to answer.**
1. σ
2. $\sigma.\sigma$

3. $\sigma[question].\sigma$
4. σ

In (17), step (4) reverts to the information state of (1).

The model allows for intervening questions and answers, by building longer sequences of auxiliary information states.

8.3.1 Adapting Questions

The choice between giving a positive answer and declining to answer is not always a sharp one: one can know the answer only partially. One strategy is to tacitly change the question. In case the question was *Who is asleep?* and it is only known that John sleeps but nothing is known about the others, it is possible to answer the weaker question *Is John asleep?*. In this case, it is necessary to indicate that a different question is answered. Twiddly intonation on *John* is one of these devices, but also more elaborate locutions may be chosen (e.g. *John is asleep, but I do not know about the others*). One answers a subquestion and declines to answer the rest.

Overanswering is the phenomenon that the answer gives more information than the question was -strictly speaking- asking for. This again is a question of tacitly changing the question, sometimes combined with an answer to the original question.

(18) Did any stock rise yesterday?
Yes, Alcatel and Telefonos Mexicanos.

In (18) the answer to the *yes-no*-question is followed by an answer to the Wh-question *Which stock rose yesterday?*, a question that was not explicitly asked, but one which the interpreter obviously thought would be the next one the speaker would ask. Within this treatment that question must be reconstructed in order to obtain the exhaustivity effect that no stock rose (relevantly) yesterday.

Questions come with a natural order. The weakest ones are the yes-no-questions. Stronger questions can be obtained by replacing standard NPs by Wh-elements and by replacing more restricted Wh-phrases by less restricted ones. Underanswering can be seen as answering a question derived from the original one by filling in a more concrete Wh-element for one of the Wh-elements in the question or by replacing it by a non-Wh-element altogether. Overanswering can analogously be understood as adding Wh-elements to the question or as making the Wh-elements less specific. The ordering strongly resembles the unification semi-lattice of the elements subsuming a given ground term. The semi-lattice can be grounded in semantics as well: knowing the answer to a stronger question always entails knowing the answer to the weaker question, under the assumption that the knowledge subject knows that the stronger question is stronger than the weaker one.

Of course, a speaker does not change the question without good cause. Going to a weaker question is only allowed if the speaker cannot reply to the stronger question or if the speaker realises that her partner is really looking for an answer to the weaker question. Answering a stronger question results from the realisation of the speaker that she can do so and that the stronger question is the one her conversation partner is really after. Recognising the speaker's intention is as important in understanding a question as it is in understanding an assertion.

An application of question shifting are non-exhaustive answers: they can be understood as answers to a weaker question. The topic of a non-exhaustive answer is a weakening of the explicit question. The exchange (19):

(19) Where can I get some coffee?
One floor down, second door left.

does not entail that coffee cannot be had elsewhere (though sometimes it does). We can explain this by assuming an implicit condition *around here* inside the *where* or a more specific meaning of the word *where*: *which is the closest place where* to obtain a weaker Wh-question or a shift to the yes-no-question: Can I get some coffee one floor down, second door left? The intention of the questioner is to get some coffee, an intention recognised from her question. The extra information in a full answer would not contribute to achieving the intention.

8.3.2 Wh-elements

A logical representation of questions needs to have a question operator and a way for marking Wh-elements.

Wh-phrases can be represented as indefinites: a new discourse marker and possibly a new condition. That they are Wh-markers is then indicated by the fact that they are bound by the q-operator. The meaning of the q-operator is to give an exhaustive interpretation to the discourse markers that it binds. Within a DRT-context, the main syntactic problem is then to protect possible indefinites occurring in the syntactic scope of the Wh-phrase from being bound as well. A simple proposal is to add an operator that closes off the syntactic scope of the Wh-phrase, to the semantics of the Wh-phrase. Operators with this property are readily available: the double negation or $\mathbf{true} \rightarrow \varphi$.

A disadvantage of this procedure is that it makes those indefinites unavailable for future anaphora. This is incorrect because such anaphora does occur when the question is answered in a positive way.

This is an argument for following GS in assuming full propositional answers using ellipsis resolution for constituent answers and unifying the discourse markers deriving from the Wh-phrases the relevant discourse markers in the answer. The semantic representation[2] of the answer could then be standard, i.e. omitting both the q-operators and the double negation(s).

(20)	Who ate the cake?	$q(x \wedge \neg\neg eat(x, y))$
	John.	$john(x) \wedge eat(x, y)$
	A boy.	$boy(x) \wedge \#x = 1 \wedge eat(x, y)$
	The boys.	$x = BOY \wedge eat(x, y)$
	Some boys.	$boy(x) \wedge \#x \geq 2 \wedge eat(x, y)$

The question establishes x as a discourse referent pointing to the set of eaters of the contextually given cake y. In the answers, x is further constrained: it has the name John, it is a boy, the (contextually given) boys, or some of those. In combination with the question semantics, it follows that nobody but John ate the cake, nobody else except one boy ate the cake, that the cake eaters and the contextually given boys coincide or the cake eaters coincide with a plural subset of those boys. This means that there is no need for the "exhaustivity of answers": it follows from the exhaustivity of the questions. In this respect, the treatment here gives an improvement of GS.[3]

The assumption of multiple topics in the next section gives a further argument for propositional answers: if there are multiple topics for a single sentence, constituent answers cannot be the basic case.

This gives us the representation (21) for a Wh-phrase.

(21) $q(x_1 \wedge \ldots x_n \wedge \neg\neg(A))$

Here A combines a restriction possibly incorporated in the Wh-phrase and the scope of the Wh-phrase. I will in the sequel often write

[2]The syntactic mechanism required is akin to resolving VP ellipsis as described by e.g. Prüst et al. (1994), Gardent (1991) or Dalrymple et al. (2002): if the answer is a sentence fragment its semantics must be completed by material from the question semantics, and —also if the answer is a full sentence— the referents of the answering NPs must be unified or identified with the referents of the Wh-constituents. It is quite possible to envisage other mechanisms to achieve the same effect: feature percolation in a discourse grammar transporting Wh-constants and question abstracts and putting exhaustification in the semantics of answers rather than relying on the dynamics. I want to claim that my approach based on matching and dynamics is simple and economical, not that it is the only possible one.

[3]$exh(Q) = \{A \in Q : \neg\exists B(Q(B) \wedge B \neq A \wedge \Box(Q(B) \rightarrow Q(A))\}$ is an improved version of the GS operation making the NP Q exhaustive. It is provable that: $\sigma \models exh(Q)(A) \Leftrightarrow \sigma \models q(A) \wedge Q(x)$, for simple choices of Q. Here A is the question abstract, $q(A)$ the exhaustivity statement derived from the question abstract and $Q(x)$ the statement that, for the variable x constrained by A, $Q(\lambda y\ y \in x)$ is true.

$q(dm, \varphi)$ where dm is the set of discourse markers and φ is A.

Yes-no-questions can be incorporated into this scheme as $q(\emptyset, \neg\neg\varphi)$. Quantifiers can have wider scopes than Wh-phrases. In this way, one can obtain the two readings of (22a), the one that asks one question per man and gives rise to pair-list answers and the one that asks for the favourite woman of every man. The distribution operator $dist(x, \varphi)$ and the notation $x = NOUN$ (x is the (contextually restricted) extension of NOUN) are explained in the section on plurals.

(22) a. Which woman does every man like most?
$x \wedge x = MAN \wedge dist(x, q(y \wedge woman(y) \wedge like\_most(x, y)))$
$q(y \wedge woman(y) \wedge \neg\neg(x \wedge x = MAN \wedge dist(x, like\_most(x, y))))$
b. Who meets a professor?
$q(x \wedge \neg\neg(y \wedge professor(y) \wedge meet(x, y)))$
c. Who meets which professor? (embedding)
$q(x \wedge dist(x, q(y \wedge professor(y) \wedge \neg\neg meet(x, y))))$
d. Who meets which professor? (lumping)
$q(x \wedge y \wedge professor(y) \wedge \neg\neg meet(x, y))$

The scheme for dealing with questions and answers supports these embedded cases: (22a) opens an auxiliary update within an auxiliary update. The hearer's contribution "his mother" applies to that second auxiliary state.

(23) $A = \sigma$
$B = \sigma[x \wedge man(x)]$
$C = \sigma[x \wedge man(x)][q(y \wedge \neg\neg(woman(y) \wedge love\_most(x, y))]$
$D = \sigma[man(x)][q(y \wedge \neg\neg(woman(y) \wedge love\_most(x, y))]$
$[mother(y, x) \wedge love\_most(x, y)]$
$E = A \setminus (B \setminus D^{dm(D,B)})^{dm(B,A)})$

Here A is the starting state and E the result. B sets up an auxiliary state with an arbitrary man, C sets up an auxiliary state based on B for the question, D is C updated with the positive answer "his mother". E uses A, B and D to determine the update of the whole exchange.

It is much the same in (22c) but it is a technical challenge to regulate things in such a way that the two answers: "Maria professor Groenendijk. Anna professor Stokhof." manage to update the two auxiliary information states in the correct way: $x = \{Maria, Anna\}, y$ is G if x (under dist) refers to Maria and S if x points to Anna.

Multiple answers are a problem anyway and it is not solved by just lumping the contributions of the individual into sets since one loses dependencies this way. Elsewhere I have defended a proposal in which multiple answers each answer a subquestion where the subquestions together form an exhaustive splitting up of the proper question. That approach would work for this case.

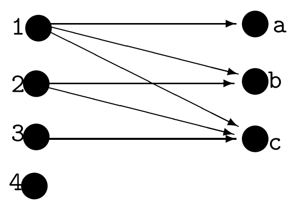
It is predicted that (24) also has two readings.

(24) Who loves who?

In the first case, we obtain a representation (25).

(25) $q(x \wedge q(y \wedge love(x, y))$

Let's consider this reading on a small domain. The internal q-operator gives us the interpretation under step 1. Possible interpretations like $\{1\} : \{a, b\}$ or $\{2\} : \{b\}$ are eliminated.



step 1	step 2
$\{1\} : \{a, b, c\}$	$\{1\} : \{a, b, c\}$
$\{2\} : \{b, c\}$	
$\{3\} : \{c\}$	
$\{1, 2\} : \{b, c\}$	$\{1, 2\} : \{b, c\}$
$\{1, 3\} : \{c\}$	
$\{2, 3\} : \{c\}$	
$\{1, 2, 3\} : \{c\}$	$\{1, 2, 3\} : \{c\}$

Fig. 2 Love in carrier i

The doubly exhaustive reading makes for a compact representation of the positive part of the relation as a relation between sets. The typical answer is: 1 loves a, b and c, 2 loves b and c and 3 loves c.

The other reading of the question is (26):

(26) $q(x \wedge y \wedge love(x, y))$

The $\forall\exists\forall\exists$-schema (see the section on plurals) gives the assignment : $x = \{1, 2, 3\}$ and $y = \{a, b, c\}$. If *love* is interpreted under this MP, that will be the only exhaustive assignment. The typical answer is 1, 2 and 3 love a,b and c.

8.3.3 Answering

There are two obstacles to adopting the GS theory of answering a question directly in the framework of this paper, apart from the obvious one of lacking the appropriate types. GS is couched in terms of the model theory of Montague, a type-logical generalisation of the modal semantics of Kripke. This semantics was set up with the specific aim of incorporating Kripke's theory of names as rigid designators, certain Aristotelian views about nouns and identity, Kaplan's theory of direct reference and accounts of *quantifying in* that rely on variables with a rigid interpretation.

Moving to an epistemic framework, rigid designation and direct reference are lost. And with it the simple concept of when an information state answers a question: when the question divides the state into a one-cell partition. The function of OA in the model is to recapture those notions. It fixes the objects, the constants referring to those objects and the structural relations between the objects. A formal ontological alternative does not really need to be ontologically possible, since it may not be a way the world could have been. Essential properties and relations need not be preserved (e.g. fatherhood, sortal properties and other putative essential identities). It is also more strict in that it does not allow for objects disappearing and coming into being.

By being an equivalence relation, OA allows a reconstruction of the GS account of answering. OA gives a partition over the information state. The cells of the partition are like the Kripke/Montague model and can in turn be partitioned by a question $q(dm, \varphi)$ into a cell where the answer is negative and cells that are dm-variants of an element $i \in \sigma[q(dm, \varphi] \cap OA_{\sigma k}$, i.e. those elements that give the same exhaustive answer to the question.

$$\{\{j \in OA_{\sigma[dm \wedge \varphi]k} : j =_{dm} i\} : i \in \sigma[q(dm, \varphi] \wedge i \in OA_{\sigma k}\}$$

And σ answers $q(dm, \varphi)$ iff every $OA_{\sigma k}$ of σ is partitioned by $q(dm, \varphi)$ into a singleton partition. This can be stated as:

$$\forall i \in \sigma\ \forall j \in \sigma\ \forall k \in \sigma[q(dm, \varphi)]\ \forall l \in \sigma[q(dm, \varphi)]$$
$$(OA(i, j) \wedge i =_{dm} k \wedge j =_{dm} l \Rightarrow \forall c \in dm\ kc = lc).$$

Is this ever satisfied? And if it is, does it correspond to the natural notion of knowing the answer to a question?

The first question must be answered positively, though on a rather speculative basis. The information states represent the common ground between a set of participants. As such they contain the common ground experience of the participants, and in particular all the utterances of the conversation. The essential components of these should be preserved under OA. Under the natural assumption that time, place, speaker and hearer of an utterance are essential components of an utterance, this will ensure that all the objects of the context of an utterance in the common ground experience are fixed within an OA-cell. Much the same holds for the objects of "joint attention" (Tomasello, 1999, Clark, 1996). An episode of "joint attention" is an experienced event in the common ground and its object is an essential property of the event. It therefore should be fixed within an OA-cell as well. When the object of joint attention is only indirectly given in the common ground experience (let's say we talk about your niece who I do not know except through the conversation), it will be part of accepting the conversational contributions that the object exists and that the contributor initiating the episode of joint attention knows who she is talking about. Within an OA cell, the referent therefore seems as much a first class citizen as any other object. So the answer to the first question should be yes.

But it is too lightly satisfied: any old discourse referent is fixed in the common ground by having been an object of joint attention in the common ground. Indeed references to old discourse referents are natural answers, even if the discourse referent has not been directly experienced by one participant. One may be more cautious however and only accept, e.g. the objects that are in the utterance situation, or the objects of joint attention that have been directly experienced. It does not help since the weaker positions are also vulnerable to versions of the circularity problem.

The circularity problem is that question updates can themselves provide the answer and in the model of this paper they necessarily do. The second time the same question is asked (with new constants), it is always already answered. (The question update changes the information state so that OA becomes sensitive to the new discourse referents.) Notice that —as the authors note themselves— the same problem occurs in the GS position, but in a more limited way. There any rigid expression (John Smith, that book, you) fixes its referent. So any question like the ones in (27) is always already answered.

(27) Who is John Smith?
Who is that?
Who are you?

And this is to some extent as it should be. There is a sense in which the answer to these questions are known but it is the same sense in which the question is answered by the description that can be formed from it (Who sleeps? The sleepers.). (28) is however a natural conversation. A speaker asks a question and so expresses her ignorance. The other speaker answers it and the first speaker can conclude as indicated. It does not seem to matter that the visual experience of the first speaker already fixes the referent or that there are thousands of Kates or that there may be more than one friend of the second speaker whose name is Kate.

(28) A: Who is that?
B: That is Kate, a friend of mine.
A: Oh, now I know who that is.

This problem can be resolved by ruling out circular answers. Any question gives a concept of its Wh-markers that is sufficient to fix it.

That concept or any concept which depends on it is never sufficient for knowing $q(dm, \varphi)$. If an information state only has that concept (or a concept depending on it) it does not answer the question.

The following is an attempt.

> σ answers $q(x_1, \ldots, x_n, \varphi)$ iff $\sigma \models y_1 \wedge \ldots \wedge y_k$ and fixes them independently of φ and $\sigma[q(x_1, \ldots, x_n, \varphi)] \models x_1 = y_1 \wedge \ldots \wedge x_k = y_k$.

The notion of "fixed independently of φ" can be approximated by the following counterfactual.

> If φ were false, $y_1, \ldots, y_n$ would still be fixed in σ.

For this to hold, it must be assumed that $q(dm, \varphi)$ is new to σ in the double sense that the discourse markers are new and that $\sigma[\varphi] \neq \emptyset$. That rules out that σ has a positive answer to $q(dm, \varphi)$.

It is however possible to define that A answers $q(x_1, \ldots, x_n, \varphi)$ with respect to σ.

> A answers $q(x_1, \ldots, x_n, \varphi)$ on σ iff $\sigma[\neg q(dm, \varphi)] \neq \emptyset$ and σ fixes $y_1, \ldots, y_k$ and $\sigma[q(x_1, \ldots, x_n, \varphi)][A] \models x_1 = y_1 \wedge \ldots \wedge x_k = y_k$

σ can then be said to answer $q(dm, \varphi)$ iff it can be decomposed into a proper superset τ and A such that $\tau[q(dm, \varphi)][A] = \sigma$ and A answers $q(dm, \varphi)$ on τ.

It is probably correct to say that a ban on circularity still does not give the proper criterion for knowing a Wh-question. There are ways of identification that have priority over others. The goals of the speaker that asks the question may rule out certain answers as uncooperative. It may be the correct way forwards to make the definition of when an information state dependent on a contextual criterion of relevance. But a non-circular notion is progress and is needed to keep our field respectable. It goes against common sense to reach the conclusion that there is no criterion for knowing the answer to a Wh-question. It is right, it seems, that one can know many different answers.

I have little to say about embedded questions that goes beyond the above. Presumably somebody who knows a question $q(dm, \varphi)$ has an information state K that can be decomposed into τ and A such that $K = \tau[q(dm, \varphi)][A]$ and A (relevantly) answers $q(dm, \varphi)$ on τ. Most of the other predicates of indirect questions can be reduced to this, e.g. "wondering who" can be approximated as the desire to "know who" that presupposes that "know who" is false, "decide who" as taking an action such that learning about it makes it the case that the information state has an answer to the question, "tell who" as supplying information that constitutes an answer on the information state.

8.4 Topic and Focus

The idea that topic and focus are related to exhaustivity goes back to Szabolcsi (1981). In her theory, a focused constituent is reinterpreted by applying an exhaustivity operator to it. Here I achieve the same by letting it supply the answer to the question resulting from omitting it in the sentence and replacing it by a suitable Wh-element. This same theory is also defended —but without the exhaustification— in van Kuppevelt (1991), who extends the theory with a connection to the theory of discourse: any sentence should be viewed as an answer to an explicit or implicit question.

How do we find out about the question? A popular view suggested by work on operators like *only* and *even* (see Rooth, 1992) and on subjunctives (see Kasper, 1992) is that it derives from a binary division coded into the form of the utterance by a variety of devices in different languages: syntactic position, case-marking, intonation etc. Others (e.g. Vallduví, 1992) assume a tripartite structure, by distinguishing within the topic, a contrastive topic and a link.

I want to suggest that it is not necessary to assume a formal division and that indeed a formal division is hard to maintain. Kasper (1992) convincingly shows that in many cases, we must even divide the semantical content of a word into a presupposition and an asserted part in order to obtain a sensible construction of the meaning of subjunctive sentences. He equally convincingly argues that this division cannot be made once and for all in the lexicon: different contexts lead to different divisions. It follows that these divisions cannot be formally marked by any device unless we assume syntax beneath the word level, intonational patterns that select part of a word meaning, lexical marking of focus, or similar unconvincing stratagems. What we are left with for the interpretation of the formal devices are just constraints: in particular constraints that tell us what cannot be topic, e.g. the NP marked by *wa* in Japanese must be in the topic of the sentence, post-Wackernagel material cannot appear (with the exception of verbal material) entirely in a topic, focus-intonation similarly indicates that some of its material must stay out of the topic. Binary (or even ternary) divisions are easy to mark in natural languages (compare quantification, subordination). So the variety of means of expression indicates that we are not dealing with a simple binary division. The fact that ternary divisions have been proposed also points in this direction.[4]

[4]Scepticism abounds in phonetic circles about the claims that are made for intonational marking. But also with respect to syntactic and morphological marking more scepticism is needed, if one looks at recent work on Japanese and Korean. And

The current context suggests a simple solution. The update formula for the sentence as a whole is computed. This formula allows a set of abstractions, corresponding to the questions that the sentence could possibly answer. Certain of these questions are ruled out by topic or focus marking. Other questions are already answered by the information state. The remaining questions together form the topic or topics of the sentence. So the informational contribution of the sentence is obtained by asserting the sentence (its representation with slots unified with Wh-elements in the topics) in an information state to which we have added the topic questions.

This predicts a series of exhaustification effects, which indeed we find in many cases. Sometimes however it appears as if there is a unique question. These are the cases like (29) where strong intonational marking suggests a single question "who does John like" or where a question is explicitly given.

(29) John likes MARY

Even then, the reconstruction into a question and an answer to the question can be performed in a number of ways, depending on the Wh-element chosen. (30) lists some possibilities for (29).

(30) a. Who does John like? Mary.
b. Which girl does John like? Mary.
c. Which of Jane and Mary does John like? Mary.

It is the information state that determines which one is chosen. If it is known that John likes a girl, or that he likes one of Jane and Mary, the last two questions are the topics that apply. If nothing is known about the answer to (30a), that will be (part of) the topic.

The variation in possible topics increases if larger foci are considered, as in (31) which may answer a question about John's emotional attitudes towards girls, John's liking of people in general, etc.

(31) John [LIKES MARY]

The assignment of a focus to a sentence is not unique, and even when it is unique, it does not give rise to a unique question.

Suppose we know that John has a farm and we are wondering about his life-stock. The assertion (32)

(32) John has 5 sheep.

is then naturally interpreted as answering a series of questions (33)

is it as clear as it should be in German and Dutch? Rather than giving up these claims, it seems that a far better case can be made now against a simple two-way distinction than in 1993. Lack of time and space prevents me from doing so.

where the (b) and (c) answers are responsible for the implicatures that John has no goats or cows and that he does not have 6 or 12 sheep. There is no other theory of topic and focus that has an explanation of these effects. They are a serious problem for the theory of Rooth and all other theories that have a binary or ternary division. There is also no way of getting these readings by stipulations about the meaning of the lexical items involved or the construction.

(33) a. Does John have any animals?
b. What animals does he have?
c. How many X does he have?

A serious side-problem for this approach is that it needs to explain *only*. In the standard analysis, *only* applies to a focus. But in our approach, the focus already has an exhaustive interpretation. Adding *only* to a sentence with a given focus would be semantically superfluous. This is illustrated in (34).

(34) Who does Mary love? She loves only John.
Mary likes only BEANS.

In both examples, *only* seems superfluous. In (34a) because of the exhaustivity of answers, in (34b) because of the exhaustivity of foci. If we do not assume that we are completely on the wrong track, an explanation must be available for these occurrences of *only*. There are two possibilities. One is that *only* here functions as a mirative pragmatic marker indicating that the answer goes against the expectations of the interlocutor: he or she would expect that Mary loves more people or likes more vegetables. This would place *only* on a par with *even* which relates to the expectation that less is the case. Another explanation could come from the underspecification involved in determining the precise topic: *only* could enlarge the extension of the restriction on the Wh-phrase in the topic (maybe from the contextually given set of alternatives that would otherwise be picked up to the full range of the possibilities) and thereby strengthen the exhaustivity. In both cases, *only* would have a role that is much less semantical than has generally been assumed[5]

8.5 Plurals

That the framework of generalised quantifiers is fruitful for analysing plural determiners has been proven by a constant stream of publica-

[5]This would be true, if there was not "only if", especially if one agrees with the logical tradition that "John will come, only if Mary comes" does not entail that "John will come, if Mary comes". No matter how much focus intonation one puts on an if-clause, it will not get rid of that entailment, inserting *only* is the only way.

tions. For a recent overview see Westerståhl (1995). My aim in this subsection is to provide an alternative not for those insights but for the view that full generalised quantifiers in natural language semantics is the only way to go. NL quantifiers are simpler and seem to be analysable by a simple set of features: cardinality restrictions, distributivity, definiteness, completeness, anaphoricity of the noun and negation.

Cardinality gives a restriction on the size of the discourse referent, the distributivity feature distinguishes various ways in which it interacts with the predicate or relation, definiteness indicates whether the denotation is identifiable to the hearer, completeness whether the discourse referent is identical to the referent of the noun or part of it, anaphoricity whether the noun extension is previously restricted to a contextually given part of its extension and negation indicates that the determiner is the negation of another one. My claim is that these features are the lexical properties a determiner can bear, not that all deteminers are specified for all features.

The proposal is close in spirit to proposals in early DRT[6]. In these proposals one merely generalises the DRT fragment to include plural discourse referents which are constrained by the sort of conditions considered here. That makes all non-negative determiners definites or indefinites (which is correct from the point of view of anaphora) but makes it hard to deal with the Evans effect and with all cases in which the quantifier seems to put an upper bound on the size of the set. Exhaustivity removes those two problems.

Certain predicates and relations obey special constraints. Some one-place predicates (e.g. nouns) are strictly distributive, i.e. they obey (35). Here and below I will use $x \in y$ as an abbreviation for $x \subseteq y \wedge \#x = 1$.

(35) $\forall x \in y \; Px \leftrightarrow Py$

Others also allow collective readings.

The situation with many-place predicates is more complicated. In this paper, I will only consider the $\forall\exists\forall\exists$-schema (36), here formulated for a 2-place predicate (it can be generalised to more places).

(36) $\forall v \in x \; \exists w \in y \; Rvw \wedge \forall v \in y \; \exists w \in x \; Rwv \rightarrow Rxy$

It is possible to define a schema $\forall\exists\forall\exists(x, y, Rxy)$ to express that Rxy is subjected to this schema. Other schemata are obtained by applying distributivity for one-place predicates in turn to more argument places. Sometimes this is a lexical property, other times collective readings are

[6] The idea of using exhaustivity for obtaining cumulative readings of Scha (1981) is due to Hans Kamp (p.c. somewhere in the '80s).

also allowed.

An example of such a derived postulate for 2-place relations is (37). This relation imposes distributivity over both coordinates.

(37) $\forall v \in x \; \forall w \in y \; Rvw \leftrightarrow Rxy$

8.5.1 Some constraints

Let x be the discourse referent of the NP, $NOUN$ be the extension of the noun (or the contextually determined restriction of that extension). The determiners *all, every, each* and *the* provide the feature of completeness (38),

(38) $x = NOUN$

when they are absent, the constraint (39) applies.

(39) $x \subset NOUN.$

To use proper subset is essential for the scalar implicatures. But it also seems that marking that the absence of completeness is important: it indicates the need for a new discourse referent in addition to the noun denotation. So completeness is an obligatorily marked feature (like plurality itself, definiteness, tense etc.).[7]

A number of determiners provide cardinality constraints. Some of these are stated in the following table. The variable n is a number value provided by the context.

$\#x = 3$	three
$\#x > \#(NOUN \setminus x)$	most
$\#x \geq 2$	some
$\#x \geq 2$	a few
$\#x < 3$	less than three
$\#x > 5$	more than 5
$\#x \geq n$	many

This deals with most meanings of determiners. The negative ones can just be defined in terms of the positive ones:

[7] The proper cardinals are compatible with definiteness and indefiniteness ("three books" vs "the three books"), the others are either definite or indefinite. While indefiniteness leads to a new discourse marker (otherwise the noun would already denote the subset), discourse markers for definites can be old and new. An important argument for this view is that one cannot use "a N" in situations where "N" is known to have a singleton denotation, even if the object is new to the discourse.

(40)*A first child born in the 22nd century

So uniqueness is marked by definite markers and the (mostly non-universal) counterexamples to the inverse principle that definite marking means uniqueness must be explained by assuming other triggers for definite marking, like e.g. inalienable possession.

(41) no:= not a
no:= not some
few:= not many

Every, many, most and *each* bind the predicate in a special way: they demand that each of the members of the discourse referent meets the condition of the predicate. In (42) I provide an update definition for distributivity. There is also a definition for fullness (intended for the semantics of *all*). These definitions are almost the same but for the fact that fullness continues to work for collective readings and mass interpretations of the constants.

(42) distributivity:
$\sigma[dist(x, \varphi)] = \{i \in \sigma : \forall j\ j =_x i \wedge jx \in ix\ \rightarrow j \in \sigma[\varphi]\}$
fullness:
$\sigma[full(x, \varphi)] = \{i \in \sigma : \forall j\ j =_x i \wedge jx \subseteq ix \rightarrow j \in \sigma[\varphi]\}$

In (42), distributivity is defined by quantifying over x-variants j of i that assign members of ix to x, for fullness, quantification is over all parts of ix.

Below a combination of the constraints is provided, combining with the verb *to run.*

A boy runs.	$x \wedge x \subset BOY \wedge \#x = 1 \wedge run(x)$
Some boys run.	$x \wedge x \subset BOY \wedge \#x \geq 2 \wedge run(x)$
The boy runs.	$x \wedge BOY = x \wedge \#x = 1 \wedge run(x)$
The boys run.	$x \wedge BOY = x \wedge \#x \geq 2 \wedge run(x)$
All boys run.	$x \wedge BOY = x \wedge \#x \geq 2 \wedge full(x, run(x))$
Every boy runs.	$x \wedge BOY = x \wedge dist(x, run(x))$
Three boys run.	$x \wedge BOY = x \wedge \#x = 3 \wedge run(x)$
Few boys run.	$\neg(x \wedge x \subset BOY \wedge \#x > n \wedge dist(x, run(x)))$
Many boys run.	$x \wedge x \subset BOY \wedge \#x > n \wedge dist(x, run(x))$
Most boys run.	$x \wedge x \subset BOY \wedge \#x > \#(BOY \setminus x) \wedge dist(x, run(x))$

This gives the simple naive approach. It is inadequate as it stands because it is not able to deal with lexically exhaustive quantifiers like "precisely 2" or readings of quantifiers like 2 in which they carry an exhaustive interpretation.

Suppose there are five sleeping boys. Then both (43)

(43) Less then four boys sleep
$x \wedge boy(x) \wedge \#x < 4 \wedge sleep(x)$

and (44) are true under a standard DRT-interpretation: just take a smaller subset of the sleeping boys.

(44) Precisely 2 boys sleep

$x \wedge boy(x) \wedge \#x = 2 \wedge sleep(x)$

Another example that comes out wrong is the cumulative reading of (45).

(45) 4 boys danced with 5 girls

(45) is true (due to our $\forall\exists\forall\exists$-meaning postulate) when the cumulative interpretation is true (the total number of boys who danced with girls is 4 and the total number of girls they danced with is 5). Unfortunately it also is true if five boys danced with six girls (in the cumulative reading), i.e. when it is intuitively false.

Hans Kamp's solution (p.c.) can be recapitulated in the following three steps, applying to the example (46) from Scha (1981).

(46) 200 Dutch firms own 600 American computers.

(47) 1. interpret the relation by the $\forall\exists\forall\exists$ schema
2. apply the "naive" approach to obtain a DRS
3. exhaustify the resulting DRS.

My one change is to do the exhaustification beforehand by updating with (48). This is assuming that (48) is a topic addressed by the sentence. (The question can be glossed as: How many Dutch firms own how many American computers.)

(48) $q(n \wedge m \wedge x \wedge y \wedge \#x = n \wedge \#y = m \wedge \neg\neg(dutch\_firm(x) \wedge american\_computer(y) \wedge \forall\exists\forall\exists(x, y, own(x, y))))$

After this update (49) is added with next to the shared constants, the unifications $n = 60$ and $m = 300$.

(49) $x \wedge y \wedge \#x = 60 \wedge \#y = 300 \wedge dutch\_firm(x) \wedge american\text{-}computer(y) \wedge own(x, y)$

Similarly for the other quantifiers. If they are in focus, they classify an exhaustively interpreted discourse referent. I will treat these exhaustivity effects under the heading of scalar implicatures.

8.6 Scalar Implicatures

Scalar implicatures is another area in which exhaustification does provide a direct explanation. If we analyse (50) as indicated,

(50) John has four sheep.
$x \wedge have(j, x)) \wedge \#x = 4 \wedge sheep(x))$

against the background of the question (51) it cannot be that there are more than 4 sheep that John owns. If there are, we can form another set of 4 sheep owned by John who are not contained in the set chosen as value for x.

(51) $q(n \wedge \neg\neg(\#x = n \wedge x \wedge have(j, x) \wedge sheep(x))) \wedge n = 4$

In this way, exhaustification explains all of the implicatures of the form (52) for n a number greater than 4.

(52) John does not have n sheep

The first group of examples are formed by monotone increasing determiners like *some, most, at least three etc.* that seem compatible with the application of *all*. If $A(det\ N)$ holds with *det* one of the mentioned determiners and A a simple context that does not bring the *det* N configuration into the scope of a quantifier or a negation, there is a scalar implicature that *not A(all N)*. An example is (53).

(53) statement: Most sheep died.
implicature: Not all sheep died.

Given an analysis of the determiners in question, exemplified in (54),

(54) $x \wedge sheep(x) \wedge die(x) \wedge \#(SHEEP \setminus x) < \#x$

it is possible to assign the set of all sheep to the discourse marker introduced by the NP. The condition $x \subset SHEEP$ introduced by the indefiniteness of *most* will prevent this for exhaustive values for x. This gives a semantic analysis of *some* that would work out on (55) as follows:

(55) Most sheep died.
$x \wedge x \subset SHEEP \wedge \#x > \#(SHEEP \setminus x) \wedge die(x)$

Exhaustification for x does not work if all sheep died. There is no value that simultaneously satisfies $q(x \wedge \neg\neg(sheep(x) \wedge die(x)))$ and (55).

A similar analysis applies to the other determiners.

(56) Two sheep died.
$x \wedge x \subset SHEEP \wedge \#x = 2 \wedge die(x)$
At least three sheep died.
$x \wedge x \subset SHEEP \wedge \#x \geq 3 \wedge die(x)$
At most three sheep died.
$x \wedge x \subset SHEEP \wedge \#x < 4 \wedge die(x)$

Notice that under the conditions that $SHEEP$ is plural, and has more than 3 members, if it holds (perforce exhaustively) that all sheep died, it still follows (non-exhaustively) that *some*, *most* and *at least three* sheep died. In our theory, it follows that the questions in (57) must be answered in the positive, though the affirmative sentences can not be used with the NP or determiner in focus.

(57) Did some sheep die?
Did most sheep die?

Did at least three sheep die?

So the normal entailments[8] come out correctly and it even holds that in the restricted sense that answers to the corresponding questions must be answered positively, these quantifiers remain monotone increasing.

Sometimes, it is better to interpret scalar implicatures as part of another phenomenon. A case in point is the scalar implicature around *or* in (58).

(58) John has sheep or John has goats.

(58)seems to exclude that John has animals of both kinds. Following the method of before, one introduces a variable that can be classified by *or* and *and* (in a mutually exclusive way) and introduce a suitable partial ordering on the values of that variable, as in (59),

(59) $z \wedge connection(z, sheep, goats) \wedge or(z)$

The values of z are the domain of connectives ordered by implication. To be precise:

f is a connective if $f \in 2^{2\times 2}$,
$f \leq g$ iff $\forall x\ g(x) \leq f(x)$,
$or(z)$ iff $z = \{\langle\langle 0,0\rangle,0\rangle, \langle\langle 1,0\rangle,1\rangle, \langle\langle 0,1\rangle,1\rangle, \langle\langle 1,1\rangle,1\rangle\}$ and
$connection(z,p,q)$ iff $z(\langle p,q\rangle) = 1$.

If John has both sheep and goats, disjunction is a proper value for z, but not an exhaustive one. Conjunction is however exhaustive. *Or* itself can never be exhaustive, since whenever it holds, there is a stronger connective (*and*, *left and not right* or *right and not left*) that wins out over *or*. So the explanation fails.

The approach is however not very natural to begin with. First, the addition of an extra variable is not warranted by anaphoric phenomena (the connection cannot be picked up by an anaphoric process). Second, the scalar implicature can equally well be derived in another way. The falsity of the conjunction is inferable if the disjunction gives two still possible distinct answers to the same question. That happens to be the most normal use of disjunctions. Exhaustivity is a crucial part of that inference, since the disjuncts may be compatible while their interpretation as an exhaustive answer to the same question is not.

Anaphora occurs with scalar implicatures like the ones in (60).

(60) John's sheep is rather heavy.

[8]Entailment intuitions can be reconstructed in two ways: (a) given that we know the premises can we answer *Yes* to the yes-no-question formed from the conclusion or (b) given that we know the premise can we sincerely and correctly assert the conclusion. For many examples in logic only the first interpretation can be maintained.

implicature: John's sheep is not extremely heavy.

The example can be continued with (61) which seems to pick up the degree of heaviness of John's sheep for applying it to Bill's sheep.

(61) Bill's sheep is just as heavy.

In this way (61) is analysed as (62) and acquires the implicature in the usual way.

(62) $q(w \wedge weight(w, s)) \wedge rather\_heavy(w)$

Here w can be thought of as a positive real, $weight(w, x)$ applies whenever weighing x gives a greater value than w[9], and *rather heavy* applies to an interval of weights distinct from that to which *extremely heavy* applies. Thus we maintain the entailment from *extremely heavy* to *rather heavy*, while obtaining a scalar implicature if exhaustification applies.

Scalar implicatures can be cancelled, as is fitting for implicatures.

(63) Does Leif have three chairs?
Yes, Leif has three chairs.

Following Kadmon (1990), the answer does not implicate that Leif has precisely three chairs. It may be that three chairs are needed for seating some extra guests, but that Leif owns six chairs in total.

Other means of cancelling the implicatures are connected with explicit cancellation and so-called twiddly intonation.

(64) a. Leif has three chairs, allright, but he may have more.
b. Leif has three —even six— chairs.
c. Leif has thReE chairs.

As exhaustification is connected with the topic-focus division in the sentence, it follows that all kinds of cancellation must be related to means of influencing this division. An explicit question changes the division: if possible, the topic will coincide with the question. The explicit question may thereby cancel the exhaustivity of the answer. Provisions also form a restriction on the topic-focus division. Constructing the topic as: *How many chairs does Leif own?*, i.e. making *three* the focus, for (64b) is contradicted by the interjection. Thereby, only the weaker question *Does Leif have three chairs?* can be the topic, with a treatment of the rejected topic included in the interjection. In (64a), the proviso similarly forces a weaker topic. Finally in (64c), the phenomenon of twiddly intonation is characteristic of topic resetting and should make it impossible to make *three* focus.

[9] I weigh one kilo, non-exhaustively, but not 100 kilos. Similarly, I am one foot tall, but not seven.

It is not the sentence as such that forms an exception to exhaustification. Cancellation can be limited to part of the sentence, while other quantifiers remain exhaustive. Compare (65).

(65) 3 boys kissed most—maybe all— girls.

One phenomenon that may be reduced to scalar implicatures, in our reconstruction, are the Evans-effects. Evans (1977) observes that there is a crucial difference between saying (66):

(66) John has sheep. Bill shaves them.

versus (67).

(67) John has sheep, that Bill shaves.

n the first, but not in the second case, Bill shaves all of John's sheep.

In the case of the single sentence, the focus can only include the whole NP, not the NP without the relative clause (this would only be possible if the relative clause were non-restrictive). In the other case, we assume that the discourse referent of the NP *sheep* receives an exhaustive interpretation by being in focus.

An obvious advantage of this treatment of scalar implicatures is that it is independent of the lexical inventory of a language. If a language has a maximal cardinal, it still has its scalar implicatures in this treatment. It has also a conceptual advantage. The decision to insert any new specification in an assertion, involves an answer on the part of the speaker to a question with respect to the dimension of the specification and suggests that the speaker is able to answer the question. New specifications therefore naturally add topical questions to the context of the assertion and are naturally interpreted as distinct answers to those topical questions. My view of scalar implicatures directly follows from sentence planning, while the classical view (Horn, 1972, Gazdar, 1979) requires a further Gricean explanation.

8.7 Conclusion

The current paper[10] is a reworking of Zeevat (1994a), especially of the flawed section on answering questions. It started very long ago as an attempt to make a theory of questions in DRT and to apply that to various exhaustivity effects, especially in plurals.

[10]There are too many people who commented on earlier versions of this paper to thank them each individually. Special thanks go to Hans Kamp for convincing me that it is possible to make sense of cumulative readings with simple means, to Werner Saurer for pointing out to me that exhaustivity also can go in the other direction and to Alastair Butler for taking some of these ideas further.

The approaches of Jäger (1997) and Groenendijk (1999) for developing an account of questions and answers in order to formalise the intuition that assertions are relevant because they answer common ground questions are limited because their models are not epistemic. One can however do the same here by demanding that a relevant assertion eliminate at least one cell in every question induced partition of a cell of the OA-partition of the information state. The set of open questions of an information state can be naturally defined as the set of sequences of discourse referents such that $\sigma \models q(\langle x_1, \ldots, x_n \rangle, \varphi)$ while σ does not answer $q(\langle x_1, \ldots, x_n \rangle, \varphi)$. This set can also be represented as a single question. There is also no need for a separate QUD (Ginzburg, 1995) since open questions are recoverable and Wh-constants are like other discourse markers.

The later aim of this paper was to analyse exhaustivity and to provide a uniform treatment of the areas where it seems to play an important role: questions, answers, focus, quantifiers, scalar implicatures and Evans effects. It does that and other phenomena have been reduced to it, especially in Butler (2001). I regard the demonstration of the possibility of having one single approach to all these phenomena as the real contribution of the paper. Any approach that loses this unity is a step backwards. As Butler demonstrates, it is not necessary to stick to the framework of Update Semantics or to my particular formalisation.

For the analysis of exhaustivity, there is a serious competitor. It is to apply Gricean reasoning on the fact that the speaker said A and not B.[11] If questions are sets of distinct propositional answers (as Hamblin, 1973 had it), a similar uniform approach can be developed, which continues to work where this account has to give up: where it becomes implausible to have variables with values and where one is dealing with contrast rather than with focus. It is even possible to see the development in this paper as the special case where distinctness can be understood as different values for the same variable. The Gricean reasoning is simple: it is the inference that the other answers were not selected because they are either entailed or false. I have recently tried to work this out (Zeevat, 2004). If I am right there, what I am doing here is not incorrect, but it is dealing with the special case where it is plausible to assume a variable.

[11] Most Gricean reasoning can be brought in this form. The speaker said that Black Bart caused the sheriff to die, not that he killed him. The speaker said that the candidate was good at cycling, not in his job. The speaker said something obviously false, not what he really thought. The speaker saw John with a woman, not with his wife. Implicatures arise in matching what the speaker could be expected to say and with what she said in fact.

Grice's original aim to maintain a simple logic and explain special effects by an additional mechanism is very much the methodological principle here. The mechanism I propose here is to reconstruct the intention behind the utterance in terms of the questions it answers. That there are such questions follows by the maxim of relevance.

The use of definite descriptions as an alternative for the DRT-analysis for various anaphoric phenomena finds important support in the Evans-phenomena. With a mechanism like the one proposed here, the difference between such an approach and DRT largely disappear: topic questions assign descriptions also to indefinite discourse markers. The fact that, for an adequate analysis of plural NPs, it seemed imperative to use the full generalised quantifier structure as proposed by Montague goes against the general spirit of the analyses proposed in early DRT for the singular NPs. These arguments no longer hold in a setting like the current one. And NL quantification becomes simpler as a result. It even becomes possible to try to understand the development of plural NPs in language evolution from floating quantifiers, bare NPs and definiteness markers.

9

Only: Meaning and Implicatures

Robert van Rooij and Katrin Schulz

9.1 Introduction

The issue of how to account for the interpretation of 'only' has always been exciting and challenging. Over the years many sophisticated proposals have been brought forward, but 'only' always managed to strike back by exposing another new and strange property. In this paper we will argue that there is a way to approach the meaning of 'only' that can deal with some of its well-known challenges but still is faithful to classical ideas.

In section 9.2 we will start our discussion by introducing the traditional and predominant view on the meaning of 'only' — we will call it the *focus alternative approach*. The main aim of the section will be to argue that this is not the right way to account for the meaning of 'only'. In section 9.3 we will then introduce a different approach, proposed by von Stechow (1991) — the *background alternatives approach*. We will develop a formalization of the latter analysis making use of minimal models and show that there is a close relation between the two contrasting approaches. But even though both approaches share the same driving idea, the background alternatives approach is better capable to deal with the challenges of the meaning of 'only'. The rest of the paper will support this claim by showing that the approach can account for well-known problems of focus alternative proposals.

Of course, we cannot discuss all the puzzles of the meaning of 'only' in one paper. We have, therefore, decided to concentrate on two well-known problems that concern pragmatic properties of 'only'. A

Questions in Dynamic Semantics.
Maria Aloni, Alastair Butler and Paul Dekker (eds.).
Current Research in the Semantics/Pragmatics Interface, Vol. 17.

closer discussion of the many semantic issues 'only' raises has to wait for another occasion. In section 9.4 we will deal with the question what part of the meaning of 'only' belongs to its semantics and what part has to be attributed to pragmatic considerations. The next section deals with the relevance dependence of 'only'. Finally, in section 9.6 we will argue that we should account for the inference from 'Only ϕ' to ϕ as a conversational implicature. This part strongly builds on a proposal made in Schulz (2005) and van Rooij and Schulz (2004). We will see that this Gricean explanation allows us to solve a well-known problem posed by Atlas (1991, 1993) for any pragmatic account of the inference ϕ from 'only ϕ'.[1] Section 9.7 ends with the conclusions.

9.2 The focus alternative approach

Intuitively, it seems to be quite clear what 'only' contributes to the meaning[2] of a sentence like, for instance, (1).[3]

(1) John only introduced $[\text{Mary}]_{\mathcal{F}}$ to Sue.

With this sentence we often communicate that, except for Mary, John introduced nobody to Sue. Thus, (1) tells us something, first, about who John has not introduced to Sue — namely everybody besides Mary, and second, about whom John *did* introduce to Sue — namely Mary. Let us introduce some terminology and call the first part of the meaning of (1) we have just distinguished the negative contribution and the second part the positive contribution of 'only'-modified sentences.

Countless proposals on how to capture this intuition have been brought forward since the nineteen-sixties.[4] One of the most influential is what we will call the *focus alternative approach*. It has been defended, for instance, by Horn (1969) and Rooth (1985, 1992, 1996). According to proposals along the lines of this approach the positive contribution of 'only' can be captured simply by claiming that the proposition in the scope of 'only' is true. The negative contribution is described as the statement that the elements of a set of alternative propositions that differ from the proposition in the scope of 'only' only with respect to the focus value are false.

[1] He observes that this inference can only be weakened but not truly cancelled.

[2] If we speak of the 'meaning' of a sentence we refer to the information conveyed by the utterance of this sentence in a particular context. If only the *semantic* meaning is meant this will be made clear explicitly.

[3] We assume that a focus feature can be attached to constituents of a sentence. How this feature is expressed in English will be not discussed in this work.

[4] But see Horn (1996) for discussion of some proposals made already by medieval monks.

We want to describe this approach somewhat more formally. To simplify things a bit, throughout this paper we will always take 'only' to denote an operator working on structured propositions $\langle F, B\rangle$ (and possibly other arguments), where F is the semantic meaning of the focus marked constituent and B the semantic meaning of the rest of the sentence (without 'only').[5] Let $Alt_R(\langle F, B\rangle)$ be the set $\{|\langle F', B\rangle| \ : \ F'$ is type-identical to $F\}$, where the function $|\cdot|$ maps structured propositions on the proposition one obtains by combining its parts. Then according to the focus alternative approach the meaning of 'only' can be described as the following function.

$only_R(\langle F, B\rangle, A) = \{w \in |\langle F, B\rangle| \ : \ \forall p \in A(p \neq |\langle F, B\rangle| \rightarrow w \notin p)\}$,
where $A \subseteq Alt_R(\langle F, B\rangle)$.

To give an example for the working of this approach, let us assume, following Rooth (1985), that proper names are of type e and allow as meaning of expressions of this type only rigid individual concepts. Then the alternatives Alt_R of sentence (1) will look as follows ($D_{\langle s,e\rangle,M}$ is the set of rigid individual concepts in model M and $[\alpha]$ denotes the semantic meaning of α).

$$Alt_R(1) = \{\lambda w.[\text{John introduced to Sue}](w)(d(w)) \ : \ d \in D_{\langle s,e\rangle,M}\}.$$

If one applies $only_R$ to (1) taking A to be $Alt_R(1)$ then, indeed, this approach does account for the intuitive interpretation (1) described above.

It is not difficult to see that one of the major challenges of this approach is to define proper restrictions on the set A. Not any member of $Alt_R(\langle F, B\rangle)$ that differs from $\langle F, B\rangle$ should be claimed to be false by a sentence 'Only F B'. Look, for instance, at (2).

(2) John only introduced [Bill and Mary]$_{\mathcal{F}}$ to Sue.

To account for plurals it has been argued that there is a reading of 'Bill and Mary' taking it to denote a group object consisting of the individuals Bill and Mary. In this case the NP would be type identical to a proper name. $Alt_R(2)$ would be defined as $Alt_R(1)$, with the difference that the individual concepts in $D_{\langle s,e\rangle,M}$ can select plural objects as well. If A is now taken to contain the propositions that John introduced Bill to Sue and that John introduced Mary to Sue — that are both elements of $Alt_R(2)$ — we obtain the wrong prediction that (2) denotes the

[5]Not all of the approaches we will discuss in this paper do assume that 'only' operates on structured propositions. However, this has no influence on the claims we will make.

absurd proposition. More generally, $only_R$ fails as soon as there are propositions among the alternatives in A that are properly entailed by $|\langle F, B\rangle|$.

The aim of this section is to show that the proposals made to provide the necessary restrictions on possible choices for A all suffer serious shortcomings. As we see it, the reason for these problems is that there is something substantial wrong with the idea underlying the focus alternative approach. 'Only' is not about excluding focus alternatives. In the next section we will then introduce a different approach that works over background alternatives instead.

But let us start with a discussion of the proposals made in the literature for how to restrict the focus alternatives. Already Rooth was aware of the necessity to provide such restrictions. In Rooth (1985, 1992) it is proposed that A is a contextually given variable that is normally not resolved to the entire set $Alt_R(\langle F, B\rangle)$. But this is not a convincing way to solve the problem outlined above. How can the way we resolve a contextual given variable systematically exclude interpretations with certain logical properties? Even though it may be that A is a contextually determined subset of $Alt_R(\langle F, B\rangle)$ there have to be additional restrictions on proper antecedents for this variable.

In his paper from 1993, Krifka imposes the following additional requirement on the set A[6]: A has to be a subset of $Alt_K(\langle F, B\rangle) = \{|\langle F', B\rangle| \ : \ F'$ is of the same type as F and $F \not\subseteq F'\}$. If we build this requirement directly into the definition of the meaning of 'only' we obtain the following description of this operation.

$only_K(\langle F, B\rangle, A) =$
$\{w \in |\langle F, B\rangle| \ : \ \forall |\langle F', B\rangle| \in A \ (F \not\subseteq F' \rightarrow w \notin |\langle F', B\rangle|)\}$,
where $A \subseteq Alt_R(\langle F, B\rangle)$.

Unfortunately, it turns out that this restriction is not sufficient to deal with examples like (2). If $b \oplus m$ is the group object consisting of Bill, b, and Mary, m, then on the group reading 'Bill and Mary' denotes the generalized quantifier $\lambda w \lambda X.X(b \oplus m)(w)$. Of course, for the generalized quantifier [Bill] $= \lambda w \lambda X.X(b)(w)$ we have [Bill and Mary] $\not\subseteq$ [Bill]. Thus, by applying Krifka's approach to example (2) we still predict that (2) implies that John did not introduce Bill to Sue, and, in general, that the sentence is interpreted as the absurd proposition.

Closely related to this account for the meaning of 'only' is a proposal brought forward by Schwarzschild (1994). He imposes the

[6]Actually, Krifka formulates more requirements A has to fulfill. We will come back to them in a minute.

same restriction Krifka uses, but now not on the focus value and its alternatives, but on the propositions they give rise to when combined with the background. In consequence, his interpretation rule for 'only' claims that the alternative statements for which 'only' concludes that they are false are restricted to propositions that are not entailed by the proposition in the scope of 'only'.[7]

$$\begin{aligned}&only_S(\langle F, B\rangle, A) = \\ &\{w \in |\langle F, B\rangle| \;:\; \forall|\langle F', B\rangle| \in A\ (|\langle F, B\rangle| \not\subseteq |\langle F', B\rangle| \rightarrow w \notin |\langle F', B\rangle|)\}, \\ &\text{where } A \subseteq Alt_R(\langle F, B\rangle).\end{aligned}$$

It is obvious, that $only_S$ will not be subject to the problem we have discussed for the focus alternative approach. The proposition that John introduced Bill and Mary to Sue implies that John introduced Bill to Sue, simply in virtue of the distributivity of a predicate like 'introduce', which is standardly guaranteed in terms of meaning postulates. Therefore, $only_S$ applied to (2) does not conclude that John did not introduce Bill to Sue.

But also this proposal has been criticized (see, for instance, Kadmon, 2001). In particular, it has been argued that $only_S$ is still too strong. The argument runs as follows. Consider (3), adapted from Kratzer (1989).

(3) Paula only painted [a still-life]$_{\mathcal{F}}$.

Among the alternatives to 'Paula painted [a still-life]$_{\mathcal{F}}$' there is also the proposition expressed by the sentence 'Paula painted apples'. This sentence is not entailed by 'Paula painted a still-life', and, therefore, when $only_S$ is applied, (3) implies that Paula did not paint apples. This is obviously a wrong prediction. The still-life may very well have contained apples.[8] There are also other problems the approach of Schwarzschild (1994) has to face. With focus constituents of the type of generalized quantifiers (from now on GQs) it is particularly obvious that one still needs restrictions on the set of alternatives. Even the most straightforward candidates for membership in A may cause trouble. Consider, for instance, cases where the NP in focus denotes an upward monotone generalized quantifier without a unique minimal element (we will call such generalized quantifiers *indefinite*).

[7] In Krifka (1995) you find a closely related but slightly weaker proposal (although it is not really used for the analysis of 'only' there): $only^*_K(\langle F, B\rangle, A) = \{w \in |\langle F, B\rangle| \;:\; \forall|\langle F', B\rangle| \in A\ ([\langle F', B\rangle] \subset |\langle F, B\rangle| \rightarrow w \notin |\langle F', B\rangle|\}$. $only^*_K$ is equivalent to $only_S$ iff A is closed under conjunction.

[8] Kratzer's (1989) solution to this problem involves her notion of *lumping*, a world-dependent entailment relation.

(4a) John only introduced [Bill or Mary]$_{\mathcal{F}}$ to Sue.

(4b) John only ate [an apple]$_{\mathcal{F}}$.

For (4a) one would expect that the propositions stating that John introduced Bill to Sue and that John introduced Mary to Sue are elements of A. However, they are not entailed by this sentence and thus, by *only*$_S$ concluded to be false. That means that (4a) is predicted to denote the absurd proposition.

Let us try to get some grip on what is the point here. Assume that we have a sentence of the form 'only $[Q]_{\mathcal{F}}$ B' where Q is an indefinite GQ. The problem is that for every world w where $Q(w)(B(w))$ is true we can find an upward monotone GQ Q' such that $Q'(w)(B(w))$ holds but $\lambda v.Q(v)(B(v)) \not\subseteq \lambda v.Q'(v)(B(v))$. We simply construct Q' as denoting in every world the set of sets containing $B(w)$. Then the claim $\lambda v.Q(v)(B(v)) \not\subseteq \lambda v.Q'(v)(B(v))$ follows as soon as we assume that there are some worlds v such that $Q(v)(B(v))$ is true and $B(w) \not\subseteq B(v)$. In consequence, the rule *only*$_S$ predicts that 'only $[Q]_{\mathcal{F}}$ B' denotes the absurd proposition.[9]

It seems that Krifka (1993) was aware of this problem and that this has driven him to impose an additional restrictions on the alternatives that are excluded by 'only'. He demands that the alternatives of indefinite generalized quantifiers are indefinite themselves. But while this seems to provide a way out for (4a), the problem is immediately back if we extend the disjunct a bit, as in (5). Now the alternative propositions 'John introduced Bill or Mary to Sue' and 'John introduced Mary or Peter to Sue' will be responsible for the prediction that (5) denotes the absurd proposition.

(5) John introduced [Bill, Mary, or Peter]$_{\mathcal{F}}$ to Sue.

There is another move in the paper of Krifka that seems to provide an escape route. Krifka (1993) distinguishes two readings for (4b). According to the first reading John ate only an apple and nothing more substantial. The second reading states that there is an apple x which John ate, and John did not eat anything else besides x. For the second reading Krifka proposes a different underlying structure: the indefinite NP has wide scope over 'only' and the focus marking is attached to the variable left behind: $\exists x : apple(x) \wedge only(ate(John, x_{\mathcal{F}}))$. Let us as-

[9] So far we have implicitly considered only rigid GQs. Actually, the problem we just discussed can be observed also for upward monotone GQs with unique minimal element if you assume that they (or their alternatives) are not rigid. For instance, if 'Mary' denotes in one world the set of sets containing individual a and in some other word the set of sets contain the individual b, then *only*$_S$ predicts (1) to denote the absurd proposition. See also the related discussion at the end of this section.

sume that the alternative set for variables is the same as Rooth (1992) proposes for proper names, namely the set of rigid individual concepts.[10] The application of $only_S$ yields in this case $\exists x : apple(x) \wedge \forall i \in D_{\langle s,e\rangle,M}[ate(John, x) \not\subseteq ate(John, i) \rightarrow \neg ate(John, i)]$. This interpretation does not give rise to the problem observed above. Other problems remain, however. For instance, one has to explain why indefinite quantifiers always take wide scope with respect to 'only'.[11] Furthermore, to be able to treat an example like (4a), we have to assume that also the disjunction can scope over 'only', i.e. the structure of this sentence can look as follows: $\exists x : (x = b \vee x = m) \wedge only(introduce(j, x_{\mathcal{F}}, s))$. Another problem of this solution is that it does not extend to focus constituents of other types than NPs, while the problem discussed above does seem to generalize. For instance, if we adopt the material implication interpretation of conditionals, then the interpretation rule $only_S$ wrongly predicts that sentences of the kind 'Only if $[\text{A}]_{\mathcal{F}}$, then C' denote the absurd proposition, because for every world w where 'If A then C' is true we can find a proposition A' such that $(A \rightarrow C) \not\subseteq (A' \rightarrow C)$ and $w \in (A' \rightarrow C)$.[12] The solution Krifka (1993) proposed for (4a)–(4b), however, is not available here.

Furthermore, even if we ignore these complications, there is a certain problem the approach inherits from Rooth's proposal. Although this problem is independent of the type of the constituent in focus, let us discuss the example (4b) at hand. The analysis proposed by Krifka works only if one assumes the alternatives of the focussed variable to be *rigid* individual concepts. Rooth (1985) explicitly makes this assumption for the focus value of expressions of type e. Krifka has to follow Rooth here. For suppose that we would allow for arbitrary individual concepts c that propositions of the form $\lambda w.ate(John, c)(w)$ are among Alt('John ate an apple'). Let us take a world w where John ate nothing besides a certain object α which is an apple in w. In such a world (4b) should come out as true. Furthermore, we assume, that the individual concept c — let us think of c as the apple you plucked yesterday — denotes α in w. There are other worlds were c does not denote the object α, but a different apple that is not eaten by John – maybe you ate the apple you plucked yourself. Then, the proposition $ate(John, c)$ will be true in w but not identical to the proposition that John ate object α. But then (4b) would come out as false in w, because there

[10] Krifka (1993) is not particularly clear on this point. He says that we should treat variables as names. However, he treats names as generalized quantifiers.

[11] A possible explanation could be that otherwise the sentence would denote the absurd proposition and pragmatic considerations exclude such an interpretation.

[12] See von Fintel (1997a) for more discussion.

is an alternative that is true in w but not entailed by the proposition that John ate object α. More generally, all approaches to the meaning of 'only' we have discussed so far have to make the assumption that all alternatives to the focus denotation F have a different extension from F in all worlds or in no world. The question is how we can motivate this necessary restriction on alternatives.[13]

So far we have seen that none of the proposed restrictions on the focus alternatives that are excluded by 'only' lead to convincing results. As we see it, this is due to a general misunderstanding of the working of 'only' by the focus alternative approach. Proper restrictions on focus alternatives cannot be given because 'only' simply does not operate on focus alternatives.

Let us take a step backward and ask ourselves what makes the focus alternative approach intuitively so attractive. It is its closeness to the intuitive meaning of a sentence like (1): it implies that for all other individuals besides Mary, John did not introduce them to Sue. The problem is that 'other individuals besides Mary' cannot in general be translated into focus alternatives. But how can we then capture this intuitive meaning? We can reformulate the claim that John introduced nobody besides Mary to Sue also as the statement that the set of people that John introduced to Sue is the smallest set containing Mary. But 'the set of people that John introduced to Sue' is nothing else than what is denoted by the background of (1). So, why not try this: while we may not be able to systematically translate 'other individuals besides Mary' into focus alternatives, we can systematically translate 'the set of people John introduced to Sue' into background alternatives. The function of 'only' could then be described as selecting minimal elements among these background alternatives such that still the proposition in the scope of 'only' is true. This is the fundamental idea behind the approach introduced in the next section.

[13]Krifka's proposal, however, to take the element in focus to be a variable left when moving the NP above 'only', is not necessarily subject to this criticism. We said in footnote 10 that Krifka is not explicit about what the alternatives are for variables. We assumed what appeared to us most straightforward and treated them as Rooth treats proper names. But according to most theories of formal semantics variables are of type e, i.e. denote individuals and not individual concepts. We might propose that therefore also their alternatives have to be of this type. Under this assumption the problem discussed above disappears. But notice, that this change would not solve the other problems of Krifka's (1993) proposal discussed above.

9.3 A background alternative approach

Assume that the extension of the background is of type $\langle f, t\rangle$ (thus, the background denotes a property of objects of type f). In consequence, the focus extension is either of type f or of type $\langle\langle f, t\rangle, t\rangle$ — let us assume, without loss of generality, that the second is the case. A quite direct formalization of the informal description of the meaning of 'only' we ended up with in the last section is this:

$$only_{vSt}(\langle F, B\rangle) = \\ \{w \in W : F(w)(B(w)) \ \& \ \neg\exists B' \subseteq D_{f,M}(F(w)(B') \ \& \ B' \subset B(w))\}.$$

$only_{vSt}$ claims that for each world w the extension of the background property, $B(w)$, is a minimal element of the extension of the focus, $F(w)$. For example (1), for instance, F = [Mary] denotes in w a generalized quantifier of type $\langle\langle e, t\rangle, t\rangle$ and B = [John introduced to Sue] a predicate of type $\langle e, t\rangle$. According to this approach to 'only' (1) is predicted to be true in w if $B(w)$ is a smallest element of $[Mary](w) = \{B' \subseteq D_{e,W} \ : \ \{mary\} \subseteq B'\}$, i.e., if $B(w) = \{mary\}$. Thus, it is predicted for (1) that John introduced Mary to Sue and nobody besides Mary.[14]

In contrast to focus alternative approaches $only_{vSt}$ does not make use of focus alternatives but quantifies over alternative background extensions. We will call such accounts for the meaning of 'only' *background alternative approaches*. If you take F to be a term answer to a question with question predicate B, then this rule for the interpretation of 'only' is what Groenendijk and Stokhof (1984) have proposed to describe the exhaustive interpretation of this answer. von Stechow (1991) was the first to adapt their approach in this way to a semantic rule for 'only'.

In an earlier paper (Schulz and van Rooij, 2005), we have proposed a slightly altered description of exhaustive interpretation than what has been proposed by Groenendijk & Stokhof. This was motivated by certain false predictions of their approach. For instance, by quantifying over all possible extensions for the background (or question-predicate) meaning postulates for these properties cannot be respected.[15] Because these problems arise with $only_{vSt}$ as well — consider for instance example (3) — , we propose as a starting point a parallel altered version for the interpretation of 'only'. This interpretation makes essential use of the model with respect to which we interpret expressions. Therefore,

[14] For expository reasons we treat proper names here as denoting rigid GQs. In contrast to the proposals discussed in the last section this assumption can be dropped for the background alternative approach.

[15] For more details see Schulz and van Rooij (2005).

we have to be a little bit more precise on our notion of model. We take a model M to fix a set of objects W_M, which we call worlds, a set D_M of individuals, and an interpretation function $[\cdot]^M$ for the non-logical vocabulary. The formal definition of $\text{Only}(\langle F, B\rangle)$ will make use of the ordering relation '$<_B$' between the worlds W_M of a model M. We say that $v <_B w$ iff v is exactly like w except that the extension of B in v is smaller than in w: $B(v) \subset B(w)$.

Definition 9.1 (The meaning of 'only' - the basic case) Let ψ be a sentence of the form 'only ϕ' where F is the semantic meaning of the focus in ϕ and B the semantic meaning of its background. We define the meaning $\text{Only}^M(\langle F, B\rangle)$ of ψ with respect to model M as the following proposition:

$$\text{Only}^M(\langle F, B\rangle) =$$
$$\{w \in W_M : F(w)(B(w)) \ \& \ \neg\exists v \in W_M(F(v)(B(v)) \ \& \ v <_B w)\}.$$

In contrast with $only_{vSt}$, the function Only does not select minimal extensions for B among all possible semantic objects having the same type as B, but only among those objects that are adopted by B as extension in some world of model M. Still, both approaches to the meaning of 'only' are closely related. As explained in Schulz and van Rooij (2005), if the background predicate does not occur in the focus and we assume that W_M is the set of all possible worlds/models, then $only_{vSt}$ gives rise to the same predictions as Only^M.[16]

In this and the previous section we have contrasted two conceptually different semantic analyses of 'only': one where we quantify over *focus*-alternatives, and one where the quantifier ranges over *background*-alternatives. In the end, in definition 1, we implemented the latter approach by quantifying over alternative worlds. It is interesting to note that the minimal model analysis can also be reformulated as involving a set of alternative propositions. In this reformulation it looks more like the versions we discussed in section 9.2, like $only_S$. Let us define a function *Alt* mapping sentences ϕ with background predicate

[16]Nevertheless, as we will see later on, the new version has a lot of conceptual advantages over $only_{vSt}$. For instance, the reformulation of the condition $B' \subset B(w)$ as an order over possible (admissible) worlds, $v <_B w$, allows for high flexibility and generality in the proposed meaning of 'only'. As we have mentioned earlier, Krifka (1993) claimed that there is a second reading for sentences like (4b) that we have not discussed so far. It is the nowadays well-known *scalar reading* of 'only'. The definition given above may provide a description that is able to account for both readings.

B on the set of propositions that claim certain objects to have the background property. Thus if the extension of the background of ϕ is of type $\langle f, t \rangle$, then $Alt^M(\phi) = \{B(j) \ : \ j \in D_{f,M}\}$. For example (1) this comes down to the same set of alternatives Rooth proposed, namely the set of propositions claiming that John introduced j to Sue for all j in the domain of individuals. However, if the element in focus is an NP denoting a proper generalized quantifier the approaches differ. Now we can define an ordering between worlds based on $Alt(\phi)$. We say that $v <_{Alt(\phi)} w$ iff v is just like w except that $\{p \in Alt(\phi) | v \in p\} \subset \{p \in Alt(\phi) | w \in p\}$. Then, if F and B are the interpretations of focus and background of ϕ (with respect to M) the following holds.

$$\begin{aligned}&\text{Only}^M(\langle F, B \rangle) = \\ &\{w \in W_M : \ F(w)(B(w)) \ \& \neg \exists v \in W_M(F(v)(B(v)) \ \& \ v <_{Alt(\phi)} w)\}.\end{aligned}$$

Thus, we might as well say that w verifies (1) iff w verifies the sentence 'John introduced Mary to Sue' and there is no other world v which verifies this sentence that makes less elements of $Alt(1)$ true than w does. The reason for this equivalence, of course, is that if we define $Alt(F(B))$ in terms of B as suggested above, it follows that $<_B$ and $<_{Alt(\phi)}$ gives rise to the same ordering relation between worlds.

It is standard to assume that the alternatives to a certain semantic object should be type-identical to this object. The alternatives used in the formula above do not (necessarily) have this property. For instance, this is not the case if the expression in focus denotes a generalized quantifier. Notice, however, that Only^M does not have to face any of the problems of focus alternative approaches we discussed in the last section and, for instance, makes correct predictions for the examples (2), (4), and (5).

9.4 The excluded versus the non-excluded

When Only is applied to examples as (1), here repeated as (6), the sentence is interpreted as stating both, that except for Mary, John introduced nobody to Sue — this is what we called the negative contribution of this sentence — and that, in fact, he did introduce Mary to Sue — this was the positive contribution. Both, the positive and the negative contribution together constitute what we have described as the information conveyed by such a sentence. Thus, the approach seems to do a good job in describing our intuitions about the meaning of 'only'.

(6) John only introduced [Mary]$_{\mathcal{F}}$ to Sue.

But 'meaning' is still a very general term. The next question we can ask is whether Only is also a correct description of the *semantic* meaning of this word, or, to put it otherwise, whether we should put [*only*] in place of Only, the former representing in our notation the semantic meaning of 'only'. Horn (1969, 1996) and others have given convincing evidence that this is not the case. More in particular, certain observations strongly suggest that what we have called the positive contribution of a sentence containing 'only' — the claim that John introduced Mary to Sue for example (6) — should *not* be part of the semantic meaning of this sentence. Let us review the critical observations.

The first argument involves negative polarity items (NPIs). NPIs like 'any' are appropriate when they occur in the background of a sentence with 'only', as in (7a), but not when they are part of the focus, as in (7b).[17]

(7a) Only $[\text{John}]_{\mathcal{F}}$ has *any money* left.

(7b) *John only has $[\textit{any money}]_{\mathcal{F}}$ left.

It is well established that NPIs are licensed in assertions only in case they occur in downward entailing contexts. A context $X - Y$ is downward entailing (DE) iff from the truth of $X\alpha Y$ and the fact that β entails[18] α it follows that $X\beta Y$ is true as well. Thus, a context is DE iff an expression occurring in it can be replaced by a semantically stronger expression *salva veritate*. If the semantic meaning of 'only' combines both the positive and the negative contribution discussed above, one cannot account for (7a), because the background is then not predicted to be downward entailing. If the semantic meaning of 'only' is exhausted by the negative contribution, however, we can. Moreover, in this way we predict correctly that the focus part of a sentence is not a licenser of NPIs.

A second observation provided by Horn (1996) in favor of an approach that takes only the negative contribution to constitute the semantic meaning of 'only' is the fact that the appropriateness of the following sentences clearly indicates that in contrast to the negative contribution (i.e., nobody but John smokes in (8a)–(8b)), the positive contribution (John smokes) is *cancelable*. Parts of the semantic meaning

[17]Notice that under certain circumstances NPIs can occur in the focus. Consider, for instance, the following example from Horn (1996).

(i) Only the students who had *ever* read *anything* about polarity passed.

According to Beaver (2004), the NPIs in (i) are not licensed by 'only' but by 'the students who'.

[18]The notion of entailment we employ here is polymorph, applied to multiple types.

of a sentence, however, should not be cancellable.

(8a) Only [John]$_{\mathcal{F}}$ smokes, {if even he does/and maybe even he does not.}

(8b) *Only [John]$_{\mathcal{F}}$ smokes, {if nobody else does/and maybe somebody else does.}

Finally, if both, the positive and the negative contribution together would constitute the semantic meaning of sentences containing 'only', we would predict that the negation of such a sentence conveys that either the positive or the negative contribution is false. Thus, an example like (9) should have the semantic meaning that either there are other people besides John that smoke, or John does not smoke. Intuitively, however, only the first part of the disjunction is conveyed by (9). Thus, the negation behaves as if only the negative contribution but not the positive one is part of the semantic meaning of 'only'.

(9) Not only [John]$_{\mathcal{F}}$ smokes.

The same arguments holds for denials of assertions with 'only', as demonstrated with the following example (due to Horn, 1969):

(10a) Only [John]$_{\mathcal{F}}$ smokes.

(10b) No, that's not true. {Mary does as well/ *He does not.}

All three problems suggest that the positive contribution is not part of the semantic meaning of 'only'. Therefore, we propose as description of the semantic content the following adapted version of Only.

Definition 9.2 (The semantic meaning of 'only') Let ψ be a sentence of the form 'only ϕ' where F is the semantic meaning of the focus in ϕ and B the semantic meaning of its background. We define the semantic meaning $[only]^M(\langle F, B\rangle)$ of ψ with respect to model M as the following proposition:

$$\begin{aligned}
&[only]^M(\langle F, B\rangle) = \\
&\{w \in W_M : \exists v \in W_M[F(v)(B(v)) \ \& \\
&\qquad\qquad [\neg\exists u \in W_M(F(u)(B(u)) \ \& \ u <_B v)] \ \& \ w \leq_B v]\} = \\
&\{w \in W_M : \exists v \in \textsc{Only}^M(\langle F, B\rangle)(w \leq_B v)\}.
\end{aligned}$$

If ϕ has background predicate B, according to this rule 'Only ϕ' is true in worlds where B has a smallest extension such that ϕ is true or an extension that is a subset of such a minimal element. Applied to an example, 'Only [John]$_{\mathcal{F}}$ smokes' is predicted to be true in all worlds where the extension of 'smoke' is either $\{john\}$ or $\emptyset$. Similarly, the sentence 'Only [men]$_{\mathcal{F}}$ smoke' is true only in case all smokers are men or there are no smokers. This analysis of 'only' excludes that, in the first example, somebody else besides John smokes, and, in the second, that someone smokes who is not a man. Thus, this rule takes exclusively the negative contribution to be the semantic meaning of 'only'. In this way all observations made above are accounted for.

Now that the positive contribution is no longer taken to be part of the semantic meaning of 'only', we are left with the question what then is the status of this information. The obvious way to solve this problem is to propose that the inference from 'Only ϕ' to ϕ is one of a pragmatic nature. We will discuss in section 9.6 what kind of analysis is most appropriate. But before we come to the pragmatics of 'only' let us first discuss a problem that arises for our context independent analysis of 'only'.

9.5 Context dependence

9.5.1 The problem of context dependence

Problematic for the semantic analysis of 'only' proposed in the previous section is that it does not mirror the context dependence of its truth conditions. Not from every use of 'only' one concludes that everything not described by the focus does not have the background property — as claimed by [*only*]. For instance, if Johnny comes back from the swimming pool and his mother asks him who else was there, his answer 'Only Billy' is by [*only*] predicted to mean that except for Billy and little John, nobody was there at all. In certain contexts, however, the answer only rules out that other *friends* of Johnny were there. Thus, it seems that in this case 'only' does not restrict the extension of the predicate λx. *x was at the swimming pool with John* but rather the contextually relevant subset λx. *x is a friend of John and was with him at the swimming pool*. We observe similar effects of context dependence in many other cases as well. For instance, suppose that Ann and Bob are playing poker, Ann called, and Bob gives up putting his cards on the deck. Now the following dialogue takes place:

(11a) Ann: What cards did you have?

(11b) Bob: Only two kings.

Our interpretation rule [*only*] takes Bob's answer to convey the same information as if he had said 'I had two kings'. Thus, no information is added by 'only' to the sentence in its scope. The reason is that because of the poker-game rules, in every world Bob had exactly five cards. Therefore selecting worlds where Bob had a minimum of cards such that two of them are kings or less than this will give you all the worlds where Bob had 5 cards and two of them where kings — certainly the wrong result. Intuitively, however, Bob's answer *does* exclude certain hands of cards that Bob could have had — for instance, that he had additional kings. In general, it is excluded that he had a *better* hand in terms of the rules of the game. Thus again, 'only' seems to restrict the extension of a contextually relevant subset of the background predicate, namely the set of cards that contribute to the value of Bob's hand. This reading of 'only' is also known as the *scalar reading*.[19] So far, [*only*] cannot account for this interpretation.

9.5.2 Solving the problem by Relevance

To model the context dependence of 'only' we have to provide a formal description of this relevance dependent subset of the background predicate 'only' operates on. In order to do so what we need first is some formal way to access contextual relevance. Fortunately, a lot of work has been done on this subject and a whole family of orders comparing the relevance of propositions in a particular context have been proposed.[20] As in Schulz and van Rooij (2005) we will use the ordering of propositions defined in terms of their utility values here and call it $\geq^r$. The utility value of a proposition is defined in terms of the extent to which learning that proposition helps the addressee to solve a decision problem he has to face. How can we use this order to find the relevant subset of the extension of some predicate B? We use it to define a second ordering between possible extensions of B. We will say that X is at least as relevant a set with respect to background B as Y is, $X \geq^r_B Y$, if the information that all elements of X have property B, $\lambda v(X \subseteq B(v))$, is at least as relevant as the corresponding information for Y.

$$X \geq^r_B Y \quad \text{iff} \quad \lambda v(X \subseteq B(v)) \geq^r \lambda v(Y \subseteq B(v)).$$

We will propose that 'only' is defined relative to the set of all minimally large but maximal relevant subsets of the background predicate — such that it only contains those individuals really cared for in the

[19] In fact, we think that the reading of 'only' in this example is the same as the reading Krifka (1993) claimed as one of the readings of example (4b), repeated below.

(4b) John only ate [an apple]$_{\mathcal{F}}$.

What our function [*only*] cannot account for yet is the reading according to which John ate only an apple and nothing more substantial.

[20] See van Rooij (2004) for a number of candidates and relations between them.

context. These minimal elements are not necessarily uniquely determined. Therefore we define $Opt(B, w)$ as the set of all subsets of B that fulfill these two requirements. ('$>^r_B$' and '$\cong^r_B$' are defined in the usual way.)

$$Opt(B, w) = \\ \{X \subseteq B(w) | \neg\exists Y \subseteq B(w)(Y >^r_B X) \ \&\ \neg\exists Z \subset X(Z \cong^r_B X)\}.$$

Obviously, it depends on what is (known to be) relevant to the addressee what kind of set $Opt(B, w)$ denotes. Suppose that the addressee is known to be interested in learning the full extension of predicate B. Then $\leq^r$ predicts that in w, $\lambda v[B(w) \subseteq B(v)] \geq^r \lambda v[X \subseteq B(v)]$ iff $B(w) \supseteq X$ (and thus that $\geq^r$ comes down to entailment). Then it will be the case for each world w that $Opt(B, w)$ denotes the singleton set $\{B(w)\}$. Assume now that the addressee is only interested in who of John, Mary, and Sue have the property denoted by B, i.e., in w, $\lambda v[(B(w) \cap \{j, m, s\}) \subseteq B(v)] \geq^r \lambda v[X \subseteq B(v)]$ iff $B(w) \cap \{j, m, s\} \supseteq X$. In that case $Opt(B, w)$ will denote the singleton set $\{B(w) \cap \{j, m, s\}\}$. In our card-game example, $Opt(B, w)$ will consist of the singleton set consisting of exactly those cards that Bob has in w that determine the value of his hand according to the rules of poker. Finally, if the addressee is only interested in learning of one place where she can buy an Italian newspaper *that* she can buy one there, $Opt(B, w)$ will consist of the set of all singleton sets of places where she can buy an Italian newspaper in w.

If there were always only one such optimal subset $X \in Opt(B, w)$ for each w we were done by now: we could simply define a predicate $B^* := \lambda w.X$ for $X \in Opt(B, w)$ and say that the meaning of 'only' has to be described as $[only](F, B^*)$. Thus, to describe 'only' correctly we could have kept our old formalization, but apply it to the relevant subset B^* of B. However, we saw above that $Opt(B, w)$ may contain more than one element. That makes our definition a bit more complicated. We have to introduce a new order comparing worlds.

Definition 9.3 (Relevance 'only') Let ψ be a sentence of the form 'only ϕ' where F is the semantic meaning of the focus in ϕ and B the semantic meaning of its background. We define the relevance-dependent semantic meaning $[only]^M(\langle F, B\rangle)$ of ψ with respect to model M as the following proposition:

$$
\begin{aligned}
&[only]^M_{rel}(\langle F, B\rangle) = \\
&\{w \in W_M : \exists v \in W_M\ [F(v)(B(v))\ \& \\
&\qquad [\neg \exists u \in W_M(F(u)(B(u))\ \&\ u <^r_B v)]\ \&\ w \leq^r_B v]\} \\
&\text{where } v \leq^r_B w \text{ iff } Opt(B, v) \cap Opt(B, w) \neq \emptyset \text{ or} \\
&\qquad \forall X \in Opt(B, v) \exists Y \in Opt(B, w) : X \subseteq Y.
\end{aligned}
$$

Making use of $[only]_{rel}$ instead of $[only]$ immediately improves our predictions. In a context where it is only relevant who of Johnny's friends were at the swimming pool, Johnny's answer 'Only [Billy]$_{\mathcal{F}}$ was at the swimming pool', for instance, we now predict that it only excludes that other *friends* of Johnny were at the swimming pool. The reason is that at each world w, the only element of $Opt(B, w)$ is the set of friends of Johnny in w that were at the pool. For the poker-game dialogue (11a)–(11b) something similar is obtained: By applying $[only]_{rel}$ we predict that Bob's answer 'Only two kings' only rules out that Bob has additional cards that would have increased the value of his cards. Thus, by means of relevance, we have explained the *scalar* reading of 'only' and shown that it can be thought of as a natural special case.[21]

In the above examples $Opt(B, w)$ denoted a singleton set for each w. It is easy to see that in this case $[only]_{rel}(\langle F, B\rangle)$ comes down to $[only](\langle F, B^*\rangle)$.[22] This is typically not the case if the questioner is interested just in some object fulfilling the question predicate. For instance, Ann in the example below wants to buy an Italian newspaper. She does not have to know every place in town to get one. One place is sufficient.

(12a) Ann: Where can I buy an Italian newspaper?

(12b) Bob: At the central station.

(12c) Bob: Only [at the central station]$_{\mathcal{F}}$.

It is a well-known observation that in such a context answer (12b) is not understood as implying that the central station is the only place to buy an Italian newspaper. In fact, Bob's answer conveys nothing more than its semantic meaning: the central station is one place to buy an Italian newspaper. Thus, in such contexts answers are not interpreted exhaustively, or, as is proposed in Schulz and van Rooij (2005), exhaustive interpretation has no effect because the semantic meaning of the answer conveys already all the information Ann wants.

[21] It should be clear that in terms of it we can also account for the reading of (4b), according to which John ate only an apple and nothing more substantial.

[22] $[only]$ is a special case of $[only]_{rel}$: the case where for each w, $Opt(B, w) = \{B(w)\}$. As suggested in the main text, this results in case $\geq^r_B$ reduces to the superset relation (and $\geq^r$ to standard entailment).

As observed by Alastair Butler (p.c.), Bob's answer (12c) means something different from (12b). From (12c) we *do* infer that Ann cannot buy an Italian newspaper at any other place than at the central station. Apparently, the well-known similarity between the exhaustive interpretation of answers and the meaning of 'only' breaks down in this case. Let us see how our approach to the meaning of 'only' can deal with this observation. Suppose, that we have a model M with $W_M = \{u, v, w, x\}$ and where the background B = 'Can buy an Italian newspaper' has the following extensions: $B^M(u) = \{c(entral)s(tation)\}, B^M(v) = \{p(alace)\}$, $B^M(w) = \{cs, p\}$, and $B^M(x) = \emptyset$. In a context where Ann is known to be only interested in some place to buy an Italian newspaper, we obtain that $Opt(B, x) = \{\emptyset\}$, $Opt(B, u) = \{\{cs\}\}, Opt(B, v) = \{\{p\}\}$, and $Opt(B, w) = \{\{cs\}, \{p\}\}$. From this it follows that the four worlds are related by $\leq^r_B$ in the order: $x <^r_B u =^r_B w$. When we now select the worlds where it is true that at the central station one can buy Italian newspapers and for which there exists no other world making this true and that is strictly $\leq^r_B$-smaller, we end up with the set $\{u, w\}$. $[only]^M_{rel}$ is true in those worlds of W_M that are smaller or equal to the elements of this set, thus, in the worlds $\{u, v, w, x\} = W_M$. That means that according to our approach Bob's answer is trivial. We propose that therefore the context is reinterpreted. Ann concludes that Bob got the contextual relevance wrong and switches to the default notion of relevance in the context of questions, namely that the whole extension of the predicate in question is relevant, i.e. Ann wants to know all places where she can buy an Italian newspaper. In this case $[only]_{rel}$ comes down to $[only]$ and we predict the observed interpretation for (12c) that Ann cannot buy an Italian newspaper at the palace.

9.6 The pragmatics of 'only'

9.6.1 The pragmatic contribution as a conversational implicature

Finally, we want to explain how the positive contribution of an 'only' modified sentence comes about, i.e. why we normally infer from 'Only ϕ' that ϕ is the case. It has often been proposed (see, for instance, Horn, 1969) that this information, for example (13) the inference that John smokes, is due to the presuppositions of 'Only ϕ'.

(13) Only $[\text{John}]_{\mathcal{F}}$ smokes.

An important argument in favor of a presuppositional analysis is that, not only from (13), but also from its negation, (14), we typically infer that John smokes.

(14) Not only [John]$_{\mathcal{F}}$ smokes.

But various authors have argued against this presuppositional analysis. First of all, although it is only seldomly heard, one can bring forward a theoretical argument against this proposal: according to the most popular analysis of presuppositions, viz the satisfaction theory of Karttunen, Stalnaker, and Heim, presuppositions are not cancelable. But we have seen already in section 9.4 that the inference that John smokes from (13) can explicitly be cancelled by the speaker.[23]

Second, Geurts and van der Sandt (2004) argue that for other sentential operators than negation, the supposed presupposition does not show the standard projection behavior. To them, at least, none of (15a)–(15c) very strongly suggests that John smokes.[24]

(15a) It is possible that only [John]$_{\mathcal{F}}$ smokes.

(15b) Did only [John]$_{\mathcal{F}}$ smoke?

(15c) If only [John]$_{\mathcal{F}}$ smokes, there is no reason to get upset.

Furthermore, the presuppositional analysis would predict that (16) is a pragmatically well-formed sentence, though Geurts and van der Sandt (2004) note that this is not the case.

(16) ?If John smokes, then only [John]$_{\mathcal{F}}$ smokes.

Finally, Horn himself (in 1996, followed by Geurts and van der Sandt (2004)) argues that the following dialogue should be quite peculiar if (13) presupposed that John smokes, because the latter is then already taken to be common knowledge. In fact, however, the dialogue seems to be perfectly ok.

(17a) Paul: Who smokes?

(17b) Paula: Only [John]$_{\mathcal{F}}$ smokes.

Abandoning the strong presuppositional view discussed above, Horn (1996) — followed by Geurts and van der Sandt (2004) — proposes, instead, that (13) gives rise to the weaker *existential presupposition* that somebody smokes. He notes that by combining this proposed presupposition of (13) with an analysis that takes the semantic meaning of (13) to be exhausted by what we have called its negative contribution, we still make the desired prediction that John smokes. Adopting

[23]One of the authors that has used this argument is Rooth (1992). He takes it to show that a sentence like (13) does not even give rise to an existential presupposition, let alone the one Horn (1969) proposed.

[24]To be honest, for us these examples *do* indicate that John smokes, but, then, Geurts and van der Sandt use some other examples where this suggestion is also for us less strong.

an existential presupposition also seems correct to account for sentences like (18).

(18) Only [men]$_{\mathcal{F}}$ smoke.

As observed by (McCawley, 1981, pg. 226) and others, this sentence seems to 'imply' only that some men smoke, not necessarily that all of them do. And this is exactly what we predict on the proposal under consideration.

Whether or not 'only' sentences come with an existential presupposition, it is easy to see that in general it cannot be the correct analysis to account for the positive contribution of a sentence 'Only ϕ'. Although the proposed analysis gives rise to pleasing predictions for examples like (13) and (18), for only slightly different examples it fails to give the desired outcome. For instance, for sentences as (19) we would like to predict the inference that John and Peter smoke.

(19) Only [John and Peter]$_{\mathcal{F}}$ smoke.

This will not come out, however, if we assume that (19) only gives rise to the existential presupposition that somebody smokes.

McCawley (1981) and Horn (1992) have claimed that the inference from (13) 'Only [John]$_{\mathcal{F}}$ smokes' that John smokes; from (19) that John and Peter smoke; from (18) that some men smoke, and from 'B, only if A' to the truth of 'If A, then B' is a conversational implicature. This is supported by the observation that these kinds of inferences pass standard tests for conversational implicature such as *'but'*-reinforcement ('Only John smokes, but he does.') and (epistemic) cancellation ('Only John smokes and perhaps even he does not'). In the remainder of this paper we want to discuss in how far such a Gricean approach to the inference can be made precise. First, we will show that the positive contribution ϕ of a sentence 'only ϕ' can be described as a result of the *exhaustive interpretation* of such a sentence. Here we will make use of a description of exhaustive interpretation proposed in van Rooij and Schulz (2004), Schulz and van Rooij (2005). In these papers it has also been argued that exhaustive interpretation itself has to be understood as a Gricean interpretation rule, based in particular on the conversational maxim of quality, the first subclause of the maxim of quantity, and an additional principle of competence maximization. We will sketch this approach here and show how in terms of it we can account for the cancellation of the inference to ϕ from 'only ϕ'.

In van Rooij and Schulz (2004), Schulz and van Rooij (2005) the following rule of exhaustive interpretation of a sentence with respect to a question predicate B has been proposed.

Definition 9.4 (Exhaustive interpretation) Let ϕ be an answer to a question with question predicate B. We define the exhaustive interpretation $[exh]^M(\phi, B)$ of ϕ with respect to background B and model M as the following proposition:

$$[exh]^M(\phi, B) = \{w \in [\phi]^M \ : \ \neg\exists v \in [\phi]^M (v <_B w)\}.$$

Under the additional assumption often defended that the background predicate of a sentence is the predicate of an implicit or explicit question the sentence answers, $[exh]$ is identical to Only. This should not come as a surprise given the often noticed similarity between exhaustive interpretation and the meaning of 'only'. However, there are important theoretical differences between the operators $[only]$, Only, and $[exh]$. Although $[exh]$ and Only describe the same interpretation function, they are complementary with respect to which part of their meaning is analyzed as semantic meaning and which part as due to pragmatic considerations. For a sentence 'Only $[\text{Peter}]_{\mathcal{F}}$ smokes' we have argued that its semantic meaning is that nobody besides Peter smokes and its pragmatic meaning that Peter smokes. Exhaustive interpretation, however, is understood in van Rooij and Schulz (2004), Schulz and van Rooij (2005) as a pragmatic interpretation function based on Gricean maxims of conversation that strengthens the semantic meaning of a sentence ϕ. The answer '$[\text{John}]_{\mathcal{F}}$ smokes' to a question 'Who smokes?' semantically conveys that John smokes and exhaustive interpretation then adds the pragmatic information that John is the only one that smokes. This difference between $[exh]$ and Only nicely reflects the opposite cancelation behavior in both cases and predicts answers 'John' and 'Only $[\text{John}]_{\mathcal{F}}$' to be non-equivalent.

It turns out that in terms of $[exh]$ we can not only account for the fact that the answer '$[\text{John}]_{\mathcal{F}}$ smokes' pragmatically implies that John is the only smoker, but also that 'Only $[\text{John}]_{\mathcal{F}}$ smokes' pragmatically conveys that John does smoke. To see this, notice that in sentences like (13), (18) and (19) the background-predicate occurs negatively, i.e., in a downward entailing context. As argued by von Stechow and Zimmermann (1984) and van Rooij and Schulz (2004), in these cases we should interpret exhaustively not with respect to background-predicate B, but rather with respect to the complement of B. Thus, we should interpret (13) as $[exh]([only](\langle \lambda P.P(john), S\rangle), \bar{S})$. In this way, we predict that the background-predicate 'Smoke' has *at most* John in its extension due to the truth-conditional meaning of (13), and *at least* John because of exhaustive interpretation.[25] By a similar reasoning we can account for the inference from (19) that John and Peter smoke, something that Geurts and van der Sandt (2004) could not.

9.6.2 The epistemic force of the implicature

In the previous section we have shown that the inference from 'Only [John and Peter]$_{\mathcal{F}}$ smoke' that John and Peter smoke can be explained as an effect of exhaustive interpretation, and we have claimed that exhaustive interpretation should be thought of as a conversational implicature. However, we have not explained yet why what follows from the exhaustive interpretation of a sentence can be taken to be a conversational implicature, nor how such an implicature can be canceled. With respect to cancelation, the most challenging aspect of our analysis of the inference from 'only ϕ' to ϕ is that we must be able to explain Atlas' (1991, 1993) asymmetry in acceptability between the following sentences:[26]

(20a) Only [Hillary]$_{\mathcal{F}}$ trusts Bill, if (even) she does/ and perhaps even she does not.

(20b) *Only [Hillary]$_{\mathcal{F}}$ trusts Bill, and (even) she does not.

As the examples show, in case of the sentence 'Only [Hillary]$_{\mathcal{F}}$ trusts Bill' it is possible to cancel the implicature that the speaker *knows* that Hillary trusts Bill — as in (20a) —, but not to cancel the inference that the speaker takes it to be *possible* that Hillary trusts Bill. Thus, the challenge we are faced with is that, although the inference might be cancelable, it is only cancelable to a certain extent.

This difference in behavior of the pragmatic information of a sentence can be taken to suggest that the pragmatic meaning splits in two parts with different cancellation behavior and maybe also different sources. Thus, one could propose that a sentence like 'Only [Hillary]$_{\mathcal{F}}$ trusts Bill' gives rise to two kinds of pragmatic inferences: one with *weak epistemic force* saying that the speaker takes it to be possible that Hillary trusts Bill, and one with *strong epistemic force* saying that the

[25] This is based on the fact that in general $[exh]([only](\langle F, B\rangle), \bar{B}) = [exh]([F(B)], B)$.

[26] These examples motivated Atlas to adopt for (13) a 'conjunctive' analysis according to which both the negative and the positive contributions discussed at the beginning of section 2 are taken to be semantically entailed by the 'only'-sentence. The examples also convinced Horn (2002) to give up his earlier analyses (Horn, 1969, 1992, 1996) of 'only' where the inference from 'Only Hillary trusts Bill' that Hillary trusts Bill is taken to be due to a presupposition or conversational implicature. One should be aware of the fact that Atlas' observations are also problematic for an approach that takes the positive contribution to be part of the semantic meaning of 'only'. Such an analysis has difficulties to account for (20a).

speaker knows that Hillary trusts Bill. The epistemic weak inference is difficult to cancel, while the inference with strong epistemic force can be suspended easily. Only the second one entails (by the veridicality of knowledge) the inference we actually want to explain: that Hillary *in fact* trusts Bill.

This fits nicely with an ongoing discussion in the literature on conversational implicatures. A complaint often heard against interpretation rules like [*exh*] has it that all we can conclude by standard Gricean reasoning from '[John]$_{\mathcal{F}}$ smokes' is that the speaker *only knows* of John that he smokes, leaving it open that he does not know of anyone other than John *that* he or she smokes. The strengthening from *not know p* to *know that not p* and further to *not p* is then mostly contributed to the extra assumption that the speaker knows who smokes. We fully agree with this intuition, and we have shown in van Rooij and Schulz (2004) how to make it precise. In this section we give a quick and somewhat informal review of this work.[27]

Here is the general idea behind the approach presented in van Rooij and Schulz (2004), Schulz and van Rooij (2005). Exhaustive interpretation can be shown to be the product of (i) taking the speaker to obey the Gricean maxim of quality and the first subclause of the maxim of quantity plus (ii) an additional assumption that the speaker is as competent on the issue under discussion as is consistent with (i). From (i) alone one obtains weak epistemic inferences of the kind that for certain claims the speaker does not know that they hold. The competence maximization in (ii) strengthens the inferences in (i) from not knowing to knowing not, hence, to inferences with strong epistemic force. The veridicality of knowledge then allows to conclude the truth of the fact. We claim that assumption (ii) on the competence of the speaker is highly context dependent and therefore easy to cancel. The first assumption on the obedience to the Gricean maxims, however, is much more robust and the inferences that follow from this assumption are therefore more difficult to cancel.[28] We will show that in this way we can account for the behavior of 'only' with respect to cancelation.

Before we can come to some technical details of the approach we have to introduce additional logical machinery. In order to take the knowledge state of speakers into account, we make use of the tools provided by modal logic. We first extend the language with one modal

[27] The work of Benjamin Spector (2003, and in this volume) is closely related, although not based on the non-monotonic theory of 'only-knowing' due to Halpern and Moses (1985) that we make use of.

[28] Though also these inferences are cancelable, i.e., when the speaker is taken to be uncooperative.

operator, $\mathbf{K}$, where $\mathbf{K}\phi$ expresses that the speaker knows that ϕ is the case. The formula of the enriched language are interpreted with respect to *pointed models* or *states* of the form $s = \langle M, w\rangle$ that also represent what the speaker knows (assuming a designated speaker). The model M is a quadruple consisting of a set of worlds W_M, a set of individuals D_M, an interpretation function $[\cdot]^M$, and a binary accessibility relation R^M on W_M. R^M is a reflexive, transitive, and symmetric accessibility relation connecting a world w with those worlds in W_M that are consistent with what the speaker knows in w. World w of $\langle M, w\rangle$ is a designated element of W that represents the actual world. Let us call the class of all states that fulfill these conditions $\mathcal{S}$. All sentences are interpreted in the standard way with respect to pointed models, where the accessibility relation is only relevant for the interpretation of sentences of the form $\mathbf{K}\phi$. As usual, such a sentence is counted as true in $\langle M, w\rangle$ if and only if ϕ is true in all worlds in W_M accessible from w according to R_M. The semantic meaning of a sentence consists as always of the set of its verifying states. Thus, we define for each sentence ϕ its semantic meaning $[\phi]^{\mathcal{S}}$ as $\{s \in \mathcal{S} \mid \phi \textit{ is true in } s\}$. Instead of '$\phi$ is true in s' we will also write $s \models \phi$.

Now we want to formalize what it means to take the speaker to obey the Gricean maxims of quality and the first subclause of the maxim of quantity. Formalizing that the speaker obeys quality is not that difficult: If our designated speaker utters ϕ, we simply assume that the actual pointed model is one that verifies $\mathbf{K}\phi$. Thus, it is one of the following: $\{s \in \mathcal{S} \mid s \models \mathbf{K}\phi\}$. To account for the first subclause of the maxim of quantity that demands speakers to convey all (relevant) information they posses, we are going to select among those states where the speaker knows her utterance to be true the states where she has least additional relevant knowledge. This is formalized by defining — as in the case of [*only*] and [*exh*] — an order on pointed models and then select minimal elements of this order. But this time the order compares the relevant knowledge of the speaker and we select minimal elements in the set $\{s \in \mathcal{S} \mid s \models \mathbf{K}\phi\}$.[29] How much relevant knowledge a speaker has is taken to be represented by how many of a class of relevant sentences she knows to hold. To define the set of relevant sentences we make the following simplifying assumption: Let the extension of background predicate B be of type $\langle f, t\rangle$. We assume that $D_{\langle s,f\rangle,\mathcal{S}}$, the set of names of objects of type $\langle s, f\rangle$ in our language, contains one and

[29] Remember that the order $\leq_B$ compares the extension of predicate B and Only/[*exh*] select minimal elements out of those worlds where the (embedded) sentence is true.

only one name for every objet of type $\langle s, f\rangle$.[30] Now, we come to the definition of the set of relevant sentences:

Definition 9.5 If the extension of the background predicate B is of type $\langle f, t\rangle$ then the following conditions hold for the set $Rel(\phi)$ of sentences relevant to $\phi = \langle F, B\rangle$:
(i) for every $e \in D_{\langle s,f\rangle,\mathcal{S}}$, $B(e)$ is in $Rel(\phi)$,
(ii) if $a, b \in Rel(\phi)$ then $a \wedge b \in Rel(\phi)$ and $a \vee b \in Rel(\phi)$,
(iii) nothing else is in $Rel(\phi)$.

According to this definition what counts as relevant is information that a certain object has the background property. If $\phi =$ '[John]$_{\mathcal{F}}$ smokes', for instance, the set $Rel(\phi)$ contains sentences like 'John smokes', 'Mary smokes' and 'Bill smokes' as well as the conjunctive and disjunctive combinations of them. This is compatible with standard theories about relevance and focus. Therefore, it is not surprising that there is a close connection between $Rel(\phi)$ and the way focus alternatives are defined, remember, for instance, our definition of $Alt(\phi)$. Now we say that the speaker has less relevant knowledge in state s than in s', $s <^{\mathbf{K}}_{Rel(\phi)} s'$, iff the set of alternative sentences known in the former state is a proper subset of the set of alternative sentences known in the latter state:

Definition 9.6 (Ordering knowledge states)
$s \leq^{\mathbf{K}}_{Rel(\phi)} s'$ iff $\{\psi \in Rel(\phi) \;:\; s \models \mathbf{K}\psi\} \subseteq \{\psi \in Rel(\phi) \;:\; s' \models \mathbf{K}\psi\}$.

We define the Gricean interpretation of ϕ as the set of minimal models where the speaker knows ϕ with respect to the set of alternatives $Rel(\phi)$.

Definition 9.7 (A Gricean Interpretation)

$$[Grice]^{\mathcal{S}}(\phi, Rel(\phi)) = \{s \in [\mathbf{K}\phi]^{\mathcal{S}} \;:\; \forall s' \in [\mathbf{K}\phi]^{\mathcal{S}} : s \leq^{\mathbf{K}}_{Rel(\phi)} s'\}.$$

According to this interpretation function, if the speaker utters '[John]$_{\mathcal{F}}$ smokes' we conclude that the speaker knows that John smokes, but not that Mary smokes, and if she utters '[John or Mary]$_{\mathcal{F}}$ smoke' we conclude that the speaker does not know of anybody that he or she

[30]This restriction is in principle not necessary. In Schulz and van Rooij (2005) you find a version of the approach that does not make use of it. But we thought that this formalization would be more intuitive to readers used to alternative semantics.

smokes. This is a nice result, but, as suggested in the previous section, in many cases we conclude something stronger: in the first example that Mary, Bill, and all the other relevant individuals *do not* smoke, and the same for the second example, except that now this is not true anymore for Mary. How do we account for this extra inference in terms of our richer modal-logical setting?

In van Rooij and Schulz (2004) we show that this can be accounted for by assuming that speakers, in addition to obeying the Gricean maxims, are *maximally competent* (as far as this is consistent with obeying these maxims). This can be described by selecting among the elements of $[Grice](\phi, Rel(\phi))$, the ones where the competence of the speaker is maximal. To account for this we need a new order that compares the competence of the speaker. This order is described in definition 9 (as usual, we define $\mathbf{P}\phi$ as $\neg\mathbf{K}\neg\phi$).

Definition 9.8 (Ordering by possibility statements)

$$s <^{\mathbf{P}}_{Rel(\phi)} s' \text{ iff } \{\psi \in Rel(\phi) : s \models \mathbf{P}\psi\} \subset \{\psi \in Rel(\phi) : s' \models \mathbf{P}\psi\}.$$

The minimal models in this ordering are those states where the speaker knows *most* about the alternatives. Now, finally, we define the function $[Grice + C](\phi, Rel(\phi))$ (C stands for competence) by selecting the minimal elements in $[Grice](\phi, Rel(\phi))$ according to the ordering $<^{\mathbf{P}}_{Rel(\phi)}$:

Definition 9.9 (Maximizing competence)

$$[Grice\ +\ C]^{\mathcal{S}}(\phi, Rel(\phi)) =$$
$$\{s \in [Grice]^{\mathcal{S}}(\phi, Rel(\phi)) : \neg\exists s' \in [Grice]^{\mathcal{S}}(\phi, Rel(\phi))(s' <^{\mathbf{P}}_{Rel(\phi)} s)\}.$$

There exists a close correspondence between our pragmatic interpretation rule $[Grice\ +\ C]$ and a simplified version of our rule of exhaustive interpretation: $[exh^*]^{\mathcal{S}}(\phi, Rel(\phi)) = \{s \in [\phi]^{\mathcal{S}} : \neg\exists s' \in [\phi]^{\mathcal{S}}(s' <^*_{Rel(\phi)} s)\}$, where $s' <^*_{Rel(\phi)} s$ iff $\{\psi \in Rel(\phi) : s' \in [\psi]^{\mathcal{S}}\} \subset \{\psi \in Rel(\phi) : s \in [\psi]^{\mathcal{S}}\}$. Under the assumption that $\forall s \in \mathcal{S}\exists s' \in [exh^*]^{\mathcal{S}}(\phi, Rel(\phi))(s' \leq^*_{Rel(\phi)} s)$ one can show that $[Grice + C]^{\mathcal{S}}(\phi, Rel(\phi)) \models \psi$ if and only if $[exh^*]^{\mathcal{S}}(\phi, Rel(\phi)) \models \psi$.[31]

One respect in which $[exh^*]$ differs from $[exh]$, is that the latter, but not the former takes a ceteris paribus condition into account as well when we compare states: the order '$<^*_{Rel(\phi)}$' used in $[exh^*]^{\mathcal{S}}(\phi)$ only compares the set of sentences in $Rel(\phi)$ that are true in the states,

[31] The proof of this claim is very similar to the one given in van Rooij and Schulz (2004).

and, thereby, information about the extension of background predicate B. For $[exh]^W(\phi)$ we use the ordering '$<_B$' that not only compares the extension of B (in a way that is very close to what $<^*_{Rel(\phi)}$ does) but also demands that the worlds agree on the interpretation of all other non-logical vocabulary. In Schulz and van Rooij (2005) we show that a *ceteri paribus* condition is needed to obtain correct predictions.[32] Fortunately, as discussed in the mentioned paper, the definitions of $[exh]$ and $[Grice\ +\ C]$ can be adapted in such a way that again for the non-modal case $[Grice\ +\ C]^{\mathcal{S}}$ comes down to $[exh]^{\mathcal{S}}$. This version has the additional advantage that it is not restricted to the propositional case. We stick here to the simplified definitions because they are sufficient to illustrate the working of the general mechanism without getting us involved in too much technical details.

From the above discussion we can conclude that as far as sentences are concerned that do not contain epistemic operators, exhaustive interpretation can be given a natural Gricean justification. For sentences that do contain modal operators the predictions made by $[Grice\ +\ C]$ differ from those of $[exh^*]$. However, it turns out that here $[Grice\ +\ C]$ improves on $[exh^*]$. We will illustrate this in a moment with some examples. Another advantage of the proposed Gricean derivation of exhaustive interpretation is that it allows us to see the pragmatic information described by exhaustive interpretation as due to two different sources. First due to taking the speaker to obey the maxims of quality and the first subclause of the maxim of quantity, and second due to the assumption that the speaker is as competent as is consistent with the first assumption. This allows us to attribute different cancellation properties to both classes of information. In particular, we will propose that the competence assumption is cancelled as soon as it conflicts with the maxims of Grice - this is already inherent in the way we defined $[Grice\ +\ C]$. For $[Grice]$ we propose that it is not that easily given up. As we will see below, this allows us, among other things, to account for Atlas' cancellation data.

What are the consequences of the proposed modal analysis of conversational implicatures for sentences involving 'only'? Let us first look at examples (10a) and (15a)–(15c) again, repeated below.

(10a) Only $[\text{John}]_{\mathcal{F}}$ smokes.

(15a) It is possible that only $[\text{John}]_{\mathcal{F}}$ smokes.

(15b) Did only $[\text{John}]_{\mathcal{F}}$ smoke?

---

[32] However, this condition should not be as strong as in $\leq_B$. The best predictions are obtained when the *ceteris paribus* condition is restricted to the non-logical vocabulary besides B that occurs in ϕ.

(15c) If only [John]$_{\mathcal{F}}$ smokes, there is no reason to get upset.

Remember that these sentences all imply that John smokes, if 'only'-sentences are taken to presuppose the truth of their embedded clauses. Though we noted in the beginning of this section that not everybody has the intuition that all these sentences strongly suggest that John smokes, we feel that in many circumstances these examples indicate at least something concerning the smoking of John, although, perhaps, not the strong inference the presuppositional analysis would predict. For (10a) used in isolation, however, this inference is uncontroversial. And indeed, we predict that (10a) conversationally implicates that John smokes. In the previous section we have assumed that a sentence of the form 'Only $(\langle F, B\rangle)$' should be interpreted pragmatically as $[exh]([only](\langle F, B\rangle), \overline{B})$, i.e. that exhaustive interpretation has to be applied to the complement of B. For the simplified formalization $[exh^*]$ of exhaustive interpretation we have discussed here and its pragmatic derivation via Grice $[Grice\ +\ C]$, this means that we have to apply them to the 'complement' of the set of relevant sentences: $\overline{Rel(\phi)} \equiv \{\neg\psi\ :\ \psi \in Rel(\phi)\}$. In other words, instead of comparing how many statements of the form 'object x has property B' are true (or does the speaker knows to be true) we now compare how many statements of the form 'object x does not have property B' are true (or does the speaker not know to be true). $[Grice]([only](\langle F, B\rangle), \overline{Rel(F(B))})$ entails — in addition to the semantic meaning of the sentence: nobody different from John smokes — that the speaker takes it to be possible that John smokes. If additionally the competence of the speaker is maximized, i.e., (10a) is pragmatically interpreted as $[Grice\ +\ C]([only](\langle F, B\rangle), \overline{Rel(F(B))})$ the interpreter infers secondary that the speaker knows that John smokes.

Also (15a) conversationally implicates that John smokes, if the speaker is taken to be competent. That is,

$$[Grice\ +\ C](\Diamond([only](\langle \lambda P.P(j), S\rangle)), \overline{Rel(\langle \lambda P.P(j), S\rangle)})$$

entails that the speaker knows that John smokes, though now she does not know (but takes it to be possible) of anybody else that he or she smokes. If we do not maximize competence, however, and pragmatically interpret (15a) just with $[Grice]$, the first prediction is lost, and we do not predict anymore that the sentence implicates that John smokes. We are not sure which of these two predictions is empirically more adequate and leave this to future research.

We make exactly the same predictions for example (15b), at least if we replace the maxim of quality for assertions (the speaker has to know that the sentence is true) by a version for questions: the speaker does not know the answer to the question he is asking. That is, the speaker can ask question (15b) appropriately only if she does not know yet whether all people besides John do not smoke, i.e., it has to be the case that the questioner takes it to be possible (i) that each individual different from John does not smoke, and (ii) that an individual different from John smokes. When applying the accordingly adapted version of [*Grice*] we predict for John and his alternatives, e.g. Mary and Bill, that the questioner does not know that they do not smoke: she takes it to be possible that John smokes, that Mary smokes, and that Bill smokes. By competence maximization we cannot strengthen the latter two to the inference that the questioner knows that Mary smokes and that Bill smokes, because that would be inconsistent with the quality maxim for questions. We *can* strengthen the inference for John, however, because that the questioner knows that John smokes is compatible with the condition that she does not know yet whether somebody different from John smokes. We take these predictions to be favorable to our analysis. However, in future work more has to be said about the rationale behind taking a questioner to be obeying the first subclause of the maxim of quantity and be maximally competent.

Our treatment of example (15c) is at first sight less encouraging. What we predict in this case depends on what we take to be the background (or the set of alternatives) with respect to which we interpret the sentence. If we assume that [*Grice*] or [$Grice + C$] scopes over the whole conditional sentence — something that seems to be quite natural from a Gricean point of view — we will not predict that (15c) implicates that John smokes. We feel, however, that at least in many cases something special is going on when part of the antecedent of a conditional sentence is focussed. These sentences are used usually as reactions to earlier assertions, particularly to the claim that (it is only) [John]$_{\mathcal{F}}$ (who) smokes. In that case, the inference that John smokes is due to the semantic, or full pragmatic meaning of this earlier assertion.[33]

Finally, and most important for us, consider the examples (20a) and (20b) again:

(20a) Only [Hillary]$_{\mathcal{F}}$ trusts Bill, if (even) she does/ and perhaps even she does not.

(20b) *Only [Hillary]$_{\mathcal{F}}$ trusts Bill, and (even) she does not.

Just as (10a) implicates via [*Grice*] that the speaker takes it to be possible that John smokes, (20a) implicates that it is consistent with

[33] We suggest that the inference to 'John smokes' from 'Not only [John]$_{\mathcal{F}}$ smokes' should be treated in a similar way.

what the speaker knows that Hillary trusts Bill. In case of (10a) the extra assumption of competence, formalized in $[Grice + C]$, strengthens the latter inference to the fact that the speaker knows that John smokes. The similar inference to the conclusion that Hillary trusts Bill does not go through for (20a). The extra information '... if she does'/'... and perhaps even she does not' is inconsistent with the assumption that the speaker is competent on whether Hilary trusts Bill. Therefore, given how $[Grice\ +\ C]$ is defined, the competence assumption is not made. Thus, we predict that the second conjunct of (20a) cancels the extra inference due to the assumption of competence.

What the second conjunct of (20b) wants to do, instead, is to cancel the inference based on the Gricean maxim of quality and his first submaxim of quantity. The fact that this gives rise to an inappropriate sentence strongly suggests that one cannot cancel inferences based on these maxims that easily. In any case, once we make this latter assumption, we can explain Atlas' (1991, 1993) asymmetry between (20a) and (20b).

9.7 Conclusion

In the first part of this paper we contrasted approaches to the meaning of 'only' that quantify over focus-alternatives with ones that quantify over background-alternatives. We argued that analyses of the first type are more problematic than usually recognized, because there is in general a misfit between the alternatives that one intuitively wants to quantify over, and what one gets by varying the focus content in a systematic and compositional way. Therefore, we vote in the end for an approach along the second line and model the meaning of 'only' by quantifying over background-alternatives. Then we argued to make a systematic distinction between the semantic and the pragmatic contribution of an 'only' sentence. More particularly, we claimed that the inference from a sentence 'Only $[\text{John}]_{\mathcal{F}}$ smokes' that nobody else smokes constitutes its semantic meaning, while the information that John smokes is pragmatically implied by the statement. We provided a minimal model analysis of the semantic part, based on Groenendijk & Stokhof's (1984) rule of exhaustive interpretation. It is shown that the resulting analysis makes some appealing predictions, especially if a notion of 'relevance' is taken into account. In the last substantial section of this paper we argued that the pragmatic inference from 'Only ϕ' to ϕ should be thought of as a conversational implicature, and we have given a precise implementation of the Gricean maxims of quality and quantity$_1$ plus an additional assumption of the competence of the speaker to account for this.

In section 6 we made crucial use of the assumption that what can pragmatically be inferred from Grice's maxims of quantity and quantity$_1$, i.e., those inferences due to [*Grice*], cannot be cancelled easily in a cooperative discourse situation. This assumption, however, might sound counterintuitive. Is it not the case that *all* pragmatic inferences can be cancelled effortlessly? For instance, we, together with many others, propose that the inference from '[John]$_{\mathcal{F}}$ smokes' to the fact that the speaker does not know that Mary smokes is due to the above mentioned Gricean maxims. It seems obvious, however, that this is an inference that can be cancelled without any trouble.

(21) Paula: [John]$_{\mathcal{F}}$ smokes. *In fact*, Mary does too.

We believe, however, that such examples do not really constitute counterexamples to our assumption. We think that (21) is appropriate only in case it is used in a context in which Mary's smoking is not at issue, for instance because Paula answered the question who of John and Bill smoke. It seems exactly the function of 'in fact' — and perhaps also of 'too' — to change, or accommodate, the topic of conversation such that Mary's smoking becomes relevant as well. This argument does not prove that our assumption is correct, although it does suggest that it is not as 'wild' as it might seem at first. Whether it makes sense in general, we have to leave to future investigations.

Acknowledgements

The authors are listed alphabetically. A short version of this paper appeared in the proceedings of Sinn und Bedeutung IX. While working on this paper, Katrin Schulz was financially supported by the NWO project 'Logic meets psychology: nonmonotonicity' and Robert van Rooij by a KNAW fellowship on 'Conversational Implicatures: rationality or convention?'.

10

Scalar Implicatures: Exhaustivity and Gricean Reasoning

Benjamin Spector

Abstract

This paper shows that both scalar implicatures and exhaustification of answers can be understood as the outcome of a pragmatic reasoning based on Gricean maxims. I offer a formalization of the Gricean reasoning that solves some of the problems (cf. Chierchia, 2002) faced by standard neo-Gricean accounts. I further show that positive and non-positive answers pattern very differently, in a way that can be predicted by stating carefully, for a given question-answer pair, what counts as an 'alternative answer' — this notion plays the same role as that of 'scalar alternative' in previous approaches. The general approach is very similar in spirit to van Rooij and Schulz (2004).

10.1 Imperfections of Standard Neo-Gricean Accounts

According to neo-Gricean accounts, scalar implicatures are computed as follows: given a sentence S containing a scalar term t, S is to be compared to all sentences which can be obtained from S by replacing t with a term belonging to t's *scale*. For any such *scalar alternative* S' such that S' asymmetrically entails S, the hearer infers that S' is not part of the speaker's beliefs. (Hereafter, rule R1; this derives the

Questions in Dynamic Semantics.
Maria Aloni, Alastair Butler and Paul Dekker (eds.).
Current Research in the Semantics/Pragmatics Interface, Vol. 17.

so-called *clausal*[1] or *primary*[2] implicatures). The underlying principle motivating this inference is Grice's first maxim of *Quantity*. Assuming further that the speaker is maximally informed, the hearer infers that S' is in fact false according to the speaker (hereafter, rule R2).

(1) A or B

(2) A and B

Suppose the speaker utters a sentence of the form of (1). Its unique scalar alternative is (2). Since (2) is logically stronger than (1), (2) is not part of the speaker's beliefs. Moreover, if the speaker is maximally informed, (2) is false, so that *or* in (1) is interpreted as exclusive, even though its literal linguistic meaning is that of inclusive disjunction.

Whatever the merits of this approach (in particular, the fact that it predicts that the exclusive reading of *or* should disappear in monotone decreasing contexts, due to the reversal of entailment patterns), it has been shown to be inaccurate in many cases, especially when a scalar term is interpreted under the scope of some operators. For instance, Chierchia (2002) points out that the neo-Gricean procedure yields too weak results for a sentence like (3):

(3) Each of the students read *Othello* or *King Lear*.

(3) (sometimes) implicates (4)[3]:

(4) Each of the students read *Othello* or *King Lear* and not both.

The neo-Gricean account predicts a much weaker implicature, namely (5):

(5) It is not the case that each of the students read *Othello* and *King Lear*.

Another problem is that the neo-Gricean account can also lead to too strong predictions. Take a sentence of the following form:

(6) (A or B) or C

Scalar alternatives of (6):

a. (A and B) or C

b. (A or B) and C

c. (A and B) and C

All these alternatives are stronger than (6), so that (6) should implicate that they are all false (by rule R2). In particular, a. should be false, in

[1] Gazdar (1979)

[2] Sauerland (2004)

[3] In section 10.3.3, I account for the fact that this inference is not systematic.

which case C is. But (6) certainly does not implicate that C is false[4]. Let me call this problem, which is actually very general, that of unwanted negations. If, on the other hand, we find a way of blocking this inference, we remain unable to predict that (6) normally implicates that only one of the three disjuncts is true.

10.1.1 Chierchia's localist solution

Chierchia (2002) presents a solution based on a recursive interpretation function which computes 'strengthened meanings' in tandem with the interpretation function that computes 'literal meanings'. For him, scalar implicatures are simply an additional dimension of meaning, and the link between scalar implicatures and general principles of conversational rationality becomes less clear, even though some basic aspects of the neo-Gricean approach are retained. Hereafter, I will defend a 'globalist' approach to scalar implicatures, in the sense that it relies on the natural hypothesis that pragmatic processes operate at least at the sentential level.

10.1.2 Sauerland (2004)

Sauerland (2004)[5] proposes a globalist approach to the puzzle of multiple disjunctions which relies on two modifications of the standard neo-Gricean account. First, he expands the set of alternatives for a given sentence, and second, he motivates a modification of the inference rules. A sentence S of the form $((A\ or\ B)\ or\ C)$ will have the following alternatives: $\{A, B, C, (A\ or\ B), (A\ or\ C), (B\ or\ C), (A\ and\ B), (A\ and\ C), (B\ and\ C), ((A\ and\ B)\ or\ C), ((A\ or\ B)\ and\ C), ((A\ and\ B)\ and\ C), ((A\ or\ B)\ or\ C)\}$. The first inference rule is meant to capture what Sauerland calls *primary implicatures*, i.e. inferences of the form "The speaker does not hold the belief that ...". For any alternative S' that asymmetrically entails S, it follows from the maxim of quantity that the speaker does not believe that S' is true. In this particular case, all the alternatives (as defined above) entail S. So we derive, among other things, the fact that the speaker does not believe A to be true, nor B nor C, and also that he does not believe $(A\ or\ B)$ to be true. Sauerland uses the following notation, borrowed from epistemic logic:

- $\neg KA, \neg KB, \neg KC, \neg K(A\ or\ B)$, etc.

[4] It has been observed long ago, for instance in Gazdar (1979), that a disjunctive statement is generally taken as indicating that the speaker is uncertain regarding the disjuncts' truth-values. Gazdar (1979) calls this kind of implicatures (i.e. inferences of the form "The speaker does not know whether p") *clausal implicatures*.

[5] A preliminary version of Sauerland's paper, though quite different from the final one, was circulated in 2002.

Next, all the logical consequences of these statements are computed. For instance, since the speaker does not know (A *or* B) to be true, and since, on the other hand, he believes ((A *or* B) *or* C) to be true (maxim of quality), it follows that he cannot know C to be false. Indeed, if he both believed C to be false and ((A *or* B) *or* C) to be true, then he would believe (A *or* B) to be true, which contradicts $\neg K$(A *or* B). Therefore $\neg K \neg C$ can be added to the set of primary implicatures. More generally, it follows that the speaker must be uncertain about the truth-value of each of the disjuncts. After all the logical consequences of primary implicatures are derived, and added to the set of primary implicatures, so-called *secondary implicatures* are computed as follows:

> If $\neg K\phi$ is a primary implicature and $\neg K \neg \phi$ has not been derived as a primary implicature or a logical consequence of primary implicatures, then infer the following: $K\neg\phi$.

In the case of multiple disjunctions, you get the intended reading by deriving first $\neg K$(A *and* B), $\neg K$(A *and* C), $\neg K$(B *and* C) and then, by using the second inference rule: $K\neg$(A *and* B), $K\neg$(A *and* C), $K\neg$(B *and* C).

A few comments on Sauerland's procedure, which is I believe basically on the right track. One question is how exactly the alternatives are defined. Sauerland needs to say that for any sentence of the form (A *or* B), the set of its alternatives is $\{A, B, (A \textit{ or } B), (A \textit{ and } B)\}$. But because he wants the relation 'being an alternative of' to be an equivalence relation (as in the standard view), he runs into the following problem: any two sentences X and Y are alternatives of each other; indeed, since (X *or* Y) is an alternative of X and of Y, X and Y are alternatives of each other (by symmetry and transitivity of the relation 'being an alternative of'). But if this were true, then no scalar implicature would ever be derived.[6] Sauerland solves this problem by an entirely *ad hoc* move: he introduces two binary connectors c_L and c_R such that (A c_L B) is equivalent to A, and (A c_R B) is equivalent to B, and then stipulates the following *scale*: $\langle or, and, c_L, c_R\rangle$. Then the alternatives of (A *or* B) are the following: $\{A\ c_L\ B, A\ c_R\ B, A \textit{ or } B, A \textit{ and } B\}$. The elements of this set are *semantically* equivalent to the previous one, but it is not the case anymore that any two sentences X and Y are alternatives of each other, even though X c_L Y and X c_R Y, which are equivalent to X and Y, are, for any X and Y. As the author notes, these

[6] If all the sentences were alternatives of each other, then no sentence could ever be interpreted as conveying more information than what it explicitly says: a speaker obeying the maxim of quantity should always choose to use a sentence whose literal meaning contains all the information he wants to express.

two connectors are actually never used — and this is accounted for by the maxim of *manner*, which says that one is supposed to be brief. Not only is this an *ad hoc* move; it is also not in accordance with the Gricean intuition that sentences are to be compared to other sentences that *could* have been uttered instead. Instead of resorting to this move, one could have simply given up the constraint that alternative sets be equivalence classes. After all, it would seem quite natural to say that A is an alternative of (A *or* B), but not the other way around, based on the plausible view that a given sentence should be compared only to sentences that are not more complex (one could interpret Grice's maxim of *manner* in this way). But this is not the solution I will advocate. Rather, I will *nearly* claim that any two sentences X and Y are alternatives of each other. More precisely, what I will claim is that any two *elementary answers* to a given question under discussion are alternatives of each other. Consider the following dialogue:

(7) Who came?
Peter came.

I define the set of *elementary answers* to the question in (7) as the set of all propositions of the form x *came*, where x ranges over the contextually given domain of quantification. The proposition that, say, *John came*, is therefore an alternative to *Peter came*. Assuming that, for any X, Y, if X and Y are alternatives, then (X *and* Y) is also an alternative, it is also the case that *John came and Peter came* is among the alternatives. This alternative asymmetrically entails the proposition expressed by the answer actually uttered. From which the hearer derives (in two steps) that the speaker believes that *John came and Peter came* is false, which, together which the fact that he believes *Peter came* to be true, entails that he believes *John came* to be false. More generally, for any individual C distinct from Peter in the quantificational domain, it follows that the speaker believes that C didn't come. What I have informally derived is the so called exhaustive interpretation of answers. My main claim in this paper is that exhaustivity can be derived from Gricean assumptions.

10.1.3 Is exhaustification the solution?

Van Rooij (2002), on the other hand, uses exhausitivity as his starting point, and claims that scalar implicatures are just a sub-case of it. He proposes to derive scalar implicatures from the fact that, if a certain question Q is under discussion and a certain sentence S is given as an answer to Q, S is generally interpreted as 'exhaustive'.

The exhaustivity operator (Groenendijk and Stokhof, 1984) operates on answers of the form $GQ\ P$, where GQ stands for a generalized quantifier and P for a predicate. The question under discussion is understood as *for which objects is P true of these objects?*. The exhaustivity (exh) operator works as follows[7]:

> $[\![exh(GQ\ P)]\!] = 1$ iff $[\![P]\!] \in Min[\![GQ]\!]$, where $Min[\![GQ]\!]$ is the set that includes only the minimal members of $[\![GQ]\!]$, i.e: $Min[\![GQ]\!] = \{x \mid x \in [\![GQ]\!]$ and there is no $x' \in [\![GQ]\!]$ such that $x' \subset x\}$ ($\subset$ = *is a proper subset of*).

Example:

a. Among John, Mary and Peter, who came?
b. John or Mary came.

$[\![\textit{John or Mary}]\!] = \{\{J, M, P\}, \{J, M\}, \{J, P\}, \{J\}, \{M, P\}, \{M\}\}$. $Min[\![\textit{John or Mary}]\!] = \{\{J\}, \{M\}\}$. $[\![exh(\textit{John or Mary came})]\!] = 1$ iff $[\![came]\!] \in \{\{J\}, \{M\}\}$ i.e. iff only John came or only Mary came. Van Rooij (2002) shows that when exhaustification is applied to monotone increasing contexts, it can solve some of Chierchia's puzzles.

10.1.4 When exactly do we exhaustify answers?

However, if exhaustification is applied to a sentence $GQ\ P$ where GQ is decreasing, exhaustification as defined above leads to unrealistic implicatures: 'less than two chemists came' should implicate that nobody came! So van Rooij uses a second exhaustivity operator (exh') in these cases, following an intuition of von Stechow and Zimmermann (1984), according to whom a negative answer gives rise to positive inferences regarding individuals that the answer does not 'talk about':

> $exh'(GQ\ P)]\!] = 1$ iff $[\![P]\!] \in (Max[\![GQ]\!])$, where $(Max[\![GQ]\!])$ is the set that includes only the maximal members of $[\![GQ]\!]$.

There are several problems with this account.

First, the second rule of exhaustification makes wrong predictions:

(8) a. Among the chemists and the philosophers, who came?
b. Less than two of the chemists

Exhaustification leads to b':

b' Exactly one chemist and all the philosophers came.

But b. does not seem to implicate b'; b. actually does indeed suggest that some chemist came, but does not implicate anything regarding

[7] I reformulate Groenendijk & Stokhof's exhaustivity operator in more simple terms, but the difference is immaterial as long as, as we assume here, the GQ that occurs in the answer to which the operator applies is semantically rigid (i.e. has the same denotation across models).

non-chemists. It rather suggests that the speaker does not know much about them[8].

Second, these two rules are unable to account for cases where the speaker combines increasing and decreasing quantifiers, thus creating a non-monotone GQ, as in (9)b[9]:

(9) a. Among the chemists, the philosophers and the linguists, who came?
b. Less than two chemists but one philosopher came

If we apply the first exhaustivity operator, what we get is that b. implicates that no chemist and no linguist came, while exactly one philosopher came. If we apply the second exhaustivity operator, what we get is that exactly one chemist, all the philosophers and all the linguists came. None of these predictions is in fact borne out. Rather, it seems that (9) implicates that at least one chemist came, exactly one philosopher came, and that the speaker does not know much about linguists.

10.1.5 Goal of this paper: deriving exhaustivity

In the next sections, I show that both scalar implicatures and exhaustification of answers can be understood as the outcome of a pragmatic reasoning that is based on the Gricean maxims. I will first offer a precise formalization of the Gricean reasoning, meant to replace the two rules R1 and R2. I will then show that it is possible to predict the facts reviewed above by defining carefully what counts as an 'alternative answer' for a given answer to a certain question under discussion[10].

10.2 Formalizing the Gricean reasoning

I now assume that a certain sentence A is uttered as an answer to a (maybe implicit) question Q, and I adopt a partition semantics for questions (Groenendijk and Stokhof, 1984): Q induces an equivalence relation R_Q, over the set of worlds.

[8]Von Stechow and Zimmermann (1984) report judgments that conflict with mine; most speakers seem to agree that no positive inference arises in the case of purely negative answers.

[9]Von Stechow and Zimmermann (1984) noticed that exhaustive readings arise with some but not all non-positive answers, those which have, in their terms, 'a negative direction of closure'.

[10]Since the first draft of this paper was written, Robert van Rooij and Katrin Schulz have also attempted to derive the exhaustivity facts from Gricean maxims, in a very similar way. See van Rooij and Schulz (2004). Van Rooij and Schulz (2004), however, do not pay close attention to non-positive answers.

Notation

wR_Qw'	w and w' belongs to the same 'cell'
$R_Q(v)$	$= \{w \mid wR_Qv\}$
	(= the set of worlds equivalent to v, or v's 'cell')
$\alpha(w)$	α is true in w (alternatively: $w \in \alpha$)
$\alpha \subseteq \beta$	α is a subset of β; α entails β
$\alpha \subset \beta$	α is a proper subset of β; α asymmetrically entails β.

The proposition α expressed by A is supposed to meet the condition of strong relevance.

Definition 10.1 (Strong Relevance) A proposition α (= set of worlds) is strongly relevant with respect to a question Q if

1. $\exists w, (R_Q(w) \cap \alpha) = \emptyset$ (i.e.: α excludes at least one cell) and
2. $\forall w, (\alpha(w) \leftrightarrow (R_Q(w) \subseteq \alpha))$ (α does not distinguish between two worlds that belong to the same cell, i.e. provides no irrelevant information).

The speaker's information state is modeled as a set of worlds, i.e. a proposition. As an agent believes a lot of things that are irrelevant in the context of a given question, it is useful to define what counts as the relevant information contained in a certain information state:

Definition 10.2 (Relevant Information) Let i be an information state and Q a question. Then we define i relativized to Q, written as i/Q, as follows:

$$i/Q = \{w \mid \exists w', (w'R_Qw \textit{ and } w' \in i)\} \; (= \textstyle\bigcup_{w \in i} R_Q(w)).$$

The Gricean reasoning is based on the idea that α (the proposition given as an answer) must be compared to a certain set of *alternative propositions*[11] which the speaker could have chosen instead of α. This **alternative set**, call it S, must contain α itself, and be such that all its members are relevant[12]. The hearer's task when interpreting the speaker's utterance is to address the following question: *given that the speaker has preferred α to all the other members of S, what does this entail regarding his information state i_0*? First, the speaker must believe α to be true (Grice's maxim of quality), i.e. i_0 must entail α. Second, α must be optimal in the sense that there must be no more informative proposition in S entailed by the speaker's beliefs (Grice's maxim of quantity), i.e. there must be no proposition α' in S such that i_0 entails

[11] As my formulation makes clear, I am now adopting the simplifying view that what the hearer compares are *propositions*.

[12] The exact definition of alternative sets is the topic of section 3.

α' and α' asymmetrically entails α. More formally:

Definition 10.3 Let Q be a question and α be a proposition that is strongly relevant with respect to Q. Then α is an **optimal answer** to Q in information state i with respect to an alternative set S if:

1. $i \subseteq \alpha$ (i.e. i entails α) and
2. $\forall \alpha'(\alpha' \in S$ *and* $i \subseteq \alpha') \rightarrow \neg(\alpha' \subset \alpha)$ (i.e. for any proposition α' belonging to S, if i entails α', then α' does not asymmetrically entails α)

Put differently, i_0, the speaker's information state, must belong to the following set $I(S, \alpha, Q)$:

Definition 10.4 $I(S, \alpha, Q) = \{i \mid \alpha$ is an optimal answer to Q in information state i with respect to $S\}$ (i.e. $I(S, \alpha, Q) = \{i \mid i \subseteq \alpha$ *and* $\forall \alpha'(\alpha' \in S$ *and* $i \subseteq \alpha') \rightarrow \neg(\alpha' \subset \alpha)\})$

So if a certain proposition β is entailed by no member of $I(S, \alpha, Q)$, the hearer can conclude that β is not part of the speaker's belief. This reasoning plays the role of rule R1. It is immediately predicted that if the speaker utters a sentence P of the form A *or* B and if the propositions expressed by A and by B belong to the alternative set S, as I will assume (so does Sauerland, 2004), then the speaker cannot know A to be either true or false: if A were true, then A would have been a better answer than P; if A were false, B would be true (since P is), and B would have been a better answer than P[13]. Now, let the hearer assume that the speaker is *as informed as possible given the answer he made*. This means that his information state i_0 is maximal in $I(S, \alpha, Q)$ in the following sense: there is no i' in $I(S, \alpha, Q)$ such that i' (relativized to Q) asymmetrically entails i_0 (relativized to Q). In other words, i_0 belongs to $Max(S, \alpha, Q)$, defined as follows:

Definition 10.5 $Max(S, \alpha, Q) = \{i \mid i \in I(S, \alpha, Q)$ *and* $\forall i'(i' \in I(S, \alpha, Q)) \rightarrow \neg(i'/Q \subset i/Q)\}$

From this the hearer can conclude that if a proposition β is entailed by all the members of $Max(S, \alpha, Q)$, then β is believed by the speaker. This reasoning plays the role of R2, but is not equivalent to it: there is no way of deriving an 'unwanted negation'. In the case of a disjunctive statement in which the disjuncts are logically independent, the disjuncts and their negations are entailed by no member of $I(S, \alpha, Q)$, as shown above, so that they cannot be entailed by any member of

[13] Assuming that A and B are logically independent.

$Max(S, \alpha, Q)$ either, since $Max(S, \alpha, Q)$ is included in $I(S, \alpha, Q)$.

From now on, whenever it is clear what the question under discussion is, and assuming that the content of an alternative set only depends on the question under discussion and the sentence uttered, I will simply write $I(\alpha)$ and $Max(\alpha)$ instead of $I(S, \alpha, Q)$ and $Max(S, \alpha, Q)$. $S(\alpha)$ will denote the alternative set of α.

10.3 Alternative sets and Exhaustification

10.3.1 An example

Let P be of the form (A *or* B) *or* C, where A, B and C are logically independent. Assume that$P$ is uttered in a context in which A, B and C's truth-values are what is relevant i.e. as an answer to a question Q amounting to *Which sentence(s) are true among A, B, and C?*

For any information state i, the relevant part of i in this context (i.e i/Q) belongs to the boolean closure of $\{A, B, C\}$. So we will loose nothing if we view information states as sets of valuations of $\{A, B, C\}$, i.e. as propositions of the propositional language based on $\{A, B, C\}$, where any such proposition actually stands for a class of propositions that are all equivalent when relativized to Q. Let $S(P)$ (the alternative set of P) be *the closure under union and intersection of* $\{(A, B, C\}$[14]. Intuitively, $S(P)$ is the *set of positive answers to* Q: $S(P) = \{A, B, C, A \vee B, A \wedge B, A \vee C, A \wedge C, B \vee C, B \wedge C, (A \vee B) \vee C, (A \wedge B) \vee C, A \vee (B \wedge C), \ldots\}$. Assume $i_0 = (((A \vee B) \vee C) \wedge (\neg(A \wedge B) \wedge (\neg(A \wedge C) \wedge (\neg(B \wedge C)))))$. Then $i_0 \in I(P)$, since P is the only — and therefore best — proposition in $S(P)$ entailed by i_0[15]; i_0 can also be described as the set of the three following valuations:

	A	B	C
W_1	T	F	F
W_2	F	T	F
W_3	F	F	T

I now show that $Max(P) = \{i_0\}$, i.e. that i_0 entails all the members of $I(P)$. Suppose i_1 is an information state that is not entailed by i_0 and that belongs to $I(P)$. There is then an element of i_0 that does not belong to i_1. Suppose W_1 does not belong to i_1. Then i_1 entails P' defined as:

[14] As the reader will have noticed, I treat sentences both as sentences of the object-language and as names (in the meta-language) of propositions, i.e. names of sets of worlds, in which case conjunction and disjunction are understood as intersection and union.

[15] I do not give the proof here, but this fact is actually a special case of the theorem 3, in the appendix. It is easy to check that $P = Pos(i_0)$ (the function Pos is defined in section 3.3.2).

$$P' = \neg(A \wedge (\neg B \wedge \neg C)) = \neg A \vee (B \vee C)$$

But i_1 belongs to $I(P)$, and therefore entails P. Hence i_1 also entails P'':

$$P'' = (((A \vee B) \vee C) \wedge (\neg A \vee (B \vee C))) = (B \vee C)$$

But P'', which belongs to $S(P)$, would have been a better answer than P in information state i_1, so that i_1 does not belong to $I(P)$, contrary to the hypothesis. Things are similar if W_2 or W_3 does not belong to i_1 (by symmetry). Hence $Max(P) = \{i_0\}$, and P implicates i_0. This proof can be generalized to all formulas whose only logical operators are disjunctions.

10.3.2 Background concepts

As shown in section 1.4., answers lead to different kinds of implicatures, especially regarding exhausitivity, depending on whether they are, intuitively speaking, positive or negative. But this cannot make sense so far, as I have not said precisely what it is for an answer to be 'positive'. This is the goal of the present section.

I now assume that wh-questions are all equivalent to something like: Q: *For which x is $P(x)$ true?*, where x is of any semantic type, and P is a certain predicate (simple or complex) that can be built in a natural language. I further assume that the domain of quantification is fixed and finite, and known to all participants. Thus any relevant answer to Q can be translated into the following propositional language L_Q: let $(c_i)_{0<i<n+1}$ be an enumeration of names for each of the individuals of the domain. Then L_Q is the propositional language with disjunction and conjunction as its only binary connectors and based on the atomic sentences $(P_i)_{0<i<n+1}$, where P_i translates $P(c_i)$.

Now, relevant answers to Q can be seen as sets of valuations of $(P_i)_{0<i<n+1}$. And the relevant part of any information state can also be seen as a set of valuations. So we can assimilate information states to sets of valuations, without loosing anything.

Definition 10.6

1. **Literal**: a **literal** is an atomic sentence or the negation of an atomic sentence. A literal is **positive** if it is an atomic sentence, **negative** otherwise
2. **Sentence P *favors* literal** L[16]: a sentence or a proposition P

[16] The intuitive notion that this definition aims at capturing is the following; in a certain sense, a sentence like *Peter or Mary came*, as well as *Peter and Mary came*, is 'about' Peter and about Mary, and provides us with some positive information regarding them (in our terms, it *favors* the sentence *Peter came* and the

favors a literal L iff there is a valuation V such that $V(P) = V(L) = 1$ and $V_{-L}(P) = 0$, where V_{-L} is defined as the valuation which is identical to V except for the value it assigns to L.

3. **Sentence** P ***essentially mentions*** **literal** L: A sentence P essentially mentions a literal L iff L occurs without a negation preceding it in every P' equivalent to P and such that the scope of all negations occurring in P' is an atomic sentence.
4. **Positive sentence/positive proposition**: a sentence or a proposition is positive (resp. negative) iff it favors at least one positive (resp. negative) literal and no negative (resp. positive) literal.

We can then prove the following theorems (see Appendix):

Theorem 10.1 For any sentence P and any literal L, P favors L if and only if P essentially mentions L.

Theorem 10.2 A sentence P is positive (resp. negative) if and only if P is equivalent to a sentence which belongs to the closure of positive (resp. negative) literals under conjunction and disjunction.

Corollary 10.1 A sentence P is positive iff it is equivalent to a sentence P' which contains no negation.

We therefore have two characterizations of positive answers: an answer is positive if it is equivalent to a sentence which contains no negation, or, equivalently, if it favors at least one positive literal and no negative literal. This equivalence will prove helpful.

10.3.3 The case of positive propositions: predicting exhaustification

The alternative set of any positive proposition is defined as the set of all positive propositions[17].

sentence *Mary came*, but not their negations -recall that we treat such sentences as atomic sentences, when uttered as an answer to 'Who came?'). Von Stechow and Zimmermann (1984) defined a notion of 'aboutness' that aims at capturing the same intuition (or so it seems to me); but their notion of 'aboutness' and my notion of 'favouring' are however quite different; first, 'aboutness' is defined as a relation between generalized quantifiers and individuals; second, while, for instance, 'Peter and Mary' is *positively about* Peter (and Mary as well), 'Peter or Mary' is, according to their definition, about nothing.

[17] It should be clear that the alternative set is dependent on the question under discussion, since 'positivity' is defined in terms of the propositional language derived from the question under discussion via the translation procedure defined above.

An Other Example

Consider the following dialogue:

(10) Among John, Peter, Mary and Sue, who will come?
Well, John will come, or Peter and Mary will come.

I translate the answer into a propositional language containing four atomic sentences A, B, C and D:

$$P = A \vee (B \wedge C)$$

P clearly implicates Q: $Q = (A \wedge \neg B \wedge \neg C \wedge \neg D) \vee (B \wedge C \wedge \neg A \wedge \neg D)$ i.e. *either only John will come, or only Peter and Mary will*, which is exactly what exhaustification in Groenendijk & Stokhof's sense would yield. What I will now prove is that $Max(P) = \{Q\}$, from which it indeed follows that P implicates Q.

First, I show that $Q \in I(P)$, i.e. P is an optimal answer in $S(P)$ in information state Q. Suppose the speaker's information state is Q. Q can be represented as the following set of valuations, where a valuation is itself represented as the set of atomic sentences that this valuation makes true: $Q = \{\{A\}, \{B, C\}\}$. By hypothesis, the speaker has to choose a proposition that belongs to the alternative set. This proposition must be entailed by Q and be such that there is no better proposition in the alternative set. Let Q' be a positive sentence entailed by Q. Necessarily the valuation represented by $\{A\}$ is in Q'. But then, the valuation $\{A, B\}$ must be in Q' too: if $\{A, B\}$ were not in Q', indeed, $\neg B$ would be favored by Q', since there would be a valuation v making $\neg B$ true in Q' (namely $v = \{A\}$) and such that the valuation v' identical to v except over B ($v' = \{A, B\}$) would not be in Q'; so Q' would favor a negative literal and not be positive, contrary to the hypothesis. By the same reasoning, $\{A, C\}$, $\{A, D\}$, $\{A, B, C\}$, $\{A, B, D\}$, $\{A, C, D\}$ and $\{A, B, C, D\}$ must belong to Q', and so does $\{B, C, D\}$ (since $\{B, C\}$ is in Q and therefore in Q'). So any positive proposition entailed by Q must include the following proposition, i.e. be entailed by it:

- $\{\ \{A\},\ \{A, B\},\ \{A, C\},\ \{A, D\},\ \{A, B, C\},\ \{A, B, D\},\ \{A, C, D\},\ \{A, B, C, D\},\ \{B, C\},\ \{B, C, D\}\ \}\quad (= P)$

But this set, which turns out to represent P, is a positive proposition which is entailed by Q and which entails all other positive propositions that are entailed by Q (as I have just shown). So P is the strongest positive proposition entailed by Q, i.e. $Q \in I(P)$ (recall that $I(P)$ is the set of all information states which make P an optimal answer among positive answers).

Second, I show that $Max(P) = \{Q\}$. This amounts to proving that Q entails all the members of $I(P)$. Assume there is an information state i which belongs to $I(P)$ and is not entailed by Q. Since i is not entailed by Q, then either $\{A\}$ or $\{B, C\}$ does not belong to i. Suppose $\{A\}$ does not belong to i. On the other hand, i belongs to $I(P)$ and therefore entails P. From which it follows that i entails $P - \{A\}$, i.e. i is included in the following set of valuations:

- $P - \{A\} = \{ \{A, B\}, \{A, C\}, \{A, D\}, \{A, B, C\}, \{A, B, D\},$
$\{A, C, D\}, \{A, B, C, D\}, \{B, C\}, \{B, C, D\} \}$

But this set is itself a positive proposition, since it can be checked that $P - \{A\}$ favors no negative literal. In fact, $P - \{A\}$ can be written as: $(A \wedge (B \vee C \vee D)) \vee (B \vee C)$. So i entails a positive proposition that is stronger than P, namely $P - \{A\}$, which contradicts the hypothesis that i belongs to $I(P)$. Things work similarly if $\{B, C\}$ does not belong to i. Therefore there is no such i. From which it follows that Q entails all the members of $I(P)$. QED

Predicting exhaustification

In the general case, positive answers are predicted to be interpreted as exhaustive (see also the appendix).

Definition 10.7 (Exhaustification) Let P be any non-negative proposition, then the function *Exhaust* is defined as follows: $Exhaust(P) = \{V \mid V \in P$ and there is no valuation V' in P such that $V' \subset V\}$

This operator is the propositional counterpart of Groenendijk & Stokhof's exhaustivity operator.

Definition 10.8 (Positive extension of a proposition P) For any non negative proposition P, there is a unique positive proposition Q such that P entails Q and Q entails all the other positive propositions that P entails (i.e. Q is **the strongest positive proposition that** P **entails**).

This can be shown by using the same reasoning as in the previous section: namely, you get Q by adding to P all the valuations that are needed in order not to favor any negative literal (see the appendix). The result of this operation I call the *Positive Extension of* P, or $Pos(P)$. For any P, $Pos(P) = \{V \mid$ there is a valuation V' in P such that $V' \subseteq V\}$ (recall that a valuation is seen as a set of atomic sentences).

Fact 10.1 (proved in the appendix) For any non negative proposition P,

1. If P is positive, $Pos(P) = P$
2. $Pos(Exhaust(P)) = Pos(P)$
3. If P is a positive proposition and V a minimal member of P, then $P - \{V\}$ is a positive proposition too.

Theorem 10.3
If P is a positive proposition, then $Max(P) = \{Exhaust(P)\}$, and therefore P implicates $Exhaust(P)$.
Proof: We prove a) that $Exhaust(P) \in Max(P)$, and b) that $ExhaustP$ is the only member of $Max(P)$.

a) Let P be a positive proposition. $I(P)$ is the set of states i making P an optimal answer, i.e. such that P is the strongest positive proposition entailed by i, i.e. such that $P = Pos(i)$. Hence $I(P) = \{i \mid Pos(i) = P\}$. Since $Pos(Exhaust(P)) = Pos(P) = P$ (by facts 1 and 2), $Exhaust(P) \in I(P)$.

b) *Ad absurdum*: we want to show that $Exhaust(P)$ entails all the other members of $I(P)$. Let's assume, to the contrary, that there is a member i_1 of $I(P)$ such that $Exhaust(P)$ does not entail i_1. Then there is a valuation in $Exhaust(P)$ which does not belong to i_1, call it V. Given that i_1 entails P, i_1 also entails $P - \{V\}$. Since V, belonging to $Exhaust(P)$, is a minimal member of P, $P - \{V\}$ is positive (by fact 3), and $P - \{V\}$ is therefore a positive proposition entailed by i_1, from which it follows that P cannot be the strongest positive proposition entailed by i_1, i.e. $P \neq Pos(i_1)$. Therefore i_1 does not belong to $I(P)$, contrary to the hypothesis. QED.

Pair-list questions

Consider sentence (3) again

(3) Each of the students read *Othello* or *King Lear*.

If (3) is understood as an answer to a pair-list question like *Which students read which plays by Shakespeare?*, exhaustification predicts an exclusive reading for *or*. Note that the translation of a certain natural language sentence into a sentence of propositional logic will yield different results for different underlying questions (see section 3.2.). In the case of the above pair-list question, but not in other cases, atomic sentences represent elementary answers of the type *x read y*, and (3) will be translated as something like (3'):

(3′) $(A \vee B) \wedge (C \vee D) \wedge (E \vee F) \wedge \ \ldots \wedge (G \vee H)$

Exhaustification of (3') yields the desired result (exclusive reading for all the disjunctions). This context-dependency explains why judgments are not uniform.

10.3.4 Non-positive propositions

We have seen in 1.4. that negative answers are not exhaustified, but nevertheless trigger some implicatures. This is straightforwardly predicted if the alternative set of a negative proposition P consists in the closure under disjunction and conjunction of all the literals that P favors. The asymmetry between negative and positive answers then boils down to the fact that positive answers are compared to all positive answers, while negative answers are compared only to a proper subset of the negative answers.

Regarding answers that are neither positive nor negative, the data are quite complex, and judgments are not very robust. A good strategy is to look at the clearest cases, find which principles could account for them and then let these principles decide for the other cases:

(11) a. Among Peter, Mary and Jack, who came?
b. Peter, but not Mary

$\gg$ No exhaustivity effect: we infer nothing regarding Jack.

(12) a. Among the philosophers, the linguists and the chemists, who came?
b. Between two and five linguists

$\gg$ Exhaustivity effect: we infer that no chemist and no philosopher came. One difference between (11) and (12) is that, even though both are neither positive nor negative, (12) is quasi-positive in the following sense:

- A proposition P **strongly favors** a literal L if P favors L and P does not favor the negation of L.
- A proposition P is **quasi-positive** if P does not strongly favor any negative literal.

If we want to predict that only quasi-positive sentences lead to exhaustification, we may adopt the two following rules, which cover all the cases:

- If P is quasi-positive, P's alternative set consists in the union of the set of positive propositions and $\{P\}$ itself.
- If P is not quasi-positive, then P's alternative set consists in the closure under union and intersection of all the literals that P favors.

These rules make the following predictions (assuming the question under discussion is the same as in (12)):

(13) Between two and five linguists and no philosopher came.

$\gg$ No exhaustivity effect: nothing should be implicated regarding chemists.

(14) Between two and five linguists and three philosophers came.

$\gg$ Exhaustivity effect: suggests that no chemist came.

(15) Three philosophers but less than two chemists came.

$\gg$ No-exhaustivity effect: nothing should be inferred regarding linguists. Though judgments are not so clear, an informal inquiry seems to indicate that most people have the expected intuitions. More work needs to be done in order to understand what is really going on here[18].

10.4 Conclusion

I have offered a precise formalization of the Gricean reasoning that underlies scalar implicatures, and exhaustification of answers. I have shown that the facts regarding exhaustification can be directly derived from the Gricean reasoning[19]. The only stipulations that were needed concern the rules according to which alternative sets are built. Yet the original notion of 'scalar alternatives' is also stipulative. It remains to be seen whether the role played by polarity (namely, the distinction between positive and non-positive answers) can be derived in a more principled way. It is also necessary to generalize the results achieved here, in particular in order to treat cases where the domain of quantification is not finite nor mutually known. van Rooij and Schulz (2004), which implements, among many other things, some of the ideas presented here in a very general setting, can provide a basis for such investigations.

Finally, let me point out that while the procedure I have defined is context-dependent (since implicature computation depends on what the question under discussion is), it is possible to devise a very similar procedure that would not be context-dependent. These two procedures, taken together, can provide us with an analytic tool for investigating to what extent scalar implicatures are *generalized* rather than extremely sensitive to context.

[18] I do not give the proof that my two rules achieve the results I claim they do, due to lack of space.

[19] As an anonymous reviewer noticed, I have not addressed all the cases that Chierchia pointed out as problematic for the standard neo-Gricean procedure. Once again, limitation of space prevents me from doing so. Let me mention that a more sophisticated version of my proposal is able to predict the phenomenon of conditional perfection (inference from *If A, then B* to *B if and only if A*).

Acknowledgements

This paper is a revised version of a paper presented at the ESSLLI 2003 student session and at the DIP-colloquium of the Institute of Logic, Language and Computation of Amsterdam in February 2003.

10.5 Appendix

10.5.1 Language

Let L be the following propositional language:

Vocabulary

(i) Atoms: $p_1, p_2, \ldots, p_n$. (N.B.: there is a finite number of atoms.)[20]

(ii) $\bot, \top, (,), [,], \neg, \wedge, \vee$.

Syntax

(i) If p is an atom, then $[p]$ and $[\neg p]$ are a literal; $\bot$, $\top$ are literals.

(ii) If L is a literal, then L is a formula.

(iii) For any two formulae F and G, $(F \vee G)$ and $(F \wedge G)$ are formulae.

Terminology: A positive literal is a literal of the form $[p]$; a negative literal is a literal of the form $[\neg p]$; $\bot$ and $\top$ are neither positive nor negative.
Notation: Let L be a literal whose atom is p. Then $-L$ (the negation of L) is defined as follows: $-L = [\neg p]$ if $L = [p]$ and $-L = [p]$ if $L = [\neg p]$.

Semantics

A valuation V is a function from all formulae to $\{0, 1\}$ such that:

1. $V(\bot) = 0$
2. $V(\top) = 1$
3. For any atom p, $V([\neg p]) = 1 - V([p])$
4. For any formulas F and G, $V((F \vee G)) = max(V(F), V(G))$
5. For any formulas F and G, $V((F \wedge G)) = min(V(F), V(G))$

A valuation is uniquely defined by the values it assigns to the positive literals. Hereafter, we treat valuations as functions from atoms to $\{0, 1\}$.

[20] This limitation on the cardinality of the set of atoms proves to be essential for some of the proofs below to go through; since atoms represent elementary answers of the form $P(x)$, where P is the question-predicate, this restriction amounts to constraining the mutually known domain of quantification to be finite.

10.5.2 Definitions

Definition 10.5.1 For any valuation V and any literal L distinct from $\perp$ and $\top$, we define V_{-L} as the unique valuation that is exactly like V except over the atom of L:

- For any atom p not occurring in L, $V_{-L}([p]) = V([p])$
- $V_{-L}(L) = 1 - V(L)$ $(= V(-L))$

Definition 10.5.2 (Favoring) Let F be a formula and L be a literal distinct from $\perp, \top$. Then F *favors* L if there exists a valuation V such that $V(F) = V(L) = 1$ and such that $V_{-L}(F) = 0$.

Definition 10.5.3 (Essentially Mentions) Let F be a formula and L be a literal distinct from $\perp$ and $\top$; then F essentially mentions L if L occurs in every formula F' equivalent to F.

Terminological note: hereafter, I use the term 'proposition' as referring to the semantic ojects associated with formulae, i.e. sets of valuations (or characteristic functions thereof). I often refer to a proposition by using a formula that expresses it. For instance, when I say that a proposition is 'distinct from $\perp$', I mean the proposition in question is not the contradiction. It is obvious from the definitions that a formula F favors a literal L if and only if any formula F' equivalent to F favors L; in this case, I also say that the proposition expressed by F favors L.

Definition 10.5.4 (Positive Proposition) A positive proposition is a proposition that favors no negative literal and is neither the tautology nor the contradiction (i.e. is distinct from $\perp$ and $\top$).

10.5.3 Theorems

Theorem 10.5.1 For any formula F and any literal L distinct from $\perp$ and $\top$, F essentially mentions L if and only if F favors L, and there exists a formula F' equivalent to F in which all the literals that F favors occur, and only those.

The proof relies on three lemmas.

Lemma 10.5.1 If F favors L, then F essentially mentions L[21].

Sublemma 10.5.1 If F favors L then L occurs in F (equivalently: if L does not occur in F, then F does not favor L).

[21] Paul Egré contributed to the proof of this lemma.

Proof of sublemma 10.5.1. Let L be a literal. We prove by induction that for any formula F, if F favors L, then L occurs in F.

1. Suppose F is itself a literal. If F is distinct from L, then F does not favor L. (In particular, if $F = -L$, then F does not favor L). Therefore, if F favors L, then $F = L$, and L occurs in F.
2. Suppose F and G are formulae such that if F favors L, then L occurs in F and if G favors L, then L occurs in G. We prove that if $F \vee G$ favors L, then L occurs in $F \vee G$, and that if $F \wedge G$ favors L, then L occurs in $F \wedge G$.

- Assume $(F \wedge G)$ favors L. Then there exists a valuation V such that $V((F \wedge G)) = V(L) = 1$ and $V_{-L}((F \wedge G)) = 0$, i.e. $min((V(F), V(G)) = V(L) = 1$ and $min((V_{-L}(F), V_{-L}(G)) = 0$. From which it follows that $V(F) = V(G) = V(L) = 1$ and either $V_{-L}(F) = 0$ or $V_{-L}(G) = 0$. Therefore F favors L or G favors L. Therefore L occurs in F or in G, hence in $(F \wedge G)$.
- Assume $(F \vee G)$ favors L. Then there exists a valuation V such that $V((F \vee G)) = V(L) = 1$ and $V_{-L}((F \vee G)) = 0$, i.e. $max((V(F), V(G)) = V(L) = 1$ and $max((V_{-L}(F), V_{-L}(G)) = 0$. From which it follows that $V_{-L}(F) = V_{-L}(G) = 0$ and either $V(F) = V(L) = 1$ or $V(G) = V(L) = 1$, i.e. F favors L or G favors L. Therefore L occurs in F or in G, hence in $(F \vee G)$.

Proof of lemma 10.5.1. Let F be a formula and L be a literal that F favors. Suppose F' is a formula that is equivalent to F. Then F' favors L, and therefore L occurs in F' (sublemma 10.5.1). Therefore if F favors L, then F essentially mentions L. QED

Lemma 10.5.2 For any formula F, there exists a formula F' equivalent to F in which the only literals that occur are those favored by F.

Proof of lemma 10.5.2. We consider two cases:

1. F is a tautology or a contradiction. Then F favors no literal at all and is equivalent either to $\perp$ or to $\top$, which are formulae in which the only literals that occur are those favored by F (in that case, no literal at all is favored by F).
2. F is contingent. We will construct, in two steps, a disjunctive normal form F' equivalent to F in which only the literals favored by F occur.

Let me first show that if two valuations V_1 and V_2 give exactly the same values to all the literals favored by F, then $V_1(F) = V_2(F)$. Suppose this is not the case, i.e., for instance, $V_1(F) = 0$ and $V_2(F) = 1$.

Let $\{M_1, \ldots, M_N\}$ be the set of positive literals on which V_1 and V_2 disagree (by assumption, they agree on those favored by F). Then $V_{2(-M_1 \ldots -M_N)}(F) = 0$, since $V_{2(-M_1 \ldots -M_N)} = V_1$[22]. Consider the first integer i such that $V_{2(-M_1-M_2 \ldots -M_i)}(F) = 0$. Since

$$V_{2(-M_1-M_2 \ldots -M_{(i-1)})}(F) = 1 \text{ and}$$
$$V_{2(-M_1-M_2 \ldots -M_i)} = V_{2(-M_1-M_2 \ldots -M_{(i-1)})-Mi},$$

F favors M_i, contrary to the hypothesis that M_i is not favored by F.

Let us say that two valuations V_1 and V_2 are F-*equivalent* if: $V_1(F) = V_2(F) = 1$ and for any literal L favored by F, $V_1(L) = V_2(L)$. This equivalence relation defines a partition over the set of the valuations making F true. Each equivalence class can be represented by a partial valuation V_i that gives a value only to the atoms occurring in the literals favored by F. Let us consider the set $E = \{V_1, \ldots, V_n\}$ consisting of all these partial valuations. Let $K = \{L_1, \ldots, L_m\}$ be the set of the literals favored by F. To each partial valuation V_i, I associate the conjunctive formula D_i defined as follows: for each member L of K, L occurs in D_i iff $V_i(L) = 1$ and $-L$ occurs in D_i iff $V_i(L) = 0$. We define G as $D_1 \vee \ldots \vee D_n$. G is a normal disjunctive form in which the only literals that occur are literals favored by F or negations of literals favored by F. I prove a) that G is equivalent to F, and b) that there exists a formula F' equivalent to G in which the only literals that occur are those favored by F.

a) i) F entails G. Let V be such that $V(F) = 1$, and let V_i be the partial valuation that represents V's equivalence class; let D_i be the conjunctive formula that is associated to V_i as explained above. By construction, V_i makes D_i true and therefore also makes G true, and $V(G) = V_i(G) = 1$.
ii) G entails F. Let V be such that $V(G) = 1$. Then necessarily there is a conjunctive sub-formula of G, call it D_i, such that $V(D_i) = 1$. Let V_i be the partial valuation corresponding to D_i. Since D_i is a conjunctive formula, V must make true all the literals that occur in it, and therefore agrees with V_i on all the members of K; Since any two valuations that give the same values to the members of K also give the same value to F, V belongs to the equivalence class represented by V_i, and therefore $V(F) = 1$.

b) There is a formula F' equivalent to G in which the only literals that occur are those favored by F. I show that it is possible to eliminate from G all the literals that do not belong to K. Recall

[22] $V_{2(-M_1-M_2 \ldots -M_N)}$ is defined as the valuation identical to V_1 except over $\{M_1, \ldots, M_N\}$

that all the literals that occur in G are already either members of K or negations of members of K. Let us consider a disjunct D that occurs in G. Let $-L$ be the negation of a member of K that occurs in D. D is then equivalent to a formula of the form $R \wedge -L$ (where R is a conjunction that contains all the other literals occurring in D). If $-L$ is itself a member of K, then there is no need to eliminate it. If $-L$ is not a member of K, then there exists a disjunct D' occurring in D that is equivalent to $R \wedge L$: indeed, let V be a valuation such that $V(D) = 1$. In particular, we have $V(-L) = 1$ and $V(R) = 1$; since G does not favor $-L$, $V_{-L}(F) = 1$ and there is therefore a disjunct occurring in G that represents the equivalence class to which V_{-L} belongs, and this disjunct is necessarily equivalent to $R \wedge L$. Since $(R \wedge -L) \vee (R \wedge L)$ is equivalent to R, $-L$ can be eliminated. This procedure can be repeated for each literal in D that does not belong to K, and then for each disjunct in G. QED.

Lemma 10.5.3 For any formula F and any literal L distinct from $\perp$ and $\top$, F favors L if and only if F essentially mentions L:

- if F favors L, then F essentially mentions L (Lemma 10.5.1)
- If F essentially mentions L, then F favors L.

By contraposition: let me prove that if F does not favor L, then F does not essentially mention L. Suppose F does not favor L. Let F' be a formula equivalent to F in which only the literals favored by F occur (such a formula exists by Lemma 10.5.2). Then L does not occur in F', and therefore F does not essentially mention L. QED

Proof of theorem 10.5.1. Theorem 10.5.1 follows from Lemma 10.5.1, Lemma 10.5.2 and Lemma 10.5.3. QED

Theorem 10.5.2 If F favors only positive literals, then there exists a formula F' equivalent to F that contains no negation.

Proof. Obvious from theorem 10.5.1.

Theorem 10.5.2 amounts to saying that any positive proposition can be expressed by a formula that contains no negation. Conversely, any formula that contains no negation and in which neither $\perp$ nor $\top$ occurs expresses a positive proposition.

Theorem 10.5.3 For any non negative-proposition P, there is a unique positive proposition Q such that P entails Q and Q entails all the other positive propositions that P entails (i.e. Q is the strongest positive proposition that P entails). The proposition Q in question is provably equivalent to the *positive extension of* P, noted $Pos(P)$, as defined a few lines below.

We now represent a valuation as the set of atoms it makes true. (A valuation defined as a function from atoms to truth-values is simply the characteristic function of a set of atoms.) Propositions are sets of valuations, i.e. sets of sets of atoms. We will show that for any non-negative P, $Pos(P)$ as defined below is the unique positive proposition that P entails and that entails all the other positive propositions entailed by P.

Definition 10.5.5 (Positive extension of a non-negative proposition) For any non-negative proposition P, $Pos(P) = \{V \mid V$ is a valuation such that there exists $V' \in P$ such that $V' \subseteq V\}$ (i.e. $Pos(P)$ is the set that contains all the supersets of the members of P).

Lemma 10.5.4 For any positive proposition Q, if a valuation V belongs to Q, then any superset V' of V belongs to Q.

Proof of lemma 10.5.4. Let Q be a positive proposition, and V be a member of Q. We first show that for any atom p that is not a member of V, $V \cup \{p\}$ belongs to Q. Suppose $V \cup \{p\}$ does not belong to Q. Then V is a valuation making both Q and $[\neg p]$ true and such that $V_{-[\neg p]}$, i.e. $V \cup \{p\}$, makes Q false. Therefore Q favors a negative literal, namely $[\neg p]$, contrary to the hypothesis. Hence for any valuation V belonging to Q, every valuation V' obtained from V by adding one atom to V is also in Q. By repeating the same reasoning to all the valuations obtained from V by adding one atom, we conclude that any valuation V'' obtained from V by adding two atoms is also in Q, and so on for valuations obtained from V by adding a finite number of atoms. Since valuations are finite sets, it follows that all the supersets of V are in Q. QED

Proof of theorem 10.5.3. Let P be a non-negative proposition. Recall that P is viewed as a set of valuations. Let $Pos(P) = \{V \mid$ there exists $V' \in P$ such that $V' \subseteq V\}$. In other terms $Pos(P)$ is the set consisting of all the supersets of the members of P. We prove that $Pos(P)$ is the unique positive proposition entailed by P and entailing all the propositions entailed by P. Keep in mind that 'A entails B' now means the same as 'A is included in B'.

We show that a) P entails $Pos(P)$, b) $Pos(P)$ is a positive proposition, and c) $Pos(P)$ entails all the positive propositions entailed by P.

a) P entails $Pos(P)$. Obvious from the definition of $Pos(P)$.

b) $Pos(P)$ is a positive proposition. i) If a valuation V belongs to $Pos(P)$, then any superset of V belongs to $Pos(P)$. Indeed, if V belongs to $Pos(P)$, then V is a superset of some member of P, call it A, and any superset of V is also a superset of A, and hence belongs to $Pos(P)$, by definition. ii) Ad absurdum: Suppose $Pos(P)$ favors a negative literal $L = [\neg p]$. Then $Pos(P)$ contains a valuation V such that V makes L true, i.e. such that p does not belong to V, and such that V_{-L} does not belong to P. But V_{-L} is the valuation identical to V except over p, i.e. $V_{-L} = V \cup \{p\}$. V_{-L} is therefore a superset of V, and thus also belongs to $Pos(P)$, given i). $\gg$ contradiction.

c) $Pos(P)$ entails all the positive propositions entailed by P. Suppose Q is a positive proposition entailed by P, i.e. such that P is included in Q. By Lemma 10.5.4 and the fact that P entails Q, all the supersets of the valuations belonging to P also belong to Q. Since all the elements of $Pos(P)$ are supersets of the elements of P, they all belong to Q. QED

Definition 10.5.6 (Exhaustification) The function *Exhaust* is defined as follows: for any non-negative proposition P, $Exhaust(P) = \{V \mid V \in P$ and for any valuation V' in P, if $V' \subseteq V$, then $V' = V\}$.

In other words, $Exhaust(P)$ is the set of all the minimal members of P (where minimal is defined w.r.t. the ordering relation $\subseteq$).

At last we prove the following three facts for any non-negative P:

Fact 10.5.1 If P is positive, $Pos(P) = P$.

Proof. Obvious: if P is positive, then P is the strongest positive proposition entailed by P.

Fact 10.5.2 $Pos(Exhaust(P)) = Pos(P)$.

Proof. We first prove the following lemma:

Lemma 10.5.5 Any member V of P is a superset of some member of $Exhaust(P)$.

Ad absurdum: Suppose that there is a valuation V_1 in P that is not a superset of a member of $Exhaust(P)$. Then V_1 does not belong to $Exhaust(P)$, and there is therefore (by definition of *Exhaust*) a valuation V_2 that is properly included in V_1 and belongs to P. But this valuation itself is not a member of $Exhaust(P)$ (otherwise V_1 would in fact be a superset of a member of $Exhaust(P)$). Consequently, there is a valuation V_3 properly included in V_2 that is a member of P but not of *Exhaust*(P). By iteration of this reasoning, there is an infinite sequence $(V_i)_{i\in N}$ such that each of the members of the sequence is properly included in its predecessor and all of them belong to P. Since valuations are finite sets, however, there is an integer n such that V_n is the empty set (since each valuation has strictly less members than its predecessors); but then V_{n+1} cannot be properly included in V_n, which is contradictory. QED

To prove fact 10.5.2, we prove first that a) $Pos(Exhaust(P)) \subseteq Pos(P)$ and b) that $Pos(P) \subseteq Pos(Exhaust(P))$

a) $Pos(Exhaust(P)) \subseteq Pos(P)$. Let V be a member of $Pos($ $Exhaust(P))$. Then V is a superset of some member of *Exhaust*(P). Call V' this member of *Exhaust*(P). Since $Exhaust(P) \subseteq P$, V' is also a member of P and therefore V is a superset of a member of P. Consequently, $V \in Pos(P)$. QED

b) $Pos(P) \subseteq Pos(Exhaust(P))$. Let V be a member of $Pos(P)$. Then there is a V' in P such that $V' \subseteq V$. By Lemma 10.5.5, there is a valuation V'' in *Exhaust*(P) such that V' is a superset of V''. Therefore V' belongs to $Pos(Exhaust(P))$. Since V is a superset of V', by lemma 10.5.4, V also belongs to Pos(*Exhaust*(P)). QED

Fact 10.5.3 If P is a positive proposition and V a minimal member of P, then $P - \{V\}$ is a positive proposition.

Proof. Let P be a positive proposition and V be a minimal member of P, i.e. $V \in Exhaust(P)$. We prove that $P - \{V\} = Pos(P - \{V\})$, from which it follows that $P - \{V\}$ is positive.

Assume $V_1 \in P - \{V\}$. Then $V_1 \in P$, and, by Lemma 10.5.4 and the fact that P is positive, any superset of V_1 also belongs to P. Let V_2 be a superset of V_1 (which therefore belongs to P). We show that $V_2 \in P - \{V\}$. We consider two cases:

i) $V_2 = V_1$. Then $V_2 \in P - \{V\}$.

ii) V_1 is properly included in V_2. Then necessarily $V_2 \neq V$; indeed, if $V_2 = V$, then V would not be a minimal member of P, since V_1 would be a proper subset of V belonging to P. Since $V_2 \neq V$ and $V_2 \in P$, it is also the case that $V_2 \in P - \{V\}$.

Therefore any valuation V_1 belonging to $P - \{V\}$ is such that all its supersets also belong to $P - \{V\}$, i.e. $Pos(P - \{V\}) \subseteq P - \{V\}$; since $P - \{V\} \subseteq Pos(P - \{V\})$, $P - \{V\} = Pos(P - \{V\})$. QED

Part IV

Intonation and Syntax

11

Nuclear Accent, Focus, and Bidirectional OT

Maria Aloni, Alastair Butler and Darrin Hindsill

Abstract

We propose an account within Bidirectional Optimality Theory (BiOT) of the relationship between sentence accent and focus. Three violable constraints ranked according to their relative strength explain the placement of accent within a focus: a syntactic constraint which gives the default case; and two stronger pragmatic constraints which get us to shift to alternatives. It is shown how the analysis captures the standard cases of accent placement, while also extending to interesting cases of stress shift.

Keywords: nuclear accent, focus, Bi-directional Optimality Theory, syntax/semantics/pragmatics interface

11.1 Introduction

This paper gives an analysis in the framework of Bidirectional Optimality Theory (BiOT) of the relationship between nuclear accent and focus. Nuclear accent is a pitch accent that occurs near the end of an intonational phrase. Prosodically, it is the most prominent syllable in the phrase (for a more technical definition see e.g., Pierrehumbert 1980). In what follows, we indicate the nuclear accent with capitals. Intuitively it is the word or syllable that carries the most stress in an

Questions in Dynamic Semantics.
Maria Aloni, Alastair Butler and Paul Dekker (eds.).
Current Research in the Semantics/Pragmatics Interface, Vol. 17.

utterance. We will make the simplifying assumption that an utterance comes with a single nuclear stress. We follow the tradition of using the notion of focus to explain the correlation that holds between nuclear accent and discourse context. Nuclear accent normally signals focus (Rochemont 1986; Lambrecht 1994; Rooth 1992), where the focus can basically be taken to correspond to the constituent that fills the location of a WH-phrase in a WH-question answer. In the following example and henceforth we indicate the focus with brackets $[.]_F$:

(1) Q: Who's building a desk?
A: [My NEIGHBOUR]$_F$ is building a desk.
A′: #My neighbour is building [a DESK]$_F$.

The response of A′ in (1) is infelicitous because the placement of the nuclear accent indicates that the focus is not on the constituent corresponding to the WH-phrase of the question. The result is a mismatch between discourse structure and the phonological coding. In what follows we will simply assume a theory of focus (e.g., Aloni and van Rooij 2002 among others) and so bypass the problem of which focal structure is felicitous in which context.[1] Instead, we concentrate solely on the nuclear accent placement within a focus. placement of nuclear accent within a focus.

The paper is structured as follows. The next section introduces and motivates three Optimality Theoretic (OT) constraints that form the basis of our analysis. Section 11.3 introduces Bidirectional Optimality Theory. Section 11.3.1 looks at a number of illustrations of bidirectional optimisation procedures involving the choice of nuclear accent/focus pairs for a given context. Section 11.4 looks at several examples that suggest future extensions of the theory. Section 11.5 is the conclusion.

11.2 Constraints

Optimality Theory (OT) makes use of a limited number of soft constraints (violable principles) ranked according to their relative strength (see Prince and Smolensky 1997). Ranked constraints are used to select a set of optimal candidates from a larger set of candidates. A given candidate can be optimal even if it violates a constraint provided all alternative candidates lead to more severe constraint violations. A single violation of a higher ranked constraint overrides in severity multiple violations of a lower ranked constraint. Bidirectional Optimality Theory

[1] We would eventually like to provide an account of this in terms of BiOT (cf., Schwarzschild 1999, Blutner 2000).

(BiOT) evaluates sets of candidates that are potential form-meaning pairs (Blutner, 2000). In our analysis candidates will be ⟨(placement of) nuclear accent, (placement of) focus⟩ pairs. In this section, we (i) describe the three constraints that will generate the rankings of the ⟨nuclear accent, focus⟩ pairs, and (ii) provide motivation for their ordering with respect to one another.

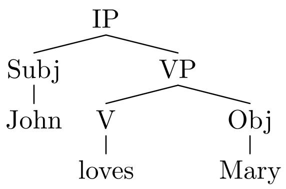
11.2.1 A structural constraint

As a structural constraint on the placement of accent within focus we assume a version of the Nuclear Stress Rule (Chomsky and Halle 1968, Cinque 1993, Reinhart 1997, among others):

- **Nuclear Stress Rule (NSR):** Put accent on the most embedded constituent

For example, in a canonical [Subj V Obj] sentence, the Obj is the most embedded constituent, as (2) illustrates.

(2)



It follows from the NSR that the nuclear accent in an utterance of (2) should fall on the Obj *Mary*, as (3) demonstrates.

(3) Hey, guess what?

a. John loves MARY.
b. #JOHN loves Mary.
c. #John LOVES Mary.

NSR Violations

A number of counter examples to Chomsky and Halle's (1968) formulation of the NSR were soon found, which lead some (e.g., Bolinger 1972) to reject the idea of a syntactic account of accent. In examples (4)–(6), the felicitous versions violate the NSR, with the nuclear accent falling on constituents that are not the most embedded.

(4)
a. #He was arrested because he killed a PERSON.
b. He was arrested because he KILLED a person.

(5)
a. #The telephone is RINGING.
b. The TELEPHONE is ringing.

(6) a. #John$_i$'s cat licked HIM$_i$.
b. John$_i$'s cat LICKED him$_i$.

But unlike Bolinger, we do not have to abandon structural constraints like the NSR to account for examples like (4)–(6). We are using a default framework where contrasts between different constraints are resolved by ranking one constraint over another. To account for these violations of the NSR, rather than eliminate the constraint altogether, we need to provide motivation for higher ranked (semantic/pragmatic) constraints. To this effect, we turn next to the introduction of a Destress constraint.

11.2.2 Destress

The examples (4)–(6) have in common that the constituent that should receive the nuclear accent in accordance with the NSR is already implicitly or explicitly present in the context. In this section we introduce a constraint that prevents such "uninformative" constituents from receiving the nuclear accent.

In example (7), we see that the notion of "semantic weight" plays a role in accent placement (cf., Bolinger 1972, 1986). Certain content words such as *man*, *thing*, *person*, *place*, etc., are perceived of as being inherently empty or uninformative and therefore the accent moves to a more contentful word. The contrast between the "empty" *person* and the contentful *policeman* illustrates this.

(7) a. He was arrested because he KILLED a person.
b. He was arrested because he killed a POLICEMAN.

In example (8), *ringing* is left unaccented, being predictable from the mention of *telephone*. In contrast, that a telephone should be green is not predictable.

(8) a. The TELEPHONE is ringing.
b. The telephone is GREEN.

In example (9a) the pronoun is destressed since it is coreferential with *John*, an activated discourse entity. In contrast, the pronoun of (9b) can receive the nuclear accent as predicted by the NSR, picking up on a non-activated referent.

(9) a. John$_i$'s cat LICKED him$_i$.
b. John$_i$'s cat licked HIM$_j$.

The above discussion motivates the following constraint:

- **Destress:** destress activated, predictable, semantically empty words, etc. (Bolinger, Ladd, Reinhart, among others).

A case can be made for replacing Destress with a family of constraints with an internal hierarchy which may vary cross-linguistically, but we will ignore this complication in what follows.

To sum up, by making Destress a stronger constraint than the NSR, the contrasts of (7)–(9) are explained.

11.2.3 Focus set rule

The final constraint that we will introduce is the Focus Set Rule (FSR). In Reinhart (1997), the notion of a focus set is introduced thus:

- **Focus set:** the focus set of a sentence *S* comprises all and only subtrees (constituents) which contain the nuclear accent of *S*

For example, the following (a) sentences have the focus sets of (b):

(10) a. $[_{\mathrm{IP}}$ $[_{\mathrm{Subj}}$ My neighbour] $[_{\mathrm{VP}}$ is $[_{\mathrm{V}}$ building] $[_{\mathrm{Obj}}$ a DESK]]]
b. *Focus set*: {IP, VP, Obj}

(11) a. $[_{\mathrm{IP}}$ $[_{\mathrm{Subj}}$ My neighbour] $[_{\mathrm{VP}}$ is $[_{\mathrm{V}}$ BUILDING] $[_{\mathrm{Obj}}$ a desk]]]
b. *Focus set*: {IP, VP, V}

(12) a. $[_{\mathrm{IP}}$ $[_{\mathrm{Subj}}$ My NEIGHBOUR] $[_{\mathrm{VP}}$ is $[_{\mathrm{V}}$ building] $[_{\mathrm{Obj}}$ a desk]]]
b. *Focus set*: {IP, Subj}

Having the notion of a focus set gives rise to the following constraint:

- **Focus set rule (FSR)**: the focus of a sentence must be in the focus set of the sentence.

An application of the FSR

As an application of the FSR, consider the following example from Lambrecht and Michaelis (1998):

(13) Q: Why do you rob BANKS?
A: Because that's where the money is.
B: Because I didn't want to work in McRonald's.
C: #Because John couldn't be bothered.

Here are two focus possibilities generated by the focus set of (13)'s question:

(14) a. Why do you rob $[\mathrm{BANKS}]_{\mathrm{F}}$?
b. Why do you $[\mathrm{rob\ BANKS}]_{\mathrm{F}}$?

With the focus as in (14a), the question (13) asks might be elaborated thus: "Why does the suspect rob banks ... as opposed to say libraries or churches?", with a felicitous answer being something like (13A). With the focus as in (14b), the more pragmatically likely question asked is: "What makes you do this criminal activity?", with a felicitous answer being something like (13B). Consider the possibility of having the focus on the Subject. Under such a reading the question would have to mean "Why do you rather than somebody else rob banks?" This focal structure is however unavailable for (13Q), since this would require the nuclear accent to fall on *you*. This provides an account for why (13C) is infelicitous.

11.2.4 The ranking

We have already provided motivation for having the NSR as the weakest constraint. Examples (15) and (16) provide motivation for the FSR being the strongest constraint.

(15) Q: Did Mary feed John$_i$'s cat yesterday?
A: No, [HE$_i$]$_\mathrm{F}$ fed Snuggles.
A′: #No, [he$_i$]$_\mathrm{F}$ fed SNUGGLES.

(16) Q: Did John kill Mary?
A: No, but [SOMEONE]$_\mathrm{F}$ certainly killed her.
A′: #No, but [someone]$_\mathrm{F}$ certainly killed HER.

In (15), every word is a potential candidate for destress (assuming the hearer knows the name of the cat). The felicitous answer also violates the NSR, but obeys the focus set rule, while in the latter, infelicitous answer, the opposite is the case. The felicity of the answer to (16) follows in a similar manner. In both cases, violations of the NSR and Destress are trumped by obedience to the FSR. We will therefore assume the ranking of (17):

(17) FSR > Destress > NSR

From the relative ranking of the FSR, the assumption that there is only one nuclear accent in an utterance, and the assumption that each utterance comes with a focus, we predict the following generalisation: every nuclear accent occurs within a focus and every focus contains one nuclear accent (cf., Selkirk 1984). According to Ballantyne (2002) in an analysis of natural speech, this generalisation held for roughly 85 percent of cases. This strong correlation between focus and nuclear accent is reflected in our high ranking of the FSR. Violations of this generalisation can be accounted for by assuming additional overriding factors.

11.2.5 Some OT examples

We now illustrate the workings of the constraints on a number of examples.

A tie-breaker

We first discuss an example where a violation of a lower ranked constraint becomes a tie-breaker in a case where several candidates violate the same highly ranked constraint. In (18), an example from Cruttenden and Faber (1991), accenting either *people* or *there* violates Destress. As a consequence, the optimal pair is determined by the lower ranked NSR, as Table 1 illustrates.[2]

(18) I love both London and the people THERE.

Table 1:

		FSR	Destress	NSR
☞	[the people THERE]$_F$		*	
	[the PEOPLE there]$_F$		*	!*

In contrast, the use of a "heavy" noun, such as *penguins* in (19) (also from Cruttenden and Faber 1991) makes Destress the deciding constraint, as Table 2 illustrates.

(19) I love both Antarctica and the PENGUINS there.

Table 2:

		FSR	Destress	NSR
	[the penguins THERE]$_F$		!*	
☞	[the PENGUINS there]$_F$			*

Multiple violations

Assuming that in the coordinate structure *John and Mary*, *Mary* is the most embedded constituent, (20) gives an example in which a constraint (the NSR) being violated more than once is crucial in ruling out a candidate, as illustrated in Table 3.

(20) Q: Who called?
A: John and MARY called.

Table 3:

[2] "☞" indicates an optimal candidate, (*) indicates a constraint violation, and (!) indicates a deciding violation.

		FSR	Destress	NSR
☞	[John and MARY]$_F$ called			*
	[JOHN and Mary]$_F$ called			!**
	[John and Mary]$_F$ CALLED	!*		

Interpretational interference

With the above examples, placement of nuclear accent is evaluated with respect to candidates with the same focus. Essentially, this is a production oriented point of view, where a speaker must decide a suitable prosodic form for a given focus structure.

But there is also an interpretational perspective, where a hearer must, once given the prosodic form by the speaker, figure out the intended focus in a given context. As seen with (14) and Table 4 below, different placements of focus can have a drastic effect on the meaning of an utterance. With the nuclear accent on BANKS, our constraints predict that focus on *you* is impossible, but still leaves the ambiguity of focus that gives rise to the joke.

Table 4:

		FSR	Destress	NSR
☞	Why do you rob [BANKS]$_F$			
☞	Why do you [rob BANKS]$_F$			
	Why do [you]$_F$ rob BANKS	!*		

However, the constraints alone are not enough to always allow the hearer to interpret the focus assignment correctly. Consider (21).

(21) Bill only PUFFED a joint (he didn't inhale).

For (21), there is an unambiguous narrow focus on the V. However, the constraints alone predict an ambiguity between V and VP focus, as Table 5 shows.

Table 5:

		FSR	Destress	NSR
☞	Bill only [PUFFED]$_F$ a joint			*
☞	Bill only [PUFFED a joint]$_F$			*

Intuitively, broad focus for (21) is ruled out by the existence of a better prosodic form to express that particular focus interpretation, namely (22).

(22) Bill only puffed a JOINT.

From Table 6, it can be seen that the form of (22) expresses the VP focus interpretation with less severe constraint violations.

Table 6:

		FSR	Destress	NSR
☞	Bill only [puffed a JOINT]$_F$			
	Bill only [PUFFED a joint]$_F$			*!

Imagine the hearer's perspective. If she hears nuclear accent on PUFFED, the constraints give her two possible focus interpretations, as Table 5 shows. But she also must take into account that the speaker could have utilised an alternative form to express the broader focus that would have incurred less severe constraint violations (i.e. JOINT). That the speaker *chose* not to, provides a cue for the interpreter to seek her focus elsewhere.

In the next section we introduce the notion of BiOT, which is a formal way of evaluating the above optimisation procedures at once. Essentially, what this does is incorporate both the speaker and hearer perspectives in tandem.

11.3 Bi-directional optimality

In this section we analyse the relationship between accent and focus in the framework of Bi-directional Optimality Theory (Blutner, 2000).

Optimal solutions are searched along two dimensions: (i) the dimension of the speaker who compares different prosodic forms for one and the same focal structure to be communicated; and (ii) the dimension of the hearer who compares different focus interpretations for a given prosodic form. Different form-meaning pairs are ordered with respect to the ranked constraints introduced in the previous section. Candidate C_1 is at least as good as C_2, ($C_1 \leq C_2$) iff C_1's constraint violations are no more severe than C_2's. A candidate (accent, focus) is *optimal* iff there are no other better pairs (accent1, focus) or (accent, focus1), i.e.,

(i) For all (accent1, focus): (accent, focus) $\leq$ (accent1, focus)

(ii) For all (accent, focus1): (accent, focus) $\leq$ (accent, focus1)

See the notion of *strong optimality* in Blutner (2000) and Jäger (2002).

11.3.1 Illustrations

In this section we look at a number of illustrations of optimisation procedures involving the choice of nuclear accent/focus pairs for a given context. We begin with a basic example to illustrate how the NSR and

FSR constraints interact, and then we consider a more complex example where Destress plays a decisive role.

The basic case

In the example of this section, we will consider the problem of the possible placement of nuclear accent/focus on a family of sentences resembling (23).

(23) My neighbour is building a desk.

We formalise this as a competition between speaker and hearer, in which the speaker chooses a nuclear accent (given a focus) and the hearer chooses a focus given the nuclear accent she hears. This gives rise to an optimisation procedure between a number of accent/focus pairs. In Table 7 we illustrate the interesting competing candidates, together with their specific constraint violations (for a full table see the appendix).

Table 7: (condensed version)

		FSR	Destress	NSR
☞	My neighbour is building [a DESK]$_F$			
	My neighbour is [building]$_F$ a DESK	!*		
☞	My neighbour [is building a DESK]$_F$			
☞	[My neighbour is building a DESK]$_F$			
	[My neighbour]$_F$ is building a DESK	!*		
☞	My neighbour is [BUILDING]$_F$ a desk			*
	My neighbour [is BUILDING a desk]$_F$			!*
	[My neighbour is BUILDING a desk]$_F$			!*
	[My NEIGHBOUR is building a desk]$_F$			!**
☞	[My NEIGHBOUR]$_F$ is building a desk			**

This optimisation has five optimal solutions, which are illustrated in (24)–(28), respectively. These are the default accent, focus pairs.

(24) Q: Is your neighbour buying a desk? ⟨VERB, [V]$_F$⟩
A: No. He is [BUILDING]$_F$ a desk.

(25) Q: What's your neighbour doing? ⟨OBJ, [VP]$_F$⟩
A: He [is building a DESK]$_F$.

(26) Q: What's happening? ⟨OBJ, [IP]$_F$⟩
A: [My neighbour is building a DESK]$_F$.

(27) Q: What's your neighbour building? ⟨OBJ, [Obj]$_F$⟩
A: He is building [a DESK]$_F$.

(28) Q: Who's building a desk? ⟨SUBJ, $[\text{Subj}]_F$⟩
A: [My NEIGHBOUR]$_F$ is building a desk.

Candidate ⟨VERB, $[V]_F$⟩ in (24) is optimal. The alternative focus interpretations for stress on the verb, namely ⟨VERB, $[VP]_F$⟩ and ⟨VERB, $[IP]_F$⟩, although equally ranked by our constraints, are blocked by the more preferred form OBJ for the respective meanings. Stress on the object in these cases does not lead to any constraint violations. VERB and SUBJ involve one and two violations of the NSR, respectively. This explains why OBJ is selected to express a VP or IP focus (examples (25) and (26)). In the other cases of narrow focus ($[\text{Obj}]_F$, and $[\text{Subj}]_F$), stressing the focused constituent is trivially optimal since the alternative candidates violate the FSR (examples (27) and (28)).

A Destress case

In the previous example Destress played no role since nothing was activated, predictable, etc., to trigger the Destress constraint. In this section we consider a family of examples like (29) that involve an activated pronoun that as a consequence counts as a candidate for destressing.

(29) John$_i$'s cat ate him$_i$.

The problem of the possible placement of accent and focus for this type of sentence can be formalised again as a competition between different accent-focus pairs. Table 8 represents the interesting candidates (for the full table, see the appendix):

Table 8: (condensed version)

		FSR	Destress	NSR
☞	John$_i$'s cat ate [HIM$_i$]$_F$		*	
	John$_i$'s cat [ate HIM$_i$]$_F$		!*	
	[John$_i$'s cat ate HIM$_i$]$_F$		!*	
☞	John$_i$'s cat [ATE]$_F$ him$_i$			*
☞	John$_i$'s cat [ATE him$_i$]$_F$			*
☞	[John$_i$'s cat ATE him$_i$]$_F$			*
	[John$_i$'s CAT ate him$_i$]$_F$			!**
☞	[John$_i$'s CAT]$_F$ ate him$_i$			**

This table has five optimal solutions, illustrated in (30)–(34), respectively:

(30) Q: Did John$_i$'s cat$_j$ lick him$_i$? ⟨VERB,$[V]_F$⟩
A: No, it$_j$ [ATE]$_F$ him$_i$.

(31) Q: What did John$_i$'s cat$_j$ do next? ⟨VERB,[VP]$_F$⟩
A: It$_j$ [ATE him$_i$]$_F$.

(32) Q: What happened next? ⟨VERB,[IP]$_F$⟩
A: [John$_i$'s cat ATE him$_i$]$_F$.

(33) Q: What did John$_i$'s cat eat next? ⟨OBJ,[Obj]$_F$⟩
A: It ate [HIM$_i$]$_F$.

(34) Q: Who ate John$_i$? ⟨SUBJ,[Subj]$_F$⟩
A: [John$_i$'s CAT]$_F$ ate him$_i$.

VERB is optimal for [V]$_F$, but also for [VP]$_F$ and [IP]$_F$ despite violating the NSR, since the alternative candidates involve more severe constraint violations: OBJ violates the higher ranked Destress, and SUBJ involves two violations of the NSR, and for [VP]$_F$ the FSR as well. Interestingly, the pair ⟨OBJ,[Obj]$_F$⟩ is optimal despite violating Destress, because any alternative accenting option for [Obj]$_F$ involves a violation of the higher ranked FSR. The pair ⟨SUBJ,[Subj]$_F$⟩ is also trivially optimal for the same reason.

Note that in Table 7, OBJ led to three possible focus interpretations ([Obj]$_F$, [VP]$_F$ and [IP]$_F$). In Table 8, OBJ allows only a narrow focus interpretation, namely [Obj]$_F$. On the other hand, VERB, which in Table 7 unambiguously expressed the narrow focus [V]$_F$, in Table 8 allows in addition the broad focus interpretations [VP]$_F$ and [IP]$_F$.

As we noted earlier, and as is clear from the two examples of this section, our OT analysis predicts an interesting difference in complexity between production and interpretation tasks. The production of focal stress can be obtained by optimising unidirectionally from meaning to form, whereas bidirectional optimisation is crucial for correctly interpreting focal stress (see the interpretation for VERB in Table 7 and OBJ in Table 8). Recent experimental findings in language acquisition seem to confirm this mismatch (see Szendröi (2003)). Children seem to produce focal stress correctly from the two-word stage. At the same time, their comprehension abilities lag behind until they are 6 years old. Hendriks and Spenader (2004), de Hoop and Krämer (2004) and Hendriks (2005) have proposed that children acquire bidirectional optimisation strategies only later (around 6;6). Initially their interpretations seem best described by uni-directional OT. In this light, these findings cease to be paradoxical and find a natural explanation with our analysis.

11.4 Accent beyond focus

So far we have concentrated on building a theory for predicting (placement of nuclear accent, placement of focus) pairings in neutral contexts. In this section we discuss three types of cases where our BiOT analysis ostensibly fails. The first case is easily dealt with by examining the pragmatic nature of the Destress constraint. The latter two cases cannot be explained so easily: what they share in common is that they arise in situations where speakers are using nuclear accent for more than just picking out the focal structure.

Example (33) illustrated how placing the nuclear accent on a candidate for destress gives rise to a narrow focus interpretation. But, the same intonation can also let the hearer know that she is in an abnormal context. As a concrete example, consider (35).

(35) [The telephone is RINGING]$_{\mathrm{F}}$.

This is an example where Destress is violated, with the nuclear stress falling on the predictable word *ringing*. Recall that (35) was considered infelicitous when presented as (5a). But, suppose this was uttered by a speaker who has had his telephone cut off for a number of weeks. That (35) is an appropriate utterance for such a speaker may appear to be a counterexample to our constraints—stress on the V retains the IP focus, even though Destress is violated. Actually, the pragmatic nature of Destress comes to the rescue. In this context Destress is no longer violated from the speaker's point of view. For him, a ringing telephone is no more predictable than a telephone on fire. A hearer, even if she is unaware of the context, would infer that something odd is going on, as the predictability of "ringing" with "telephone" normally demands that "ringing" is destressed. If she assumes that the speaker is following the constraints, her only option is to change to a context where Destress no longer applies, that is, to a context where the telephone ringing is unexpected.

We now turn to examples where a speaker uses accent to express more than focal structure. Consider (36) in the following context: (36) is a comment made while watching a movie; the scene is of a hotel room with an open bedside cabinet drawer containing a gun and a bible.

(36) You can tell it's an American hotel room. It has a bible AND a gun.

Our constraints predict that the nuclear stress will be on *gun*, unless there is narrow focus on *and*. However, this example really seems to be a case of broad focus, leading us to conclude (unsurprisingly) that there are additional factors involved in nuclear accent placement. In general, 'x AND y' can be paraphrased as "not only x, but also y', where 'x' is either given, typical or expected, while 'y' is less expected, or at least low on a scale of expectations. The givenness or expectedness of the first conjunct can easily be seen in (36), where switching the conjuncts makes little sense.

A Bush speech (heard on BBC Radio 4, 08 March, 2005) concerns the removal of troops from Syria, and uses the same rhetorical device, but to slightly different purposes.

(37) All Syrian military forces AND intelligence personnel must withdraw before the Lebanese elections for those elections to be free and fair.

A final example comes from a detective novel, "Strange Affair" by Peter Robinson. The detective, Alan Banks, is examining the flat of his missing brother, who was always very security conscious.

(38) Banks examined the lock and saw that it was the deadbolt kind, which you had to use a key both to open AND to close.

Here, the scale refers to locks in general—most locks need a key to open them, but a more paranoid soul wants a lock that also needs a key to close.

All of these stressed *and* examples seem to allow the paraphrase of 'not only x, but also y'. Rhetorically, however, the effects run from socio-political irony to a picture of someone's security consciousness. Most likely, the different rhetorical effects arise from the combination of the paraphrase along with the contrast between the informational content of the conjuncts. Exactly what the nature of the contrast is depends on a variety of contextual factors. Interestingly, if one were to use the paraphrase rather than stressed *and*, the additive particle *also* would carry the stress. Krifka (1999) proposes that stressed additive particles associate with a contrastive topic. Something similar may be occurring here.

To end this section, we have an example where shift of stress onto a pronoun does not affect interpretation of the focus, but instead gives rise to a threatening implicature. This example comes from the 1974 Francis Ford Coppola film "The Conversation". A surveillance expert is spying on a young couple for a powerful business executive. The executive happens to be married to the unfaithful woman. While listening to the recordings, the surveillance expert hears the man utter (39), where the 'he' refers to the executive and 'us' refers to the couple.

(39) He'd KILL us if he had the chance.

Initially, the spy fears for the couple's lives and attempts to stop their murder at the hands of the executive. But it turns out that it is the executive who dies and not the couple. His actual death is a car accident and apparently unsuspicious.[3] But, the spy becomes increasingly paranoid and imagines other circumstances for the death. His paranoia leads the spy to think he has been set up in a sense and that the couple murdered the woman's husband. His memory of the intonation also changes, and by the end of the movie he hears instead

(40) He'd kill US if he had the chance.

The referents of the pronouns are unchanged, which is unusual in the sense that a stressed pronoun can often lead to a change of reference.[4] But it is unclear as to whether there is any focus change from (39) to (40). Our theory predicts that (40) has a narrow focus interpretation. However, it seems that the stress on the pronoun indicates a contrast between 'us' and 'him'—one of this pair is going to be killed. This contrast gives an implicature that basically says: "We had better kill him before he kills us." It is possible that there is a close relation between this notion of contrastive accent and narrow focus as it is used in this paper. Again, this must be left for future research.

11.5 Conclusion

In this paper we have given an account within Bidirectional Optimality Theory (BiOT) of the relationship between pitch accent and meanings within focus constructions. The three constraints illustrate the interaction between syntax, semantics and pragmatics in determining the placement of accent within focus. We have seen that syntax gives the default cases (via the NSR). Pragmatics gets us to shift to alternatives. Under our story the syntactic constraint is the weakest constraint. The constraint ranking considered captures not only the standard cases of nuclear accent placement, but also interesting cases of stress shift. Ultimately we would like to incorporate this into a broader theory of nuclear accent, so as to give a more complete account of the examples in section 11.4.

[3] The viewer learns of the death from a newspaper headline.

[4] A classic example of a stressed pronoun leading to a change of reference comes from Lakoff (1971):

a. Paul called Jim a Republican. Then he insulted him. (Paul insulted Jim)

b. Paul called Jim a Republican. Then HE insulted HIM. (Jim insulted Paul)

Appendix

Table 7: (full version)

		FSR	Destress	NSR
☞	My neighbour is building [a DESK]$_{\mathrm{F}}$			
	My neighbour is [building]$_{\mathrm{F}}$ a DESK	!*		
☞	My neighbour [is building a DESK]$_{\mathrm{F}}$			
☞	[My neighbour is building a DESK]$_{\mathrm{F}}$			
	[My neighbour]$_{\mathrm{F}}$ is building a DESK	!*		
	My neighbour is BUILDING [a desk]$_{\mathrm{F}}$	!*		*
☞	My neighbour is [BUILDING]$_{\mathrm{F}}$ a desk			*
	My neighbour [is BUILDING a desk]$_{\mathrm{F}}$			!*
	[My neighbour is BUILDING a desk]$_{\mathrm{F}}$			!*
	[My neighbour]$_{\mathrm{F}}$ is BUILDING a desk	!*		*
	My NEIGHBOUR is building [a desk]$_{\mathrm{F}}$	!*		**
	My NEIGHBOUR is [building]$_{\mathrm{F}}$ a desk	!*		**
	My NEIGHBOUR [is building a desk]$_{\mathrm{F}}$	!*		**
	[My NEIGHBOUR is building a desk]$_{\mathrm{F}}$			!**
☞	[My NEIGHBOUR]$_{\mathrm{F}}$ is building a desk			**

Table 8: (full version)

		FSR	Destress	NSR
☞	John$_i$'s cat ate [HIM$_i$]$_{\mathrm{F}}$		*	
	John$_i$'s cat [ate]$_{\mathrm{F}}$ HIM$_i$	!*	*	
	John$_i$'s cat [ate HIM$_i$]$_{\mathrm{F}}$		!*	
	[John$_i$'s cat ate HIM$_i$]$_{\mathrm{F}}$		!*	
	[John$_i$'s cat]$_{\mathrm{F}}$ ate HIM$_i$	!*	*	
	John$_i$'s cat ATE [him$_i$]$_{\mathrm{F}}$	!*		*
☞	John$_i$'s cat [ATE]$_{\mathrm{F}}$ him$_i$			*
☞	John$_i$'s cat [ATE him$_i$]$_{\mathrm{F}}$			*
☞	[John$_i$'s cat ATE him$_i$]$_{\mathrm{F}}$			*
	[John$_i$'s cat]$_{\mathrm{F}}$ ATE him$_i$	!*		*
	John$_i$'s CAT ate [him$_i$]$_{\mathrm{F}}$	!*		**
	John$_i$'s CAT [ate]$_{\mathrm{F}}$ him$_i$	!*		**
	John$_i$'s CAT [ate him$_i$]$_{\mathrm{F}}$	!*		**
	[John$_i$'s CAT ate him$_i$]$_{\mathrm{F}}$			!**
☞	[John$_i$'s CAT]$_{\mathrm{F}}$ ate him$_i$			**

12

Counting (on) Usage Information: WH Questions at the Syntax-Semantics Interface

Alastair Butler

Abstract

In this paper we introduce a semantics for interrogatives that treats WH-phrases like indefinites. We show how this captures a number of intriguing properties of the types of scoping options, dependencies and constraints on dependencies that can arise with WH-phrases. We also see how this leads to options for cross-linguistic variation in how WH-questions get realized.
Keywords: WH-phrases, indefinites, dynamic semantics, intervention effects

12.1 Introduction

This paper is concerned not so much with what interrogatives denote, but *how*. The focus is on interrogatives with WH-phrases, since, from the perspective of this paper, these provide the interesting cases. We start from what is a rather standard assumption in the literature that WH-phrases are much like indefinites (see e.g., Cheng 1991 and Haspelmath 1997). In section 12.3, we see empirical support for this. Such an assumption can only be helpful provided we are already comfortable with the way indefinites work. So, before we can think about WH-phrases, we first have to consider indefinites.

Questions in Dynamic Semantics.
Maria Aloni, Alastair Butler and Paul Dekker (eds.).
Current Research in the Semantics/Pragmatics Interface, Vol. 17.

In this paper we buy wholesale the idea that indefinites have a variable interpretation depending on the context of use. Cresswell (2002) suggests this is reflected in English by the word 'namely'. For example, it is possible to say (1) when the girl who enters is Cloris.

(1) A girl (namely Cloris) enters.

We can represent (1) in predicate logic with (2), in which y is a free variable, whose denotation in (1) is Cloris.[1]

(2) $\exists x(x = y \wedge \mathtt{G}(x) \wedge \mathtt{E}(x))$

Similarly, a pronoun's interpretation is functional on its occasions of use, as it can be taken to refer to what is its referent on these occasions. For example, the pronoun of the second sentence in (3) can be taken to refer to whatever individual is the 'namely' referent associated with the indefinite of the first sentence. Thus, we might represent (3) with (4).

(3) A girl^1 enters. She$_1$ whistles.

(4) $\exists x(x = y \wedge \mathtt{G}(x) \wedge \mathtt{E}(x)) \wedge \mathtt{W}(y)$

A problem with (4) is that it fails to predict the dependency failure of (5).

(5) *She$_1$ whistles. A girl^1 enters.

That a pronoun's antecedent ought to occur before the pronoun can be captured with an appropriately articulated notion of a context of use.[2] An elegant example of this comes with Dekker's (2002a) *Predicate Logic with Anaphora* (PLA), which gives a semantics for a language of predicate logic with atomic formulas taking, in addition to variables, "pronouns" $\{p_1, p_2, ...\}$ as terms.

Definition 1 (PLA semantics) Suppose a first-order model M with domain of individuals D. Suppose σ is a (finite) sequence of individuals from D assigned to the positions of σ. Suppose g is a (total) assignment

[1] Note that (2) is equivalent to $\mathtt{G}(y) \wedge \mathtt{E}(y)$. Hence, with (2) we actually have, what Cresswell (2002) calls, "a method whereby an apparent existential quantifier can be deprived of its quantificational effect, while remaining a syntactic part of the representing formula."

[2] There are many other ways of capturing this order dependence, e.g., Kamp (1981) uses a construction algorithm over representations; Groenendijk and Stokhof (1991b) use a dynamic semantics with *input* and *output* assignments; Zeevat (this volume) has a property of the information state; while Cresswell (2002) has a translation procedure from formulas of Dynamic Predicate Logic into formulas of predicate logic with coded dependencies in the translations that are akin to the dependencies that get established during an evaluation run of the PLA semantics.

from variables to individuals of D. The PLA semantics can be given as follows:

$\sigma \models_g \exists x\phi$	iff	$\sigma - 1 \models_{g[x/\sigma(1)]} \phi$
$\sigma \models_g \phi \wedge \psi$	iff	$\sigma - n(\psi) \models_g \phi$ and $\sigma \models_g \psi$
$\sigma \models_g \neg\phi$	iff	$\sigma'\sigma \not\models_g \phi$ for all $\sigma' \in D^{n(\phi)}$
$\sigma \models_g \mathtt{P}(t_1, ..., t_n)$	iff	$([t_1]_{g,\sigma}, ..., [t_n]_{g,\sigma}) \in M(\mathtt{P})$
$[x]_{g,\sigma} = g(x)$,		$[p_i]_{g,\sigma} = \sigma(i)$

where:
$\sigma(i)$ returns the i-th individual of σ,
$\sigma - m$ is the sequence $e_{m+1}, e_{m+2}, ...$, and
$n(\phi)$ is a count of existentials in ϕ: $n(\exists x\phi) = n(\phi) + 1$, $n(\phi \wedge \psi) = n(\phi) + n(\psi)$, $n(\neg\phi) = 0$, $n(\mathtt{P}(t_1, ..., t_n)) = 0$.

The clause for existential quantification carries out essentially the same namely linking as we saw with (2). But in addition, the information of the 'namely position' $\sigma(1)$, which is the analog of y in (2), is relocated: $\sigma(1)$ gets popped and has its denotation entered into the assignment as the value for the new binding.

The clause for conjunction brings about a division between 'old' and 'new' namely positions. A new namely position is a position at the front of σ that is waiting to be popped by an existential. An old namely position is a position towards the rear of σ that was popped in some prior conjunct. This falls out with the evaluation of $\phi \wedge \psi$, since for the evaluation of ϕ, the new namely positions for ψ are removed, on the basis of on an $n(\psi)$ count, to reveal the new namely positions for ϕ, as well as the old positions. For the evaluation of ψ, the new namely positions for ψ are reinstated, to make the new and old namely positions for ϕ the old positions for ψ.

The negation of a formula ϕ acts as a 'test': it tells us there is no way of finding values for the existentials in ϕ, or, rather, that there is no way to feed the existentials of ϕ denotations for their bindings from a sequence of namely positions σ' with length $n(\phi)$, so that, e.g., $\neg\exists x\mathtt{P}(x)$ means that no individual is P. Consequently, for a negated formula evaluated with respect to σ, all the namely positions of σ will be old. Similarly, for the evaluation of a predicate formula embedded in ϕ, all new namely positions for ϕ will have been popped and their denotations entered as values into the assignment, leaving only old positions for the pronouns of the predicate formula to link to.

We now work through an example. Consider (6), which has been suggestively glossed and indexed with subscripts to pinpoint where we will have reached during an evaluation run.

(6) $\exists x(\mathtt{G}(x) \wedge \mathtt{E}(x)) \wedge \mathtt{W}(p_1) \qquad \wedge \; \exists x(\mathtt{B}(x) \wedge \mathtt{E}(x))$

$_{\mathrm{a}}$ A$_{\mathrm{b}}$ girl enters.$_{\mathrm{c}}$ She whistles.$_{\mathrm{d}}$ A$_{\mathrm{e}}$ boy enters.$_{\mathrm{f}}$

We can evaluate (6) with respect to the sequence of namely positions in (7), which uses shading to depict moments in the evaluation corresponding to the subscripts of (6).[3]

(7)

a.	John	Cloris	d.	John	Cloris
b.	John	Cloris	e.	John	Cloris
c.	John	Cloris	f.	John	Cloris

With (7), we see an evaluation run for (6) that emerges as follows:

- To begin with, when at (6a), the namely positions are new. To indicate this, we shade the positions of (7a).
- At (6b), the first existential is met. This shifts the denotation of a position into the assignment as value for the new binding. To indicate this, we lightly shade a position to give (7b). Note that this change does not apply to the first element of the sequence, which is 'reserved' for an existential of a later conjunct.
- At (6c), the end of the open binding is reached. Consequently, the position that was used to provide a denotation for the binding takes on the status of an old position, which we indicate with a lack of shading as in (7c).
- At (6d), we reach the end of evaluating a predicate with a pronoun. This leaves the namely sequence unchanged as in (7d). What is interesting is that the pronoun has an index of 1 and so takes as its denotation the first occurrence of an old position, which happens to be the namely position that provided its denotation for the first existential. Thus, we have the effect of an anaphoric link between *A girl* and *She*, much like in (4).
- At (6e), the second existential is met. This opens a binding which takes as its value the denotation of the position that was earlier saved. This gives the pictured sequence (7e).
- Finally, (6f) is reached: the end of the discourse, with all positions being old positions, as in (7f). Thus, we see how a *discourse context*, which amounts to a sequence of old positions, providing values for pronouns, is revealed as the discourse proceeds.

The evaluation of (6), as depicted with (7), works because usage information is obtained via an $n(\phi)$ count. This gives the number of

[3]Of course, we also need an assignment, but since (6) contains no free variables, whichever assignment we choose gives the same result.

namely positions that are required to support the discourse. During the course of an evaluation, the $n(\phi)$ count gets used to manage when frontmost positions are to be kept in reserve for subsequent discourse. And if positions are not reserved, then they are either old or they will be popped and have their denotations entered into the assignment before a 'test' is encountered (either a predicate or negation).

12.2 Adding WH

We will now introduce a system that is a lot like PLA, but with a question operator (`Q`), WH binding operator ($\mathtt{wh}x$) and WH usage information (`WH`). In addition, the language has existential quantification, negation and predicates. For the points we wish to make, there is no need for pronouns like in PLA or conjunction, and so we will leave these out of the language.

Definition 2 (semantics with question operator, `Q`, `wh` binding operator and `WH` usage information)
Suppose a first-order model M with domain of individuals D. Suppose σ and ω are (finite) sequences of individuals from D. Suppose g is a (total) assignment from variables to individuals of D. The semantics can be given as follows:

$$[\![\mathtt{Q}\phi]\!]_g = \begin{cases} \{\omega \in D^{q(\phi)} \mid \exists \sigma \in D^{n(\phi)} : \omega, \sigma \models_g \phi\} & \\ \qquad\qquad\qquad \text{if } \exists \omega \in D^{q(\phi)}, \sigma \in D^{n(\phi)} : \omega, \sigma \models^{\mathrm{P}} \phi \\ \mathit{error} \qquad \text{otherwise} \end{cases}$$

$$\begin{array}{lll}
\omega, \sigma \models_g \mathtt{wh}x\phi & \text{iff} & \omega - 1, \sigma \models_{g[x/\omega(1)]} \phi \\
\omega, \sigma \models_g \mathtt{WH}\phi & \text{iff} & \omega, \sigma \models_g \phi \\
\omega, \sigma \models_g \exists x\phi & \text{iff} & \omega, \sigma - 1 \models_{g[x/\sigma(1)]} \phi \\
\omega, \sigma \models_g \neg\phi & \text{iff} & \omega, \sigma' \not\models_g \phi \text{ for all } \sigma' \in D^{n(\phi)} \\
\omega, \sigma \models_g \mathtt{P}(x_1, ..., x_n) & \text{iff} & (g(x_1), ..., g(x_n)) \in M(\mathtt{P})
\end{array}$$

$$\begin{array}{lll}
\omega, \sigma \models^{\mathrm{P}} \mathtt{wh}x\phi & \text{iff} & |\omega| \geq 1 \text{ and } \omega - 1, \sigma \models^{\mathrm{P}} \phi \\
\omega, \sigma \models^{\mathrm{P}} \mathtt{WH}\phi & \text{iff} & \omega, \sigma \models^{\mathrm{P}} \phi \\
\omega, \sigma \models^{\mathrm{P}} \exists x\phi & \text{iff} & |\sigma| \geq 1 \text{ and } \omega, \sigma - 1 \models^{\mathrm{P}} \phi \\
\omega, \sigma \models^{\mathrm{P}} \neg\phi & \text{iff} & \omega, \sigma' \models^{\mathrm{P}} \phi \text{ for some } \sigma' \in D^{n(\phi)} \\
\omega, \sigma \models^{\mathrm{P}} \mathtt{P}(x_1, ..., x_n) & \text{iff} & \omega = \epsilon
\end{array}$$

where:
$n(\phi)$ is a count of existentials in ϕ: $n(\exists x\phi) = n(\phi)+1$, $n(\mathtt{wh}x\phi) = n(\phi)$, $n(\mathtt{WH}\phi) = n(\phi)$, $n(\neg\phi) = 0$, $n(\mathtt{P}(x_1, ..., x_n)) = 0$.
$q(\phi)$ is a count of `WH` in ϕ: $q(\exists x\phi) = q(\phi)$, $q(\mathtt{wh}x\phi) = q(\phi)$, $q(\mathtt{WH}\phi) = q(\phi) + 1$, $q(\neg\phi) = 0$, $q(\mathtt{P}(x_1, ..., x_n)) = 0$.

There are a number of things to note about the setup of this semantics. Most strikingly, each component of the language has a double entry: one is for the semantics, while the other declares a *presupposition*. This technique was introduced by van den Berg (1996): it provides a way of dealing with instances of undefinedness that can creep into an evaluation. The idea is to distinguish 'undefinedness' from 'falsity' by pairing up each semantic clause with a test for definedness. Such tests take the form of presuppositions, in that they do not 'shift to a negative place' if the sentence is negated. Only if the conditions for definedness of an expression are met, can we evaluate the expression. But, of course, the evaluation will still have either of two results: the expression may be true or it may be false. This way we get a three way distinction on the information states given by the finite sequences ω and σ:

1. states in which the expression is undefined;
2. states in which the expression is true;
3. states in which the expression is false.

We get the tests for definedness by giving each semantic clause a companion that abstracts away from all contentual information.

For predicate formulas, it is required that the question namely sequence, ω, is empty. Since an evaluation run terminates with a predicate, this amounts to requiring that all WH namely values are popped, that is, get used as values for `wh`-bindings in the evaluation. This is required since, with the usage information and the `wh`-binding being possibly separated, assurance is needed that their numbers remain synchronized. This check ensures there are not too many values for too few bindings. Besides this, a predicate gives no other conditions to satisfy: we are using total assignments and have only variables as terms, so the terms will always denote. In addition, as we are about to find out, with the current set up inherited from PLA, the ordinary namely sequence, σ, cannot go out of synchronization with the number of $\exists$-bindings, making a check unnecessary.

The presuppositions take on an especially prominent role when we come to interpret a `wh`-binding. This presupposes a non-empty ω sequence of namely positions targeted for WH-phrases. This is *not* guaranteed. Only those expressions with a $q(\phi)$ count at least as large as the number of `wh`-bindings will satisfy the presupposition. Put alternatively, only those formulas with as many occurrences of the WH usage information, `WH`, as there are occurrences of `wh`x will be evaluable expressions.

A related presupposition applies to the $\exists$-binding. But this fares much better. This presupposes a non-empty σ sequence of namely positions targeted for non-WH-bindings. The length of σ is guided by the $n(\phi)$ count. The syntax that signals the $\exists$-binding *itself* increments the $n(\phi)$ count, so there is never a mismatch between the number of namely positions required by the $\exists$-bindings and the number of positions actually supplied.[4] In the coming sections we will see that what is special about WH-phrases, and what accounts for their quirkyness when it comes to their distribution, is that the information for their support can be separate from the location of their syntactic binding role.

Another thing to note about the semantics is that we have followed Dekker (2002b) in keeping to an extensional set up in which questions are sets of sequences of individuals. Provided *error* is avoided, in the case of a polar question, this can only be either the set containing the empty sequence, $\{\epsilon\}$, or the empty set, $\{\}$. These two states correspond to the truth values *true* and *false*, respectively, or alternatively, to the answers *yes* and *no*. It is easily seen that the equivalences of (8)–(10) hold.[5]

(8) $\epsilon \in [\![\texttt{QP}]\!]_g$ iff $M(\texttt{P}) = true$

(9) $d \in [\![\texttt{QWHwh}x\texttt{P(}x\texttt{)}]\!]_g$ iff $d \in M(\texttt{P})$

(10) $cd \in [\![\texttt{QWHwh}x\texttt{WHwh}y\texttt{P(}x, y\texttt{)}]\!]_g$ iff $(c, d) \in M(\texttt{P})$

We also note that a more general equivalence like (11) holds, showing that the treatment of WH-phrases really is much like the treatment of indefinites/existentials.

(11) $\omega \in [\![\texttt{Qwh}x_1 ... \texttt{wh}x_n \texttt{WH}_1 ... \texttt{WH}_n \phi]\!]_g$ iff $\exists \sigma \in D^{n(\phi)} : \epsilon, \omega\sigma \models_g \exists x_1 ... x_n \phi$

Finally, we observe that the equivalence of (12) holds.

(12) $ab \in [\![\texttt{QWHwh}x\exists y\texttt{WHwh}zP(x, y, z)]\!]_g$ iff
$\exists c \in D : \epsilon, abc \models_g \exists x \exists z \exists y P(x, y, z)$

Here, a $\texttt{wh}z$-binding that occurs under the syntactic scope of an $\exists y$-binding is actually found to semantically scope above $\exists y$ in the equivalence. This is because, while $\texttt{wh}z$ acts as a binding operator, $\texttt{wh}z$ itself

[4] This is the reason we did not have to really think about undefinedness when we looked at PLA. However, for PLA, we did need to implicitly assume that the namely sequence would always be sufficient in length, else we could still have encountered undefinedness with the pronouns. This latter worry is not part of the current semantics because of the absence of pronouns.

[5] The adequacy of such denotations is not essential, as the ideas of the analysis carry over easily to a system where interrogative clauses denote say sets of propositions instead.

picks up from `Q` the value with which it binds. `Q` gives widest semantic scope to the WH-phrases that it feeds values. This gives a uniform treatment of WH-phrases: they always receive widest scope, even when located in embedded positions.

12.2.1 Effects

So much for the semantics. What we care about are the effects that it gives rise to on the forms expressions can take. We turn to these now. In our semantics, to be an interrogative, ϕ must have form $\mathtt{Q}\psi$. That is, ϕ must have a question operator that takes up a scopal position as the outermost element. In addition, if ϕ is a WH-question, then it will need to contain both WH-binding operators ($\mathtt{wh}x$) and WH usage information (`WH`). The order in which `WH` and $\mathtt{wh}x$ occur does not matter. Also, they need not be placed together. What matters is that there are as many `WH`'s that add to the $q(\phi)$ count as there are `wh`-bindings, and that there are as many `wh`-bindings as there are `WH`'s that add to the $q(\phi)$ count. This gives the contrasts in (13) and (14). Here, the star means that the expression returns *error*, which can be viewed as a formalisation of infelicitousness/ungrammaticality.

(13) a. $\mathtt{QWHwh}x\mathtt{P}(x)$
b. $\mathtt{Qwh}x\mathtt{WHP}(x)$
c. *$\mathtt{Qwh}x\mathtt{P}(x)$
d. *$\mathtt{QWHWHwh}x\mathtt{P}(x)$

(14) a. $\mathtt{QWHwh}x\mathtt{WHwh}y\mathtt{P}(x,y)$
b. $\mathtt{QWHWHwh}x\mathtt{wh}y\mathtt{P}(x,y)$
c. *$\mathtt{QWHwh}x\mathtt{wh}y\mathtt{P}(x,y)$
d. *$\mathtt{QWHWHWHwh}x\mathtt{wh}y\mathtt{P}(x,y)$

The set up also gives us the effects in (15), since as soon as negation is hit upon by $q(\phi)$ the count bottoms out at 0. As a result, occurrences of `WH` below the scope of negation fail to make an impression on the $q(\phi)$ count. For this reason, (15d–f) are out, for basically the same reasons as (13c) and (14c); that is, they lead to a larger number of `wh`-bindings than there are `WH`-instructions that show up in the $q(\phi)$ count.

(15) a. $\mathtt{QWHwh}x\neg\mathtt{P}(x)$
b. $\mathtt{QWH}\neg\mathtt{wh}x\mathtt{P}(x)$
c. $\mathtt{Qwh}x\mathtt{WH}\neg\mathtt{P}(x)$
d. *$\mathtt{Qwh}x\neg\mathtt{WHP}(x)$
e. *$\mathtt{Q}\neg\mathtt{WHwh}x\mathtt{P}(x)$
f. *$\mathtt{Q}\neg\mathtt{wh}x\mathtt{WHP}(x)$

We should note that the $n(\phi)$ count similarly bottoms out at 0 upon meeting negation. However, we do not see a related contrast with existentials, as (16) shows. The reason is that negation itself uses a fresh $n(\phi)$ count to support the existentials within its scope, by denying the prospect of the ∃-bindings captured having *true* values.

(16) a. $\mathtt{Q}\exists x \neg \mathtt{P}(x)$
b. $\mathtt{Q}\neg\exists x \mathtt{P}(x)$

12.3 Some cross-linguistic WH data

With our semantic system in place, we are now in a position to work through some cross-linguistic WH data. We want to see how WH data matches up with the effects of our semantic system.

12.3.1 French interrogatives with a single WH-phrase

To create a standard question asking for new information with a single WH-phrase, French can either front the WH-phrase as in (17a), or leave it in-situ as in (17b).[6]

(17) a. **Qui** est-ce que tu vois ce soir?
who is-this that you see this evening
b. Tu vois **qui** ce soir?
you see who this evening
'Who are you seeing tonight?'

For our purposes we can represent (17a) with (18), which gives a form that we can feed into our semantics.

(18) $\mathtt{QWHwh}y\exists x\mathtt{S}(x,y)$

To get (18), we have made lots of simplifying assumptions. Firstly, we are dealing with an interrogative, so the representation automatically has form $\mathtt{Q}\phi$. Secondly, we only attempt to represent the verb and its arguments. Moreover arguments are either WH-phrases, in which case they are a WH binder ($\mathtt{wh}x$) with WH usage information (WH), or they are not WH phrases, in which case they form existential bindings. So the things that are carried forward into the representation are what is a WH-phrase and what is not, and the hierarchical arrangement of arguments.[7]

[6] Here and in what follows, we will use movement metaphors like 'front' and 'leave in-situ' purely as descriptive aids. Nothing in our account will require the actual movement of anything.

[7] In (18), the ordering of WH with respect to $\mathtt{wh}y$, and vice versa, is irrelevant. What *is* relevant for capturing French (non-split) WH-phrases is that WH and $\mathtt{wh}y$ come together.

Looking back at our semantics we see that our choices make a WH-phrase act as a binder that pops a namely position. In addition, a WH-phrase can come with usage information to ensure that a namely position is available for it. All this is pretty much what an indefinite does. Such a close connection with indefinites is expected considering that the morpheme *qu* in French interrogative words is not a mark of interrogation, but is instead a mark of indefiniteness; it is also found in indefinites such as *quelqu'un* 'someone' and *quelque chose* 'something'. What is exceptional for a WH-phrase like *qui* 'who' is that the namely position that is taken as value for the binding is one that was targeted for a WH-phrase. That is, we basically have an indefinite, but one that differs from ordinary indefinites (like, *quelqu'un*) in terms of the role it plays in discourse. Looking back at our semantics, ordinary indefinites are assumed to relate to individuals which are not required to be determinate; WH-phrases relate to individuals requested to be determined by the question act.

Before we give a similar representation to (18) for (17b), we note that French WH-phrases in-situ cannot receive interpretations other than WH, as (19) shows.

(19) a. *Il a parlé avec **qui**.
he has spoken with whom
Intended: 'He spoke with someone.'

b. *Il veut tout **quoi**.
he wants all what
Intended: 'He wants everything.'

c. *Il n'aime pas **quoi**.
he NE-likes not what
Intended: 'He does not like anything.'

This tells us that in-situ WH-phrases in French are not solely variables, rather they are just like their fronted counterparts: they act as WH binders ($\mathtt{wh}x$) and carry WH usage information ($\mathtt{WH}$). Hence, we should represent (17b) with (20).

(20) $\mathtt{Q}\exists x\mathtt{WHwh}y\mathtt{S}(x, y)$

Note that the only difference between (18) and (20) is the hierarchical arrangement of the arguments.

Interestingly the distribution of French argument WH-phrases in-situ is very limited (see e.g., Chang 1997, Bošković 1998, Mathieu 1999, Cheng and Rooryck 2000). In particular, such questions display *intervention effects* with a whole range of scopal elements, including negation, universal quantification and *only*. We call such scope elements *interveners*. Here we concentrate on examples with negation as the intervener. Nevertheless the gist of the account is expected to carry over to other interveners. Such intervention effects are systematically absent from the alternative where the WH-phrase is fronted. For example, negation leaves the licensing of the fronted WH-phrase in (21a) unhindered, while negation blocks the licensing of the WH-phrase in-situ in (21b).

(21) a. **Qui'** est-ce que tu ne vois pas?
who is-this that you NE see not
'Who didn't you see?'

b. *Tu ne vois pas **qui**?
you NE see not who

We can give (21b) the semantic representation (22).

(22) $*\mathtt{Q}\exists x\neg\mathtt{WHwh}y\mathtt{S}(x,y)$

With (22), we get an explanation for why (21b) is bad. The WH-phrase with its usage information remains below the scope of negation. As a result, $\mathtt{Q}$ is left without information to have namely positions available to feed to the $\mathtt{wh}x$ binder, causing a presupposition failure. The effect is a formula that cannot be evaluated, much like (15d–f).

In contrast, things are in a state of well-formedness whenever the WH-phrase is placed outside the scope of all potential interveners. Hence (21a) is okay, with its semantic representation (23).

(23) $\mathtt{QWHwh}y\exists x\neg\mathtt{S}(x,y)$

Negative subjects in French single WH interrogatives induce the same kind of intervention effects as seen with (21b), and for essentially the same reasons. Thus (24) is bad, having (25) as its semantic representation.

(24) *Aucun étudiant a lu **quoi**?
no student has read what
'What did no student read?'

(25) $*\mathtt{Q}\neg\exists x\mathtt{WHwh}y\mathtt{S}(x,y)$

In contrast, (26) is valid, with the WH-phrase outside the scope of the negative subject, yielding the representation of (27).

(26) **Qu'** est-ce qu'aucun étudiant a lu?
what is-this that-no student has read
'What did no student read?'

(27) $\mathtt{QWHwh}y\neg\exists x\mathtt{S}(x,y)$

There is one more type of construction in French involving a single WH-phrase that should be mentioned. These are the so called 'split-constructions' first discussed by Obenauer (1976). An example is (28).

(28) [$_{\text{CP}}$ [$_{\text{DP}}$ **Combien de livres**]$_1$ as-tu lus e$_1$]?
how many of books have-you read-AGR
'How many books have you read?'

In terms of their distribution, these constructions pattern identically to in-situ WH-phrases. That is, they are susceptible to intervention effects, as shown by the contrast of (29).

(29) a. [$_{\text{CP}}$ [$_{\text{DP}}$ **Combien de livres**]$_1$ n'as-tu pas lus e$_1$]?
how many of books NE-have-you not read-AGR

b. *[$_{\text{CP}}$ **Combien**$_1$ n'as-tu pas lu [$_{\text{DP}}$ e$_1$ **de livres**]]?
how many NE-have-you not read of books
'How many books have you not read?'

Our current ideas about question semantics and formation suggest the following account: it is only the `wh`-binder that gets placed in the frontmost location as the fronted operator of a split-construction, while the WH usage information remains with the nominal in-situ, under the scope of the intervener (see Butler and Mathieu 2004 for an elaboration of this account).

12.3.2 Korean

Beck and Kim (1997) observe that in Korean, intervention effects occur with interrogatives that have single or multiple WH phrases. For example, when the subject is a negative polarity item (NPI) like *amuto* 'anyone', all WH interrogatives with an unmarked word order are ungrammatical. This is because the subject NPI will require that its licensing negation scopes over everything else. A case in point is (30), which we can expect to give the uninterpretable representation (31).

(30) *Amuto **muôs-ûl** sa-chi anh-ass-ni?
anyone what-ACC buy-COMP NEG-do-PAST-`Q`
'What didn't anyone buy?'

(31) *$\mathtt{Q}\neg\exists x \mathtt{WHwh} y \mathtt{B}(x, y)$

To make an interpretable structure, the object WH-phrase must scramble to a position above the subject NPI. This is what happens in (32), which yields (33), with the usage information `WH` situated outside the scope of negation.

(32) **Muôs-ûl** amuto sa-chi anh-ass-ni?
what-ACC anyone buy-COMP NEG-do-PAST-Q
'What didn't anyone buy?'

(33) $\mathtt{QWHwh}y\neg\exists x\mathtt{B}(x,y)$

The same reasoning applies to multiple WH questions, where all WH-phrases must scramble to a scope position that is above potential interveners. For example, in (34), (a) and (b) are the only valid permutations, due to the fact that both argument and adjunct WH-phrases are scrambled over the subject NPI.

(34) a. **Ôti-esô** **nuku-lûl** amuto manna-chi anh-ass-ni?
where-LOC who-ACC anyone meet-CHI NEG-do-PAST-Q
'Where did no one meet whom?'
b. **Nukulûl ôtiesô** amuto mannachi anhassni?
c. ***Ôtiesô** amuto **nukulûl** mannachi anhassni?
d. ***Nukulûl** amuto **ôtiesô** mannachi anhassni?
e. *Amuto **ôtiesô nukulûl** mannachi anhassni?
f. *Amuto **nukulûl ôtiesô** mannachi anhassni?

In matching up the examples of (34) with their respective representations in (35), we get an account for the fall of the data.

(35) a. $\mathtt{QWHwh}z\mathtt{WHwh}y\neg\exists x\mathtt{M}(x,y,z)$
b. $\mathtt{QWHwh}y\mathtt{WHwh}z\neg\exists x\mathtt{M}(x,y,z)$
c. *$\mathtt{QWHwh}z\neg\exists x\mathtt{WHwh}y\mathtt{M}(x,y,z)$
d. *$\mathtt{QWHwh}y\neg\exists x\mathtt{WHwh}z\mathtt{M}(x,y,z)$
e. *$\mathtt{Q}\neg\exists x\mathtt{WHwh}z\mathtt{WHwh}y\mathtt{M}(x,y,z)$
f. *$\mathtt{Q}\neg\exists x\mathtt{WHwh}y\mathtt{WHwh}z\mathtt{M}(x,y,z)$

12.3.3 German Multiple WH Questions

In German WH interrogatives, a single WH-phrase must front. As (36b) shows, a WH-phrase in-situ in a single WH interrogative is ungrammatical. We will assume that WH phrases in German uniformally have the form $\mathtt{WHwh}x$. Thus German gets to circumvent all intervention effects in single WH interrogatives: the usage instruction `WH` is always placed with the WH-phrase outside the scope of potential interveners.

(36) a. **Was** hat Hans gekauft?
what has Hans bought
'What did Hans buy?'
b. *Hans hat **was** gekauft?
Hans has what bought

But interestingly, as Beck (1996b) was first to note, German *does* exhibit intervention effects with multiple WH interrogatives. That is, German will not let interveners like negation scope over WH-phrases that are under the scope of an intervener as a result of another WH-phrase taking the fronted position. Consider (37) and (39) from Beck (1996b). These give instances of multiple questions in which the nominative WH-phrase is overtly fronted. In (37), the dative NP that scopes over the accusative in-situ WH-phrase is the non-intervener *dem Karl*: the sentence is well-formed. But in (39), the dative NP is a negative quantifier *niemandem* 'nobody': the result is unacceptable.[8] The representations of (38) (for (37)) and (40) (for (39)) make exactly these predictions.

(37) **Welche Kinder** haben dem Karl **welche**
which children-NOM have the Karl-DAT which
Bilder zeigen wollen?
pictures-ACC show wanted
'Which children wanted to show Karl which pictures?'

(38) $\mathtt{QWHwh}x\exists y\mathtt{WHwh}z\mathtt{S}(x,y,z)$

(39) ***Welche Kinder** haben niemandem **welche Bilder**
which children-NOM have nobody-DAT which pictures-ACC
zeigen wollen?
show wanted
'Which children wanted to show which pictures to nobody?'

(40) *$\mathtt{QWHwh}x\neg\exists y\mathtt{WHwh}z\mathtt{S}(x,y,z)$

German has the option of scrambling its arguments. In (41), this eliminates the violation that is the downfall of (39), by lifting the accusative WH-phrase out of the scope of the negative quantifier. We get to correctly predict this with the representation of (42).

(41) **Welche Kinder** haben **welche Bilder** niemandem
which children-NOM have which pictures nobody
zeigen wollen?
show wanted
'Which children wanted to show nobody which pictures?'

(42) $\mathtt{QWHwh}x\mathtt{WHwh}z\neg\exists y\mathtt{S}(x,y,z)$

[8] Beck (1996b) notes that some speakers are able to give (39) the same range of readings that are available for (37). When we turn to look at French interrogatives with multiple-WH, we will see how our approach can accommodate this variation.

12.3.4 French Multiple WH Questions and WH*

We now turn to multiple WH interrogatives in French. In French, intervention effects only occur with single WH questions. Thus (43) shows that interveners such as *pas* 'not' and *seulement* 'only' can scope over a WH-phrase in-situ in a multiple WH question without creating problems.

(43) a. **Qui** n'a pas dit **quoi**?
who NE-has not said what
'Who didn't say what?'

b. **Qui** a parlé seulement à **qui**?
who has spoken only to whom
'Who has spoken only to whom?'

Given the findings of the last section, which focused on German, this is unexpected. To account for this French data, the idea that we will pursue is to have WH usage information that represents an unspecified number of zero or more WH occurrences. We will indicate such a usage instruction with WH*. We will use the obliqueness hierarchy of Jackendoff (1972b) and much subsequent work, that is, a series placing subject first, object next, more oblique arguments later. We will suppose that the least oblique WH-phrase carries WH*, in addition to the WH instruction that we already assumed. Other, more oblique WH-phrases, will come without any usage information. For example, this gives (43a) the representation (44).

(44) $\mathtt{QWHWH}^*\mathtt{wh}x\neg\mathtt{wh}y\mathtt{S}(x,y)$

Before an evaluation can be undertaken, an exact number of WH's will need to be specified. Thus (44) is itself an underspecified formula that to be evaluated needs first to be resolved as any one of the formulas in (45). That is, WHWH* gets to be replaced by one or more occurrences of WH.

(45) a. $^*\mathtt{QWHwh}x\neg\mathtt{wh}y\mathtt{S}(x,y)$

b. $\mathtt{QWHWHwh}x\neg\mathtt{wh}y\mathtt{S}(x,y)$

c. $^*\mathtt{QWHWHWHwh}x\neg\mathtt{wh}y\mathtt{S}(x,y)$

etc.

Hence (43a) is found to be interpretable, with the specification of (45b). That all the alternative specifications should lead to uninterpretable representations is of no consequence. All that is needed, to establish grammaticality/felicity, is that one specification is okay. It follows that, provided the WH-phrase with WH* makes its impression on the $q(\phi)$ count that Q invokes, there will be no intervention effects, as sufficient support to feed all of the `wh`-bindings will be assured.

Note that this revision does not change any of our previous findings for French, we simply need to exchange instances of `WH` with `WHWH`*. But also note that we should not do this for either Korean or German.

12.3.5 English

We can suppose that the analysis just outlined for French carries over to English. The only difference is that English always fronts a WH-phrase, and so intervention effects with WH-phrases overtly in-situ almost never occur. However, there is one context where intervention effects are predicted, namely, when the WH-phrase with `WHWH`* is left in-situ to fall under the scope of an intervener owing to some other WH-phrase having occupied the sentence initial position. We assumed that the least oblique WH-phrase gets to carry `WHWH`*. This is usually the WH-phrase that is required to occupy the sentence initial position, as (46) shows. This is the so called *superiority effect*.

(46) a. **Who** liked **what**?
b. ***What** did **who** like?

However the superiority effect breaks down when the WH-phrases are D-linked. For example, the exchange in (47) is perfectly okay.

(47) Q: **Which book** did **which person** read?
A: John read Aspects and Mary read LGB and ...

This provides the right conditions for intervention effects to occur. A relevant paradigm is given in (48), attributed to É Kiss by Pesetsky (2000).

(48) a. **Which person** did not read **which book**?
b. **Which person** didn't read **which book**?
c. **Which book** did **which person** not read?
d. ***Which book** didn't **which person** read?

Given our assumptions, the examples of (48) can be matched up with the representations of (49).

(49) a. $\mathtt{QWHWH}^*\mathtt{wh}x\mathtt{wh}y\neg\mathtt{R}(x,y)$
b. $\mathtt{QWHWH}^*\mathtt{wh}x\neg\mathtt{wh}y\mathtt{R}(x,y)$
c. $\mathtt{Qwh}y\mathtt{WHWH}^*\mathtt{wh}x\neg\mathtt{R}(x,y)$
d. $^*\mathtt{Qwh}y\neg\mathtt{WHWH}^*\mathtt{wh}x\mathtt{R}(x,y)$

In (48a)/(49a), `WHWH`* is placed frontmost, outside the scope of any potential intervener. Likewise, (48b)/(49b) is okay. Despite `WHWH`* occurring with the in-situ subject WH-phrase in (48c)/(49c), negation does not scope over `WHWH`*, having been placed low in the clause. Finally, in (48d)/(49d), negation is placed with *did* at a scope position above the in-situ subject WH-phrase carrying WHWH*. This brings about an intervention effect, with negation scoping over WHWH*. That is, no matter how (49d) gets specified, the WH occurrences will all fall under the scope of negation and thus they will be invisible to Q.[9] Some specified options showing this are illustrated in (50).

(50) a. *Qwh$y\neg$WHwh$x$R(x, y)
b. *Qwh$y\neg$WHWHwh$x$R(x, y)
c. *Qwh$y\neg$WHWHWHwh$x$R(x, y)
etc.

Note that this analysis is further supported by the fact that the word order in (48d), minus the intervener, is perfectly okay, as (47) showed, which gives rise to the specified representations of (51), with crucially (51b) being interpretable.

(51) a. *Qwh$y$WHwh$x$R(x, y)
b. Qwh$y$WHWHwh$x$R(x, y)
c. *Qwh$y$WHWHWHwh$x$R(x, y)
etc.

Now consider the contrast in (52) in which an adjunct WH-phrase is fronted. While (52a) has a reading where *why* applies to the embedded clause as indicated by '~~why~~', (52a) does not.

(52) a. **Why** do you think [~~why~~ John talked to Mary]?
b. ***Why** don't you think [~~why~~ John talked to Mary]?

This contrast seems all the more surprising, since, as (53) shows, an argument WH-phrase in a frontmost position is still able to link up to its argument position when this is inside an embedded clause under the scope of negation.

(53) **Who** don't you think John talked to?

We can already say why (53) is okay. It has a frontmost argument WH-phrase that carriers WHWH*, yielding the interpretable (54).

(54) QWHWH*wh$x\neg$you_think(john_talked_to(x))

To predict (52b), we need to be able to claim that the usage information for supporting the question is placed at the location indicated

[9]Arguably, (48d) has a reading under an echo interpretation for the in-situ WH-phrase. The availability of this reading poses no problem for the current analysis, since under an echo reading the fronted WH-phrase would place WHWH* outside the scope of the intervener, being the *only* and hence least oblique questionable WH-phrase.

by "~~why~~", despite the WH-phrase overtly occurring as the frontmost element. That is, we expect to give (52b) a representation like (55).

(55) *Qwh$x\neg$you_think(WHWH*john_talked_to_mary(x))

Justification for (55) as a representation can be found with the idea that the placement of the usage information indicates where the WH-phrase is intended to apply, that is to the embedded clause rather than the matrix clause. Such strategic placement of the usage information was not a consideration in (54), since the argument WH-phrase never had any other option but to link to its argument position. This reasoning is essentially a repackaging of Williams' (1994) suggestion that the difference between (52b) and (53) is a consequence of arguments entering into both a scope relation and a theta-theoretic relation with the sentence they occur in, while adjuncts have only a scope relation.

We can assume that this account carries over to the WH-island data in (56), with *whether* leading the $q(\phi)$ count to bottom out at 0, much like negation. (See section 12.4 for a more detailed coverage of embedded questions.) Thus, while (56a) is okay with its argument WH-phrase, yielding (57a); (56b) is bad under a reading where the non-argument WH-phrase *why* applies to the fixing of the car, as indicated by '~~why~~', yielding (57b), which cannot be evaluated.

(56) a. **What** do you wonder whether to fix?
b. ***Why** do you wonder whether ~~why~~ to fix the car?

(57) a. QWHWH*wh$x$you_wonder(Qyou_fix(x))
b. *Qwh$x$you_wonder(QWHWH*you_fix_car(x))

Moreover, we can see that the same reasoning extends to the distributional restrictions placed on all other WH-phrases that, for whatever reason, have their scope restricted. For example, we can see that it extends to argument WH-phrases that have their scope restricted by occurring in an existential *there* construction.[10]

First, we note that a question like (58) is ambiguous.

(58) **How many people** do you think I should talk to?
a. QWHWH*wh$n\exists x^{|x|=n}$you_think(i_should_talk_to(x))
For what n: there are n-many people x, such that you think I should talk to x. (outer reading)
b. Qyou_think(WHWH*wh$n\exists x^{|x|=n}$i_should_talk_to(x))
For what n: you think I should talk to n-many people. (inner reading)

[10] Other constructions that invoke the same restriction on scope include the full range of so called *antipronominal contexts*, as cataloged in Postal (1998).

We see from (58a,b) that the resulting effect of a question like (58) is to always give the questioned part of the WH-phrase, namely n in the representations, matrix scope, irrespective of where $\mathtt{wh}n$ is placed in the expression. This is because, while $\mathtt{wh}n$ is itself a binding operator, it in turn picks up the value for its binding from $\mathtt{Q}$, which takes matrix scope. What gives the difference in interpretations of (58a,b) is the placement of the existential introducing *people*, which can be interpreted *de re* to give reading (58a) or *de dicto* to give reading (58b).

As (59) shows, in contrast to (58), a *how many* WH-phrase occurring in an existential *there* construction has only an in-situ interpretation.[11]

(59) **How many people** do you need there to be at the meeting?

a. $^*\mathtt{QWHWH}^*\mathtt{wh}n\exists x^{|x|=n}\mathtt{you\_need(there(at\_meeting(}x\mathtt{)))}$
For what n: there are n people x such that you need x to be at the meeting. (outer reading; not available)

b. $\mathtt{Qyou\_need(there(WHWH}^*\mathtt{wh}n\exists x^{|x|=n}\mathtt{at\_meeting(}x\mathtt{)))}$
For what n: you need there to be n people at the meeting. (inner reading)

A question like (60) has its inner reading barred, since this gives an intervention effect.[12]

(60) **How many dogs** has Karl not fed?

a. $\mathtt{QWHWH}^*\mathtt{wh}n\exists x^{|x|=n}\neg\mathtt{karl\_fed(}x\mathtt{)}$
For which n: there are n dogs that Karl didn't feed. (outer reading)

b. $^*\mathtt{Q}\neg\mathtt{WHWH}^*\mathtt{wh}n\exists x^{|x|=n}\mathtt{karl\_fed(}x\mathtt{)}$
For which n: it is not the case that Karl fed n dogs. (inner reading; not available)

It follows from (59) and (60) that (61), in contrast to (58), is expected to be bad. Its outer reading is barred by the existential *there* context and its inner reading is barred since it creates an intervention effect.

(61) ***How many people** don't you think there were at the meeting?

[11] We will not provide an account for why the presence of `there` rules out (59b), but it is tempting to think that this constraint follows from `there` requiring countable usage information to be present in the post-copula position. This would give an account much along the lines of Heim (1987) and Blutner (1993).

[12] To distinguish the outer reading from the inner reading of (60), Beck (1996b) provides the following context: suppose there are 5 dogs altogether; Karl has fed 3 of them, but he has not fed the other two. If someone asks (60), the only possible true answer is 'two', meaning: there are two dogs that Karl hasn't fed. It would not be possible to truthfully answer 'four', meaning: it is not the case that Karl has fed four dogs. This should be possible if (60) had reading (60b) in addition to (60a).

a. $*\texttt{QWHWH}^*\texttt{wh}n\exists x^{|x|=n}\neg\texttt{you\_think(there(at\_meeting(}x\texttt{)))}$
For what n: there are n people x such that you don't think x were at the meeting. (outer reading; not available)

b. $*\texttt{Q}\neg\texttt{you\_think(there(WHWH}^*\texttt{wh}n\exists x^{|x|=n}\texttt{at\_meeting(}x\texttt{)))}$
For what n: you don't think there were n people at the meeting. (inner reading; not available)

12.3.6 Chinese and WH*

The standard view in the literature on Chinese is that its WH-phrases are pure variables that acquire different interpretations when bound by different operators (see e.g., Cheng 1991, Aoun and Li 1993, Shi 1994, Tsai 1994). This can be seen in the examples of (62) from Ouhalla (1996).

(62) a. Ta gen **shei** shuohua ma?
he with whom speak Q
'Did he speak with someone?'

b. **Shenme** ta dou yao.
what he all want
'He wants everything.'

c. Ta bu xihuan **shenme**.
he not like what
'He does not like anything.'

In (62a) the WH-phrase *shei* 'whom' has an existential reading induced by the yes/no question particle *ma*. In (62b) the WH-phrase *shenme* 'what' has a universal reading induced by the quantificational element *dou* 'all'. Finally, in (62c) *shenme* has an NPI reading induced by the negation marker *bu* 'not'. It follows that a WH-phrase like *shenme* should have no more structure than is given in (63).

(63) shenme := $\texttt{wh}x \mid \exists x$

That is, *shenme* gives a binding instruction, but the type could be either a WH-binding or non-WH-binding. A conceivable consequence of this is that when *shenme* provides a WH binding, it fails to come with any usage information of its own. Under the account of questions that we have developed, this is only possible if Chinese matches this lack of usage information on phrases like *shenme* with an interrogative operator that carries its own usage information. We will assume that the interrogative operator carries a usage instruction WH*, which provides support for an unspecified number of WH occurrences, including the possibility of no occurrences. An example representation for (64) is given in (65). Since the interrogative operator introduces its own usage information $\mathtt{WH}^*$, it effectively behaves like an unselective binder, licensed to impart values for any of the bindings within its scope that can be specified as WH-bindings.

(64) Ta mai-le **shenme**?
he buy-PERF thing
'What did he buy?'

(65) $\mathtt{QWH}^*\exists x\mathtt{wh}y\mathtt{S}(x,y)$

It follows from this analysis that Chinese is predicted to never exhibit intervention effects, since the usage information the interrogative operator introduces for itself can never be adversely effected by an intervener's presence. Thus *mei* 'not' scoping over the WH-in-situ in (66) is okay.

(66) Ta mei chi **shenme**?
he not eat thing
'What didn't he eat?'

(67) $\mathtt{QWH}^*\exists x\neg\mathtt{wh}y\mathtt{S}(x,y)$

Similarly, the negative quantifier *meiyouren* 'nobody' is able to scope over the WH-in-situ in (68).

(68) Meiyouren gan gen **shei** dajia?
nobody dare with person fight
'Who will nobody dare fight?'

(69) $\mathtt{QWH}^*\neg\exists x\mathtt{WH}y\mathtt{F}(x,y)$

There is a caveat for this analysis however: WH-adjuncts in Chinese are different, as they *do* show intervention effects, as the contrast of (70) shows.

(70) a. Ni renwei Lisi **weishenme** cizhi?
you think Lisi why resign
'Why do you think Lisi resigned?'

b. *Ni bu renwei Lisi **weishenme** cizhi?
you not think Lisi why resign
'Why don't you think Lisi resigned?'

To bring this observation in line with our account, we need to assume that $\mathtt{WH}^*$ provides support only for argument WH-phrases. Consequently, to license a WH-adjunct, Chinese $\mathtt{Q}$ needs to receive usage information from the WH-adjunct itself. Support for this comes from the fact that *weishenme* 'why' can only be interpreted as a WH-phrase, that is, unlike its argument counterparts, it does carry WH-usage information. Moreover this assumption can be viewed as having deeper

TABLE 1 WH distribution

Language	no WH*, only WH's	WHWH* with WH_1	WH* with Q
Korean	yes		
German	yes		
French		yes	
English		yes	
Chinese			yes

roots as it seems to be closely related to Rizzi's (1990) referential/non-referential variable distinction, and Williams' (1994) claim that an adjunct does not have a theta-theoretic relation with its sentence.

12.3.7 Summary

Table 1 gives a summary of the proposed distribution of WH usage information cross-linguistically. WH_1 refers to the least oblique WH-phrase. These are the only differences we need to assume between languages to account for the diversity observed. The resulting account is similar, at least in spirit, to, Watanabe (1992), Aoun and Li (1993), Tsai (1994) and Cole and Hermon (1998), among others, who assume a question operator that is universally generated as a null operator (for which our Q makes an appropriate analog) and that contentive WH-phrases are universally variables (for us, they are wh-bindings that get the values for their bindings via Q). But the account squares just as well with authors, such as Cheng (1991) and Haspelmath (1997), who claim that WH-phrases are like indefinites. The key innovation is the idea that to have values under question to impart to the wh-bindings, Q is taken to rely on the presence of WH usage information (WH). When WH-phrases carry WH or WHWH*, they need to be positioned outside the scope of potential interveners (like negation), else they leave an expression that is infelicitous/ungrammatical, that is, an expression that cannot be evaluated.

12.4 Embedding Q

So far we have concentrated on occurrences of matrix Q. But, of course, questions can be embedded. And questions can be embedded in questions, etc. This gives rise to some interesting scope facts that can be easily modelled from our current perspective. But first we need to slightly adjust the semantic definition of Q to allow for an embedded Q to inherit what is left over from the WH namely sequence of a prior Q. We can do this with (71), together with the extensions to the $n(\phi)$ and $q(\phi)$ counts in (72).

(71) $$[\![\mathtt{Q}\phi]\!]_{\omega,g} = \begin{cases} \{\omega' \in D^{q(\phi)} \mid \exists\sigma \in D^{n(\phi)} : \omega'\omega, \sigma \models_g \phi\} & \\ \qquad \text{if } \exists\omega' \in D^{q(\phi)}, \sigma \in D^{n(\phi)} : \omega'\omega, \sigma \models^{\mathrm{p}} \phi & \\ error \quad \text{otherwise} & \end{cases}$$

(72) $n(\mathtt{Q}\phi) = 0$; $q(\mathtt{Q}\phi) = 0$

We also need to give a semantics to verbs such as *remember* that can take interrogative complements, but to keep things simple we will ignore this complication, since it is not the essential ingredient for the analysis, rather the revision of (71) is.

We have seen that in multiple WH questions in English, WH-phrases appear both raised and in-situ. Baker (1968) studied multiple WH questions with embeddings and found that while in-situ WH-phrases can take semantic scope beyond the immediately enclosing interrogative, raised ones cannot. For example, (73) has three WH-phrases, two of which are in an embedded interrogative. The question is ambiguous between two readings, which we can distinguish with different answer types, demonstrated with (73a) and (73b). Intuitively, to give answer (73a), the final WH-phrase, *what*, needs to be interpreted as taking wide scope; while for (73b), *what* takes narrow scope.

(73) Who remembers where we bought what?
   a. John remembers where we bought the vase.
   b. John remembers where we bought what.

Exactly the same contrast is found with (74), with the final WH-phrase, *whom*, taking either wide scope (74a), or narrow scope (74b).

(74) Who do you think remembers what we bought for whom?
   a. I think John remembers what we bought for Mary.
   b. I think John remembers what we bought for whom.

Just as we see that in-situ WH-phrases have the potential for different scope options, (73) and (74) also show that raised WH-phrases must take semantic scope exactly over the clause they are overtly raised to. Thus, in (74), *who* must take wide scope, and *what* must take narrow scope. Only *whom* has ambiguous scope; accordingly, the question has only 2 readings, not 4 or 8.

We can expect to give (74) the representation (75). This has the matrix interrogative with a $\mathtt{WHWH}^*$ contributed by *who*; and the embedded interrogative with its own $\mathtt{WHWH}^*$ contributed by *what*.

(75) $\mathtt{QWHWH}^*\mathtt{wh}x\,you\_think(rember(x, \mathtt{QWHWH}^*\mathtt{wh}y\mathtt{wh}z\,we\_buy\_for(y,z)))$

To be interpreted, (75) needs to be further specified along the lines of (76). That is, the instances of $\mathtt{WHWH}^*$ need to be specified as one or more occurrences of $\mathtt{WH}$.

(76) a. *$\texttt{QWHwh}x\,you\_think(rember(x, \texttt{QWHwh}y\texttt{wh}z\,we\_buy\_for(y, z)))$
b. $\texttt{QWHwh}x\,you\_think(rember(x, \texttt{QWHWHwh}y\texttt{wh}z\,we\_buy\_for(y, z)))$
c. $\texttt{QWHWHwh}x\,you\_think(rember(x, \texttt{QWHwh}y\texttt{wh}z\,we\_buy\_for(y, z)))$
d. *$\texttt{QWHWHwh}x\,you\_think(rember(x, \texttt{QWHWHwh}y\texttt{wh}z\,we\_buy\_for(y, z)))$
etc.

The ambiguity of (74) falls out from the possible forms of (76), two of which are interpretable, namely, (76b) and (76c). The form of (76b) supports one `wh`-binding for the matrix and two for the embedded interrogative. This gives an interpretation for which the answer of (74b) is appropriate: the in-situ WH-phrase takes narrow scope. The form of (76c) supports two `wh`-bindings for the matrix and one for the embedded interrogative. Only one `wh`-binding occurs in the matrix and so the embedded interrogative inherits a value from the WH namely sequence of the matrix. This gives the interpretation where the in-situ WH-phrase of the embedded interrogative gets to take matrix scope, for which (74a) is an appropriate answer. Note that the value inherited from the matrix can only be taken up by the in-situ WH-phrase, since the embedded interrogative itself must contribute at least one WH namely value which is placed first to be popped, with the result that the 'fronted' WH-phrase, being the first occurrence of a `wh`-binding, has to scope with the embedded interrogative.

12.5 Conclusion

In this paper we introduced a semantics for interrogatives with a set up motivated by the need to give an appropriate semantics for indefinites. We saw how, with such a semantics, we could treat WH-phrases basically like indefinites, that is, as binders that might have usage information to ensure their support. We saw how the options left available for the distribution of usage information placed restrictions on the forms expressions could take and that this matched up with the range of variation exhibited by WH questions cross-linguistically. While agreeing with the status of WH-phrases as indefinites, the account was shown to be just as consistent with the view of WH-phrases as variables, since their semantics was such that they would pop a namely position (targeted for WH) to take as the value for their binding. This in turn showed how wide scope options were available from in-situ positions, and this without any need for covert movement or WH-raising between surface syntax and the interpretable form. Finally, we saw how, as a consequence of the way WH-phrases obtain their binding value, only in-situ appearances of WH-phrases could have ambiguous semantic scope.

Acknowledgements

Thanks to Paul Dekker, Andreas Haida, Eric Mathieu and Henk Zeevat for valuable input. The research for this work is supported by a grant from the Netherlands Organization for Scientific Research (NWO) for the project *Formal Language Games*, which is gratefully acknowledged.

13

Nuclear Rises in Update Semantics

Marie Šafářová

Abstract

The main goal of this paper is to argue for an analysis of final rises in American English as 'intonational adverbs' expressing epistemic uncertainty. Furthermore, it is suggested that the question-like behavior of declaratives with final rises can be derived as a secondary effect from maxims of rational conversation and is not directly due to their intonational properties. The advantage of this approach is that it allows us to keep the semantics of sentence types uniform. The meaning of final rises is expressed in formal semantic terms as Veltman's test operator, in the framework of update semantics, enriched with a simple semantics for polar questions. A part of the formalization is also the formulation of Grice's maxims of quality, quantity and relation.

13.1 Introduction

The semantics of intonation is notoriously difficult to capture formally and it has even been suggested that its meaning is metaphorical, non-denotational and non-compositional (a.o., Cook 2002, from the perspective of a cognitive psychologist), and fundamentally related to speaker's emotions rather than rational linguistic behavior. Since there is no general consensus on what the smallest meaningful intonational units are, it makes sense to focus on sentence melody as a carrier of information. In many languages it is used to express questions and even in languages

Questions in Dynamic Semantics.
Maria Aloni, Alastair Butler and Paul Dekker (eds.).
Current Research in the Semantics/Pragmatics Interface, Vol. 17.

which possess the means to render questions morphosyntactically (e.g., in English with subject-predicate inversion, or in French, with inversion or the *'est-ce que'* phrase), intonation can still "turn" statements into questions.[1]

In general, *yes/no*-questions are usually reported to be associated with a rising contour, presence of a high pitch and/or a high boundary. Experimental evidence also confirms that rising contours facilitate questions recognition. It is thus rather tempting – and, in fact, common in many typological and semantic studies – to identify rising intonation with question intonation. Undermining this view, however, are the results of corpus studies which show that there are questions (including many declarative questions) without rise, and, crucially, rises which do not express questions. Moreover, final rise in general is associated with a number of other meanings, such as checking whether the audience has understood what is being said, maintaining speaker-hearer solidarity, politeness, tentativeness, non-conduciveness, reservations and conciliatory attitude, friendliness, uncertainty, submissiveness and pleasantness. Gussenhoven (2004), following Ohala (e.g., Ohala, 1984), considers many of these to be affective meanings of questioning. This view, however, has been disputed by van Alphen (2003), on the grounds that questions are normally used as a floor-getting device and their role in a dialogue is to assert a discourse topic and to commit the dialogue participants to its resolution – acts which cannot easily be characterized as submissive or uncertain.[2]

In this paper, I first discuss existing semantic analyses of the rise shortly (Pierrehumbert and Hirschberg, 1990 and Gunlogson, 2001, with a reference to Merin and Bartels, 1997 and Steedman, 2004) and subsequently offer an alternative which can reconcile the somewhat conflicting empirical observations regarding the use of rise in questions, as briefly summarized above. Throughout, I make use of the results of the experiments by Šafářová and Swerts (2004) and Šafářová (2005) which show that while some contours in American English are more likely to be perceived as signaling questions – in particular those described by Gunlogson (2001) – they are neither sufficient nor necessary for this end. Combined with the observation that the contours can also appear on statements and that they are associated with a number of other

[1] In a large spoken corpus of American English free conversations, 'declarative questions' were counted more frequent than interrogative questions, i.e., questions expressed by means of syntactic inversion. French is even further in that inverted and *est-ce que*-sound unnatural to native speakers outside of high register contexts.

[2] Similarly, Bartels and Merin 1998:98 recall Bolinger's remark that "questions oscillate between the force of requests and that of orders".

meanings (though not, it seems, continuation, viz below), the idea that their semantics could be expressed solely in terms of questionhood is not tenable. At the same time, however, the semantic analysis has to account for the close association of rises with questions, and for the fact that their meaning is not 'weaker' than that of the lexical-pragmatic features of the utterance Šafářová and Swerts (2004).

I will suggest that these properties of the final rise can be captured in a uniform way if we take its meaning to be that of a modal expression of uncertainty. Formally, I express the meaning in terms of Veltman's $\Diamond$-operator, defined originally for expressions such as *it might be that* as introducing tests on the content of the common ground Veltman (1996). I offer a simple update semantics for both the $\Diamond$ and the ? operators which is a combination of Veltman's update semantics with a question semantics for propositional formulas and I represent rising declaratives as $\Diamond\phi$-type of statements, rising interrogatives as $?\Diamond\phi$ and falling interrogatives and indicatives as $?\phi$ and ϕ, respectively. One advantage of the proposal is that the relation between syntactic and semantic types is kept uniform, i.e., all syntactic declaratives are analyzed as statements. We can thus do away with the "hybrid" category of declarative questions, utterances with declarative syntax but the contextual behavior of questions. For example, a declarative question like *'Those are not all related languages* $\uparrow$' (where $\uparrow$ symbolizes a final rise) is semantically analyzed as $\Diamond$ *those are not all related languages*, comparable to the statement 'It might be that those are not all related languages'. I argue that the fact that this utterance would usually receive a reply from the addressee is due to the maxims of rational conversation which force the participants to address the issue under discussion and to make the strongest possible statement given their state of knowledge. A part of the analysis is a formalization of Grice's maxims of quality, quantity and relation which I use to explain why statements of the kind $\Diamond\phi$ and questions like $?\Diamond\phi$ are not redundant in discourse, despite their semantics (according to which an update with $?\Diamond\phi$ does not disconnect any worlds in the context and an update with $\Diamond\phi$ does not change the context unless there are no worlds making ϕ true). We can thus account pragmatically for what is sometimes considered a weak point of Veltman's semantics for possibility. It follows straightforwardly from the analysis that rising declaratives are sometimes interpreted as indicating politeness, tentativeness and other affective states. On a more general level, the approach shows that it is possible to address the semantics of intonation in a formal way without ignoring its 'emotional' aspects.

13.2 Empirical Observations

In this section, I sum up the properties of the 'final rise' relevant for a semantic account. Hence on, I will use the term 'final rise' as defined by Gunlogson (2001), i.e., as a nuclear contour which is non-falling and ends higher than the nuclear pitch accent. These contours have been found to be the best predictor of questioning Šafářová and Swerts (2004). I will symbolize the final rise by ↑ and the final fall by ↓.[3]

For details on the empirical claims summarized below, see, among others, Uldall (1962), Fries (1964), Pierrehumbert (1980), Hirschberg and Ward (1995), McLemore (1991a), McLemore (1991b), Hirschberg (2000), Chen et al. (2001), Chen and Gussenhoven (2003), Gunlogson (2001) and Šafářová (2005).

13.2.1 Summary of the facts

(I) Final rise is possible but not necessary with inverted *yes/no*- and *wh*-questions — compare, for instance, the realization of the question '*Can I help you?*' with a high rise in figure 1 and a fall in figure 2.

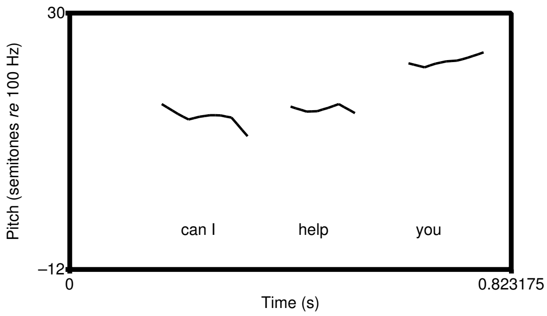


FIGURE 1 A high-rising question (H*H-H%) with the nuclear pitch accent on 'help'. [speaker L.M.]

(II) Final rise is possible on declaratives, as on the utterance '*he gets sick leave*↑' in figure 3.

[3]Note that the definition of final rises I use here excludes fall-rise, as in (i) from Hirschberg (1985).

(i) Speaker A: *do you speak Portuguese?*
Speaker B: *my husband*$_{H*}$ *does*$_{L-H\%}$

For a semantic analysis of fall-rises, see Bartels and Merin (1998).

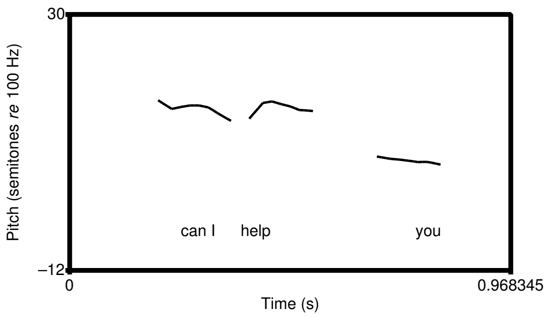


FIGURE 2 A falling question (H*L-L%) with the nuclear pitch accent on 'help'. [speaker L.M.]

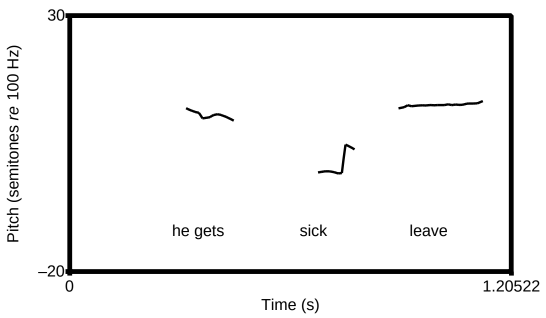


FIGURE 3 A low-rising declarative with the nuclear pitch accent on 'sick' (Santa Barbara Corpus).

(III) Rising declaratives can receive at least three different interpretations:

(i) Some rising declaratives do not result in a commitment from either the speaker or the addressee: e.g., **biased questions**, where the addressee is often considered an expert on the issue, as in (1), or **try-out statements** where the speaker is stating a likely hypothesis, as in (2-b):

(1) *you're leaving for vacation today*↑

(2) a. Speaker A: *John has to leave early*
 b. Speaker B: *he'll miss the party then*↑

(ii) Some rising declaratives result in speaker's commitment: e.g.,

checking statements where the speaker conveys new information but wants to keep contact with the addressee, as in (3), or **informative statements** expressing polite, submissive and/or uncertain attitude, as in (4-b):

(3) a. Speaker A: *I put a sign-up sheet over on the board*↑
b. Speaker B: *it's for Dad's Day*↑

(4) a. Speaker A: *how did you like the movie?*
b. Speaker B: *I thought it was good*↑

(iii) Some rising declaratives are only used in case of a previous commitment from the addressee, as in **echo questions**, viz (5-b).

(5) a. Speaker A: *that copier is broken*
b. Speaker B: *it is*↑ *thanks, I'll use a different one*

(IV) All these types of rising declaratives usually elicit a response from the addressee or give the impression of the response being welcome, i.e., they are question-like.

(V) However, in context, rising declaratives are not interchangeable with interrogative polar questions because they often convey a certain bias of the speaker, viz (6).[4]

(6) [as an exam question]
a. *is the empty set a member of itself?*
b. # *the empty set is a member of itself*↑

(VI) Rising utterances are considered to be more polite and friendly, but less confident, cmp. the minimal pair below, with a falling (7-b) and its rising version in (7-c).

(7) a. Speaker A: *what did you think of the movie?*
b. Speaker B: *I thought it was good*↓
c. Speaker B': *I thought it was good*↑

(VII) Final rise is not associated with continuations, i.e., it differs from the comma intonation (symbolized here as →) sometimes found sentence-internally on major phrase boundaries, as in (8).

(8) *I don't want shrimp* → *I want lobster.*

(VIII) The meaning of the final rise is not weaker than the lexical-

[4] The # symbolizes a semantically anomalous sentence.

pragmatic features of an utterance. For example, predicates which denote intimate experiences normally match with questions if the subject/experiencer is the addressee (second person singular) and with assertions if the subject is the speaker (first person singular). However, the absence of a final rise on the hetero-cognitive predicate in (9-b) results in an assertive interpretation, while the presence of a final rise on the auto-cognitive predicate in (10-b) creates a questioning effect. This observation suggests that intonational properties can override the conventional interpretation of the predicates (for experimental evidence, see Šafářová and Swerts (2004)).

(9) a. *it's bothering you*↑
 b. *it's bothering you.*

(10) a. *it's bothering me.*
 b. *it's bothering me*↑

In an ideal case, a semantic theory of the final rise should account for all the facts listed above. In the following subsections, I will discuss two existing semantic proposals from this perspective, Pierrehumbert and Hirschberg (1990) and Gunlogson (2001). I will also make reference to related proposals by Gussenhoven (1984), Merin and Bartels (1997) and Steedman (2004).

13.3 Existing Proposals

13.3.1 Pierrehumbert & Hirschberg (1990)

Pierrehumbert & Hirschberg suggest that particular tunes specify the relationship between the propositional content of the utterance over which they are employed and the mutual beliefs of the conversation participants. With the intonation grammar of Pierrehumbert (1980) and subsequent work by Beckman and Pierrehumbert (1986) at its core, the meaning of individual tones (specified below) combines in a strictly compositional way to give the resulting meaning of a contour. The proposed system is somewhat schematically summarized below.

H* - the accented item should be treated as new in the discourse; instantiated proposition should be added to the mutual beliefs
L* - the accented item should be excluded from the proposition the speaker wishes to add to the mutual beliefs
L+H* - evokes a salient scale and conveys that the accented item should be mutually believed
L*+H - lack of speaker's commitment to the proposed scale
H*+L - support for proposition being true can be inferred from the mutual beliefs
H+L* - same as H*+L?
H- - the intermediate phrase should be interpreted together with the following phrase
L- - the intermediate phrase should be interpreted separately from the

following phrase
H% - the intonational phrase is forward-looking
L% - the intonational phrase may be interpreted without reference to the following one

Pierrehumbert & Hirschberg's proposal is interesting in its broad outlines, in that it assumes compositionality of the tone meaning and takes intonation to signal relations to the mutual beliefs of discourse participants, but the exact semantics remains rather informal and is not quite supported by the data. As for H*H-H%, sometimes referred to as the *high rise*, Pierrehumbert & Hirschberg suggest that it is used in questions which at the same time convey new information, as opposed to L*H-H%, which, according to the authors, is a question tune that does not convey new information (the L* tone indicating that the unit carrying the pitch accent is old news). McLemore (1991a) and McLemore (1991b), however, gives examples from her corpus of checking statements (i.e., statements conveying new information where the speaker uses the final rise because she wants to maintain contact with her audience) with L*H-H%, as in (11). She notes that "[the speakers] often use L*[with a high boundary] in the first intonational phrase of a monologue when other participants are assumed to have equal rights to the speaking floor" (p. 79). It is unclear how Pierrehumbert & Hirschberg's description would apply to these contexts.

(11) *y'all I was gonna* $tell_{L*}$ $y'all_{H-H\%}$

As for L*L-H%, the authors take it to be signaling the continuation rise, an assumption that has not been supported by experimental evidence (viz the references above). They also associate the high boundary tone with a forward-looking function but the boundary tones do not appear to behave uniformly with respect to question identification. The idea of the H% tone having a 'forward-looking function' is not unintuitive, but it is not immediately obvious what the function does in a formal semantic or pragmatic sense. One could speculate that a tone with this function should not occur at points of (sub)-dialogue closure (in the sense in which it is discussed, e.g., by Muller and Prévot, 2003) but there is not enough empirical evidence at this point to prove whether this proposal is sustainable or not. Note also that Pierrehumbert & Hirschberg's system does not explain why rising declaratives convey a speaker bias and are not interchangeable with interrogatives.[5]

[5]Chen (2004) summarizes other weak points of Pierrehumbert & Hirschberg's proposal, such as the independent reality ascribed to H* and L+H*, which is highly questionable in intonational practice, and the combination of phrase accents with boundary tones (e.g., H-L% or L-%H), which appears to be difficult to interpret in

13.3.2 Gunlogson (2001)

Gunlogson's proposal is in the spirit of Pierrehumbert & Hirschberg in that it also takes the semantics of intonation to be expressing beliefs and mutual beliefs of participants about the truth of the conveyed proposition. Unlike the authors above, however, she is not concerned with the meaning of individual tones but with the contours of nuclear phrases as a whole. Disregarding interrogatives, Gunlogson focuses on the instances of final rises on syntactic declaratives and makes the following observations:

- Rising declaratives express a bias that is absent with the use of interrogatives; they cannot be used as neutral questions.
- Rising declaratives, like interrogatives, fail to commit the speaker to their content.
- Rising declaratives can only be used as questions in contexts where the addressee is already publicly committed to the proposition expressed ('Contextual Bias Condition').

As an illustration of the first point, consider the example in (12): while the interrogative in (12-a) is acceptable in a context that has to be neutral, both the rising declarative in (12-b) and the falling declarative in (12-c) are excluded.

(12) [by an insurance officer]
a. *Are you married?*
b. # *You're married?*
c. # *You're married.*

Gunlogson argues that the reason why (12-b) and (12-c) cannot be used in the context of a legal investigation is that they express a bias for the contained proposition being true.

As for the second and third observation, consider the exchange in (13):

(13) a. Speaker A: *the king of France is bold*
b. Speaker B: *France is a monarchy*↑

The rising declarative in (13-b) clearly does not commit the speaker B to the truth of its content, rather, it questions a presupposition to which the speaker A has committed herself by using (13-a).

In the semantics Gunlogson assigns to rises to account for these facts, her approach is closely related to that of Merin and Bartels (1997)

the proposed system.

who propose that rises 'alienate choices to Alter' (the addressee), while falls 'appropriate choices to Ego' (the speaker), and Steedman (2004) for whom the H% versus L% boundary tone distinction correlates with the 'ownership' of the content expressed. Specifically, Gunlogson implements the hypothesis that rising declaratives commit the addressee to the proposition expressed, while falling declaratives commit the speaker. First of all, she suggests that the context C can be viewed as composed of the commitment sets of conversation participants, cs:

> **[Context]** Let a discourse context $C_{\{A,B\}}$ be $\langle cs_A, cs_B\rangle$, where A and B are discourse participants:
> cs_A of $C_{\{A,B\}}$ = {w ∈ W: propositions representing A's public beliefs are all true of w}
> cs_B of $C_{\{A,B\}}$ = {w ∈ W: propositions representing B's public beliefs are all true of w}

The meaning of a rising declarative, $\uparrow S_{decl}$ is defined in terms of its context changing potential as:

> **[Meaning of the Rise]** C + $\uparrow S_{decl}$ = C' such that:
> a. cs_{spkr}(C') = cs_{spkr}(C)
> b. cs_{addr}(C') = cs_{addr}(C) + S_{decl}

For falling declaratives, its context changing potential is defined as follows:

> **[Meaning of the Fall]** C + $\downarrow S_{decl}$ = C' such that:
> a. cs_{spkr}(C') = cs_{spkr}(C) + S_{decl}
> b. cs_{addr}(C') = cs_{addr}(C)

Note, however, that Gunlogson's description of the rise in terms of changing the commitment set of the addressee, does not really capture the observation made with respect to (13), that rising declarative can question a commitment already made by the addressee in the context. But even that condition is in general too strong; rising declarative questions are also used and recognized in contexts where the addressee is not publicly committed *to the truth* of the expressed proposition, but at most to *knowing whether* the proposition is true or not, given that he or she is regarded as an expert on the issue (14-b).[6]

(14) a. Speaker A: *he had a lot of real wacky ideas on big levels... he wanted a world power system, that you could tap into the air basically, and get power anywhere on earth...*

[6] Only a small subset of declarative questions is actually used after the addressee has explicitly committed himself/herself to the proposition expressed – namely, echoic questions – and their main function in the dialogue seems to be asking for additional evidence in support of the proposition expressed, rather than asking for a simple confirmation.

b. Speaker B: *that's what the Tesla coil was about*↑
c. Speaker A: *yeah, the problem was, that it interfered with, well, matter...I mean, it was not a clean broadcast system*

It is also not correct that rising declaratives always fail to commit the speaker to their content. As already noted above, they can be used as a politeness or checking device in situations where the speaker is informed with respect to an issue while the addressee is ignorant, as in (15), adapted from Pierrehumbert (1980).

(15) [to a receptionist] *hi, my name is Mark Liberman*↑

One cannot reasonably claim for cases like (15) that the addressee is either already committed to the truth of the propositions expressed by the speaker, or becomes so committed after they have been uttered (while the speaker does not). In fact, it turns out that rising declaratives can also be used without a prior or a subsequent commitment from either the speaker or the addressee: this is in case they are used as questions and the addressee chooses to be uncooperative and leaves them unanswered. To illustrate, consider the example in (16): if speaker B would not reply, neither her nor speaker A would be committed to the proposition that 'B remembers Peggy White'. However, Gunlogson's description of the context change potential of rising declaratives would predict that the proposition would be in B's commitment set even without the confirmation in (16-b).

(16) a. A: *he was going to uh, Peggy ...you remember Peggy White*↑
b. B: *yeah*

This brings us to our final objection to Gunlogson's approach, which is that the analysis does not explain why rising declaratives are usually responded to by the **addressee** as if they were questions. Gunlogson stipulates that uninformativeness with respect to the addressee is a necessary condition for an utterance to qualify as a polar question, but not that it is a sufficient condition. Given that the correct use of rising declaratives is presumably a part of the rules of rational conversation exchange and thus mutual knowledge, Gunlogson's analysis would predict a response from the addressee neither in case she disagrees with the proposition – because she would be inconsistent with herself, nor if she agrees with it – because she would be agreeing with what she is already publicly committed to, which is superfluous.[7] If we accept Gunlogson's setup and make the natural assumption that the goal of the conversation is to exchange information and thus create shared commitments, it should make perfect sense that the **speaker** states whether she agrees or disagrees with the proposition. However, neither seems to be the case in conversation: rising declaratives usually elicit a confirmation or a disconfirmation from the addressee (be it at least in terms of a nod or a short backchannel) and are not commented upon by the speaker.

To sum up, Gunlogson's proposal cannot account for a prevalent number of rising declarative usage types. Specifically, it cannot deal with examples where a rising declarative is used not because the addressee is committed to its content but rather because he or she is regarded as an expert on the issue, examples where it commits the speaker to its content, as well as those were neither the speaker nor the addressee become committed. Also, the approach does not offer a plausible explanation as to why rising declaratives in all of these cases tend to elicit a response from the addressee.

13.3.3 Final Rise as a Modal Expression

General Remarks

In my proposal, I follow the approaches described above in that I take intonation use to reflect the status of propositions in the set of mutual beliefs/common ground in the conversation. I suggest that the crucial properties of rising declaratives can be captured in a uniform way if we take the meaning of the final rise to be that of a modal expression of epistemic uncertainty.[8]

The connection between final rises and uncertainty has been noted in several studies in the past (Uldall, 1962, Chen and Gussenhoven, 2003, Chen et al., 2001, Gussenhoven, 2004) and other attitudes

[7] As a matter of fact, Gunlogson would allow for the second case because for her, a sentence is informative if it is informative at least with respect to one commitment set. Note, however, that this has the unwanted consequence that a participant in a dialogue could repeat a sentence for as long as the addressee does not explicitly agree or disagree with it and still be informative.

[8] Interestingly, apart from the language internal data discussed in this section, there seems to be cross-linguistic evidence in support of the connection between questions and an expression of epistemic uncertainty (albeit of a morphological type): As noted by Palmer (1986), there are languages that use a 'dubitative' or 'uncertainty' morpheme to turn statements into questions: for example, in Hixkaryana, there are two ways to express non-past - certain and uncertain - and when the 'non-past uncertain' is used alone (without other modal particles), it expresses a question. What is relevant about these and other cases given by Palmer is that in various languages, questions appeared to be expressed with the help of a modal expression which, however, does not express interrogativity by itself or in general.

usually associated with the rise like tentativeness, submissiveness or conciliatory attitude can be seen as secondary derivatives of 'uncertainty'. In many contexts, expressing uncertainty may also sound more polite than a direct statement or a question (cmp. the examples below) because it helps to preserve the addressee's face by giving him more space to refuse a request (e.g., for information), or an update of the mutual knowledge state.

(17) *Could you maybe tell us when you'll be arriving?*

(18) *Maybe we could leave now.*

In earlier proposals, uncertainty and lack of confidence was considered to be a secondary attitude accompanying the primary meaning of rising declaratives, typically taken to be 'questionhood'. I will suggest that uncertainty is the primary meaning associated with the rises, and questioning comes as a derived pragmatic effect. In particular, I will analyze the final rise as a kind of an 'intonational adverb', comparable, for instance to *it might be that.* This allows for an analysis that stays "true to form" at least with respect to declaratives, i.e., it represents all declaratives as statements. It only follows from pragmatic reasoning about the content of the rising declarative that the addressee should comment on it.

The Proposal

In order to be able to translate both falling and rising statements and questions into the formal language, I combine Veltman's update semantics with a simple semantics for questions. Due to the semantics of the $\Diamond$, it is not possible to make direct use of the partition semantics for questions (e.g., Groenendijk and Stokhof, 1997) but I will make use of the idea that questions disconnect worlds in an information state. With respect to the language with the $\Diamond$ operator, $L_\Diamond$, I stick to Veltman's original definition: the $\Diamond$ operator can be stacked but cannot be embedded under negation or in conjunction/disjunction. In $L_?$, the $\Diamond$ can be embedded under ? but stacking and embedding of the ? operator is excluded. Hence, we can now have both statements with a $\Diamond$, $\Diamond\phi$, as well as questions, $?\Diamond\phi$, in other words (because I analyze the rise as $\Diamond$), we have both rising statements (declaratives), as well as rising questions (interrogatives).[9]

[9] Gerbrandy (1999) in his dissertation gives a formalization of Veltman's update semantics which allows for $\Diamond$ being in the scope of negation. The interpretation of the formula one gets with the semantics is, however, not intuitive: $\neg\Diamond\phi$ is interpreted as $\sigma - \sigma[\Diamond\phi]$, which is $\emptyset$ if there is at least one ϕ world and σ otherwise. In natural language, however, a statement like 'It is not the case that he might come'

Definition 1. [Language] Let us define the language L as the set of formulas $\phi ::= p \mid \neg\phi \mid \phi \wedge \psi \mid \phi \vee \psi$, where p ranges over atomic propositional formulas.
Then $L_\diamond = L \cup \{\diamond\phi \mid \phi \in L_\diamond\}$, and $L_? = L_\diamond \cup \{?\phi \mid \phi \in L_\diamond\}$.

Definition 2. [Context]
Let W be the set of possible worlds and V a valuation function which assigns to each propositional letter a truth value 0 or 1 in all $w \in W$. Then a context σ is an equivalence relation on a subset of W, $\sigma \subseteq W \times W$, and $dom(\sigma)$, the domain of a context is the set of possible worlds in σ, $dom(\sigma) = \{w \in W | (w, w) \in \sigma\}$.

I will write $\sigma/_X$, $X \subseteq W$ for a restriction of a context, such that $\sigma/_X = \{(w, w') \in \sigma | w, w' \in X\}$ and I will call $\sigma^0 = W \times W$ the state of complete ignorance and indifference where no statements have been made and no questions asked.

Definition 3. [Semantics]

- $\sigma[p] = \sigma/(dom(\sigma) \cap \{w \in W | V(p)(w) = 1\})$
- $\sigma[\neg\phi] = \sigma/(dom(\sigma) - dom(\sigma[\phi]))$
- $\sigma[\phi \wedge \psi] = \sigma/(dom(\sigma[\phi]) \cap dom(\sigma[\psi]))$
- $\sigma[\phi \vee \psi] = \sigma/(dom(\sigma[\phi]) \cup dom(\sigma[\psi]))$
- $\sigma[\diamond\phi] = \sigma$ if $dom(\sigma[\phi]) \neq \emptyset$ and $\emptyset$ otherwise
- $\sigma[?\phi] = \{(w, w') \in \sigma | w \in dom(\sigma[\phi])$ iff $w' \in dom(\sigma[\phi])\}$

Definition 4. [Common Ground and Information States]
The common ground, σ_{CG} is a context representing the shared beliefs of the speaker and the addressee in the discourse. σ_S is the speaker's information state and σ_A is the addressee's information state.

Definition 5. [Discourse and Updates]
A discourse Δ is a sequence of formulas $\phi_1, \ldots, \phi_n \in L_?$ where with each formula ϕ_i we associate a state of the common ground σ^i_{CG}, a state of speaker's belief state σ^i_S and a state of the addressee's belief state σ^i_A, such that $\forall i : dom(\sigma^i_S) \subseteq dom(\sigma^i_{CG})$ and $dom(\sigma^i_A) \subseteq dom(\sigma^i_{CG})$ and $\sigma^i_{CG}[\phi_i] = \sigma^{i+1}_{CG}$, $\sigma^i_S[\phi_i] = \sigma^{i+1}_S$ and $\sigma^i_A[\phi_i] = \sigma^{i+1}_A$. We write $\phi_1 \prec \phi_2$ for ϕ_1 precedes ϕ_2 in Δ.

With respect to answers, the aim is to have a definition which assigns to the question $?\phi$, ϕ and $\neg\phi$ as its possible answers (same for $?\neg\phi$) and to the question $?\diamond\phi$, $\diamond\phi$, ϕ and $\neg\phi$ as its possible answers. This

---

would rather be interpreted as conveying the information that 'He is (certainly) not coming', i.e, as an update with $\neg\phi$ (or stronger, if possible in the formal language), not as a contradiction if it is not yet known whether ϕ or not.
One could try to give a fixed interpretation to $\neg\diamond\phi$ formulas as being simply equal to $\neg\phi$, but such a system basically collapses to propositional logic. (Thanks to Bernhard Schröder for the argument.)

effect does not come out straightforwardly with the partition semantics of questions (as in Groenendijk and Stokhof, 1997) because, e.g., $?\Diamond\phi$ does not introduce a partition based on its 'yes' and 'no' answers (one, elements of a partition cannot be empty, and two, there is no $\neg\Diamond\phi$ in our language). Therefore, I propose a new definition of answerhood below.

Definition 6. [Syntactic Answerhood]
A syntactic answer to $?\phi$ is ϕ.

Definition 7. [Semantic Answerhood]
Let ϕ be the syntactic answer to $?\phi$, then Υ, the set of semantic answers to $?\phi$ is the set such that $\phi \in \Upsilon$ and for any $\psi \in L_\Diamond$, $\psi \in \Upsilon$ iff $\neg\exists\upsilon \in \Upsilon,\ \upsilon \in L : dom(\sigma^0[\psi]) \subset dom(\sigma^0[\upsilon])$ and $\exists\upsilon \in \Upsilon, \sigma^0[\psi][\upsilon] = \emptyset$.

Take the simple case of a question like $?p$. Then p is its answer syntactically and $\neg p$ is its answer because $\sigma^0[\neg p][p] = \emptyset$. Take $?\Diamond p$ as another example. Then $\Diamond p$ is its syntactic answer. Next, $\neg p$ is its answer because $\sigma^0[\neg p][\Diamond p] = \emptyset$. Finally, p is its answer because $\sigma^0[p][\neg p] = \emptyset$. Furthermore, the condition $\neg\exists\upsilon \in \Upsilon$, $dom(\sigma^0[\psi]) \subset dom(\sigma^0[\upsilon])$ has as its goal to exclude the possibility that $\neg p \wedge q$ would become an answer to $?p$ (because $\sigma^0[\neg p \wedge q][p] = \emptyset$) and then $\neg q$ would become an answer because $\sigma^0[\neg q][\neg q \wedge q] = \emptyset$ and so on, potentially infinitely. Also, the condition excludes contradictions as possible answers. An update of σ^0 (the state of complete ignorance) with a contradiction gives $\emptyset$, which would be a proper subset of the state of ignorance updated with, e.g., the syntactic answer to the question. Note that if the question itself concerns a contradiction, this is not the case; e.g., a question $?p \wedge \neg p$ can have anything as its answer, including contradictions, because its syntactic answer is $p \wedge \neg p$.

Given this definition, the question *is Sarkozy a clever man*$\downarrow$ (with falling intonation) would have in its set of possible answers only (19-a) and (19-b), while the question *is Sarkozy a clever man*$\uparrow$ (with rising intonation) would have all (19-a), (19-b) and (19-c) as its possible answers.[10]

(19) a. *Yes. (Sarkozy is a clever man).*
b. *No. (Sarkozy is not a clever man).*
c. *Maybe. (Sarkozy might be a clever man).*

Based on Grice's principles of rational conversation, I define four maxims which restrict the number of eligible discourses, namely Quality,

[10] To be precise, given the analysis of rises here, it can also receive (19-a) and (19-b) and (19-c) with rising intonation as an answer.

Relation, Quantity (1) and Quantity (2). Note that one of the goals of the analysis is to explain why both $\Diamond$ statements and $\Diamond$ questions are nonredundant. Existing formulations of redundant conversation moves (e.g., Groenendijk, 1999) assume that a statement is redundant if updating with it does not change the content of the common ground. Similarly, a question would be redundant if an answer to it would already be known, which technically translates into 'not disconnecting any possible worlds' or 'not creating a (non-empty) partition' of the common ground. Under this view, both $\Diamond$ statements and $\Diamond$ questions come out as being redundant, which is an undesirable effect. Therefore, I propose a different definition of redundant conversation moves, formulated in Quantity (2).

Definition 8. [Maxims of Conversation]

• **Quality:** A discourse Δ conforms to Quality iff for every statement $\phi_i \in \Delta$, $\sigma^i_S[\phi_i] = \sigma^i_S$.
• **Relation:** A discourse Δ conforms to Relation iff for every statement $\phi_i \in \Delta$, ϕ_i is a semantic answer to the most recent unresolved question. $?\phi_i$ is unresolved in σ^i_{CG} iff $\exists w, w'$ such that $w \in dom(\sigma^i_{CG})$ and $w' \in dom(\sigma^i_{CG})$ and $(w, w') \notin \sigma^0[?\phi_i]$.
• **Quantity (1):** A discourse Δ conforms to Quantity (1) iff for every statement $\phi_i \in \Delta$, there is no stronger statement given σ^i_S, speaker's knowledge at that point in the conversation. ϕ is stronger than ψ iff $dom(\sigma^0[\phi]) \subseteq dom(\sigma^0[\psi])$.
• **Quantity (2):** A discourse Δ conforms to Quantity (2) iff for every $\phi_i \in \Delta$, ϕ_i is not redundant in σ^i_{CG}. A question $?\phi_i$ is redundant with respect to σ^i_{CG} if all its semantic answers are redundant in σ^i_{CG}. A statement ϕ_i is redundant with respect to σ^i_{CG} iff with respect to $\phi_i^{SUB} \in L$, ϕ_i^{SUB} being the largest propositional subformula of ϕ_i, $\sigma^i_S[\neg\phi_i^{SUB}] = \sigma^i_{CG}[\neg\phi_i^{SUB}]$.

By Quantity (2), questions like $?\Diamond\phi$ are only redundant if it is already known whether ϕ or $\neg\phi$. A statement $\Diamond\phi$ is not redundant iff the speaker's information state updated with $\neg\phi$, would be a proper subset of the common ground updated with $\neg\phi$, i.e., $\sigma^i_S[\neg\phi] \subset \sigma^i_{CG}[\neg\phi]$. This will be the case if there are less $\neg\phi$ worlds in σ^i_S than in σ^i_{CG}, i.e., if the speaker believes $\neg\phi$ to be less likely.

To see how the proposed theory works in practice, in the next section of this paper, I return to the points (I)-(VIII) from section 2.1.

13.4 Discussion

It is easy to express the observation that inverted *yes/no*-interrogatives can sometimes appear with a rise. If they do, we represent them as $?\Diamond\phi$ and correctly predict that they will be perceived as more polite (but possibly also more hesitant) than the falling $?\phi$: they allow for the weak answer $\Diamond\phi$, while their falling counterparts require a stronger commitment from the addressee.[11]

Similarly, rise on a declarative, $\Diamond\phi$, is interpreted as a weaker type of statement than a falling declarative ϕ. Using it does not result directly in any commitment (either from the speaker or from the addressee), because an update with a test does not eliminate worlds from the common ground. However, by Quantity (2), the addressee can derive that there is at least one world in the common ground in which $\neg\phi$ holds and in which the speaker does not believe. In a common ground in which there is only *one* $\neg\phi$ world, uttering $\Diamond\phi$ will thus effectively result in an update with ϕ! We can thus also account for cases in which uttering a rising declarative results in a commitment by the speaker. As for echo questions, the present setup predicts that using a rising declarative $\Diamond\phi$ directly after ϕ has been uttered by the other participant is redundant. The fact that the speaker uses it nevertheless suggests that for some reason, the update of the common ground with ϕ was not successful and/or the common ground has to be revised. This corresponds to the intuition that echo questions involve disagreement between the participants and can be interpreted as requests for additional information or at least confirmation. Accounting for this process exactly, however, requires a more fine-grained machinery than the one proposed in the present paper.

In general, I assume that uttering a possibility statement, i.e., a $\Diamond$-statement, accommodates a question to which it is a syntactic answer, i.e., $?\Diamond p$, which has $\Diamond p$, p and $\neg p$ among its answers. In a rational conversation, participants cooperate on finding the strongest possible answers to questions that have been raised (whether overtly or accommodated). Therefore, if a $?\Diamond p$ question has been raised and there is a participant who knows that either p or $\neg p$ is the case, she has to say so. Thus, a rising declarative (a $\Diamond$-type of statement), will frequently be followed by a 'response'. Crucially, this response is not an answer to the rising declarative but to the question accommodated due to the use of the rising declarative.

The analysis can easily model the fact that rising declaratives are not interchangeable with questions: after all they are assertions, which express a bias also in contexts in which the ratio of worlds making them true and worlds making them false should remain 1:1. For example, used as an exam question, a rising declarative *the empty set is a subset of itself*↑ would swing the odds of the proposition 'the empty set is a

[11] Given the semantics I use, I cannot say anything about *wh*-question.

subset of itself' being true for its favor in a common ground which is supposed to be absolutely neutral.

Similarly to rising *yes/no*-questions, also rising declaratives come out as being more polite than their falling counterparts. If the speaker updates the common ground with a falling declarative ϕ and the addressee believes $\neg\phi$ to be true, the participants are in an open disagreement and a correction of the common ground may be needed. If, on the other hand, the speaker uses a rising declarative $\Diamond\phi$, she generally does not eliminate all $\Diamond\neg\phi$ worlds (unless there is only one) and the addressee can still utter the stronger statement $\neg\phi$, if she believes it to be true, without overtly disagreeing.

The proposal does not predict any link between final rises and continuations, which is correct, given that in English, empirical studies suggest that different kinds of intonational patterns are involved (see Šafářová (2005) and the references cited there). Note also that the meaning of the rise is here treated on the same level as the meaning of the lexical features of the utterance and interacts with them; intonation is not semantically "weaker".

As a final remark, I would like to stress that in the present proposal, the final rise is not exactly synonymous with a particular lexical adverb and all the translations of the final rise with a lexical expression should be understood very loosely. The syntactic and semantic behavior of lexical adverbial expressions and corresponding adjectival phrases is rather complicated (viz, a.o., Cinque, 1999, Nilsen, 2003): for example, the adverb *possibly* appears to be excluded from some (but not all) interrogatives, while its adjectival counterpart *it is possible that* is not. Also, it is generally assumed that there is a syntactic and presumably also semantic difference between *it might be that, maybe, possibly* or *perhaps.* In principle, I do not exclude the option of formalizing the meaning of one of these operators with Veltman's test diamond (the semantics of which I make use does not exclude multiple presence of the epistemic operator which will be represent with a $\Diamond$, so the option of combining intonational and lexical expressions exists). At least *'maybe'*, however, seems to function differently from the rise, as show by the following dialogue:

(20) a. A: *I lost my ring*
b. B: *did you leave it in the bathroom?*
c. B': *maybe you left in the bathroom*
d. B": *you left in the bathroom*$\uparrow$

The reply (20-d) patterns with the reply in (20-b) in that a response by speaker A is expected. The relevant difference seems to be that in (20-b) and (20-d), but not necessarily in (20-c), the speaker A is assumed to be knowledgeable with respect to the content of the utterance. Unfortunately, this example cannot be handled by the formalization proposed here, because it lacks the machinery to express propositions of the type 'A knows that. . . '.[12]

13.5 Summary and Future Work

The proposal in this paper can be summarized as $\uparrow = \diamond$. While it can model a number of facts about the use of rising intonation in American English, the formal language is quite simple and cannot express *wh*-questions and propositions of the type 'A knows that' or the effect of utterances like *'I don't know'* on the common ground. Employing a knowledge operator could possibly help to address the fact as well that not only rising declaratives, but also falling declaratives are often responded to by the addressee if they concern an issue on which she is an expert.

Acknowledgements

I would like to thank Marc Pauly, Paul Dekker, Hans-Christian Schmitz, Bernhard Schröder and the audience of *Sinn und Bedeutung 9* in Nijmegen for their helpful comments. All the remaining mistakes are my own.

[12] Thanks to David Ahn for bringing this example to my attention.

Bibliography

Aloni, Maria. 2001. *Quantification under Conceptual Covers*. Ph.D. thesis, ILLC/Department of Philosophy, University of Amsterdam.

Aloni, Maria, David Beaver, and Brady Clark. 1999. Focus and topic sensitive operators. In P. Dekker, ed., *Proceedings of the Twelfth Amsterdam Colloquium*, pages 55–60. Amsterdam: ILLC, University of Amsterdam.

Aloni, Maria and Robert van Rooij. 2002. The dynamics of questions and focus. In B. Jackson, ed., *Proceedings of SALT XII*. Ithaca, NY: CLC Publications, Cornell.

van Alphen, Ingrid. 2003. De interactionele kracht van vragen (en vrouwen). In *Artikelen van de vierde sociolinguistische conferentie*, pages 11–21.

Andréka, Hajnal, Johan van Benthem, and István Németi. 1998. Modal logics and bounded fragments of predicate logic. *Journal of Philosophical Logic* 27(3):217–274.

Aoun, Joseph and Yen-Hui Li. 1993. WH-elements in situ: Syntax or LF? *Linguistic Inquiry* 24:199–238.

Asher, Nicholas and Alex Lascarides. 1998. Questions in dialogue. *Linguistics and Philosophy* 21:237–309.

Asher, Nicholas and Alex Lascarides. 2003. *Logics of Conversation*. Cambridge: Cambridge University Press.

Atlas, Jay David. 1991. Topic/comment, presupposition, logical form and focus stress implicatures: The case of focal particles *only* and *also*. *Journal of Semantics* 8:127–147.

Atlas, Jay David. 1993. The importance of being 'only': Testing the neo-gricean versus neo-entailment paradigms. *Journal of Semantics* 10:301–318.

Baker, Carl L. 1968. *Indirect Questions in English*. Ph.D. thesis, University of Illinois.

Ballantyne, Jocelyn. 2002. What's the difference between pitch accent and focus? Manuscript, Utrecht University.

Bartels, Christine and Arthur Merin. 1998. Towards a formal semantics of English phrasal intonation. In O. Fujimora, B. D. Joseph, and B. Palek, eds., *Proceedings of LP'98*, pages 91–110. Charles University in Prague, The Karolinum Press.

Bayer, Josef. 1999. Bound focus or how can association with focus be achieved without going semantically astray. In G. Rebuschi and L. Tuller, eds., *The Grammar of Focus*, pages 55–82. John Benjamins.

Beaver, David. 2004. Five *only* pieces. *Theoretical Linguistics* 28:45–64.

Beaver, David and Brady Clark. 2002a. Monotonicity and focus sensitivity. In B. Jackson, ed., *Proceedings of SALT XII*. Ithaca, NY: CLC Publications, Cornell.

Beaver, David and Brady Clark. 2002b. The proper treatments of focus sensitivity. In C. Potts and L. Mikkelsen, eds., *Proceedings of WCCFL XXI*, pages 15–28. Cascadilla Press.

Beaver, David and Brady Clark. 2003. *Always* and *only*: Why not all focus sensitive operators are alike. *Natural Language Semantics* 11(4):323–362.

Beck, Sigrid. 1996a. Quantified structures as barriers for LF movement. *Natural Language Semantics* 4:1–56.

Beck, Sigrid. 1996b. *WH-constructions and Transparent Logical Form*. Ph.D. thesis, Universität Tübingen.

Beck, Sigrid and Shin-Sook Kim. 1997. On WH- and operator scope in Korean. *Journal of East Asian Linguistics* 6:339–384.

Beckman, Mary and Janet Pierrehumbert. 1986. Intonational structure in Japanese and English. *Phonology Yearbook* 3.

van Benthem, Johan. 1996. *Exploring Logical Dynamics*. Stanford: CSLI Publications.

van den Berg, Martin H. 1996. *Some Aspects of the Internal Structure of Discourse: The Dynamics of Nominal Anaphora*. Ph.D. thesis, University of Amsterdam, Amsterdam.

Blutner, Reinhard. 1993. Dynamic generalized quantifiers and existential sentences in natural languages. *Journal of Semantics* 10(1):33–64.

Blutner, Reinhard. 2000. Some aspects of optimality in natural language interpretation. *Journal of Semantics* 17(3):189–217.

Bolinger, Dwight. 1972. Accent is predictable (if you're a mind reader). *Language* 48:633–644.

Bolinger, Dwight. 1986. *Intonation and its parts: Melody in spoken English*. Stanford: Stanford University Press.

Bonomi, Andrea and Paolo Casalegno. 1993. *Only:* association with focus in event semantics. *Natural Language Semantics* 2(1):1–45.

Bošković, Željko. 1998. LF Movement and the Minimalist Program. In P. N. Tamanji and K. Kusomoto, eds., *North East Linguistic Society 28*, pages 43–57. University of Massachusetts, Amherst: GLSA.

Büring, Daniel. 1999. Topic. In P. Bosch and R. van der Sandt, eds., *Focus — Linguistic, Cognitive, and Computational Perspectives*, pages 142–165. Cambridge UP.

Butler, Alastair. 2001. *Control and Exhaustification*. Ph.D. thesis, University of York, York.

Butler, Alastair and Eric Mathieu. 2004. *The Syntax and Semantics of Split Constructions: A Comparative Study*. New York: Palgrave Macmillan.

Carlson, Lauri. 1983. *Dialogue Games: An Approach to Discourse Analysis*. Synthese Library. Reidel.

Chang, Lisa. 1997. *WH in situ Phenomena in French*. Master's thesis, University of British Columbia.

Chen, Aoju. 2004. *Universal and Language-specific Perception of Paralinguistic Intonational Meaning*. Ph.D. thesis, LOT dissertation series 102.

Chen, Aoju and Carlos Gussenhoven. 2003. Language dependence in the signaling of attitude in speech. In *Proceedings of Workshop on the Subtle Expressivity of Emotion at CHI 2003 Conference on Human and Computer Interaction*.

Chen, Aoju, Toni Rietveld, and Carlos Gussenhoven. 2001. Language-specific effects of pitch range on the perception of universal intonation meaning. In *Proceedings of Eurospeech*, pages 327–352.

Cheng, Lisa. 1991. *On the typology of WH-questions*. Ph.D. thesis, MIT. Published by Garland, New-York, 1997.

Cheng, Lisa and Johann Rooryck. 2000. Licensing WH-in-situ. *Syntax* 3:1–19.

Chierchia, Gennaro. 2002. Scalar implicatures, polarity phenomena, and the syntax/pragmatics interface. In A. Belletti, ed., *Structures and Beyond*. Oxford: Oxford University Press.

Chomsky, Noam and Morris Halle. 1968. *The Sound Pattern of English*. New York: Harper and Row.

Cinque, Guglielmo. 1993. A null theory of phrase and compund stress. *Linguistic Inquiry* 24:239–298.

Cinque, Guglielmo. 1999. *Adverbs and Functional Heads: A Crosslinguistic Perspective*. Oxford: Oxford University Press.

Clark, Herbert. 1996. *Using language*. Cambridge University Press.

Cole, Peter and Gabriella Hermon. 1998. The typology of WH-movement. WH-questions in Malay. *Syntax* 1:221–258.

Cook, Norman. 2002. *Tone of Voice and Mind*. John Benjamins.

Cooper, Robin. 1998. Mixing situation theory and type theory to formalize information states in dialogue. In J. Hulstijn and A. N. (eds.), eds., *Proceedings of Twendial, Formal Semantics and Pragmatics of Dialogue*. Twente: University of Twente.

Craig, William. 1957. Three uses of the Herbrand-Gentzen theorem in relating model theory and proof theory. *Journal of Symbolic Logic* 22:269–285.

Cresswell, Max J. 2002. Static semantics for dynamic discourse. *Linguistics and Philosophy* 25:545–571.

Cruttenden, Alan and David Faber. 1991. The accentuation of prepositions. *Journal of Pragmatics* 15:265–286.

Dalrymple, Mary, Stuart Shieber, and Fernando Pereira. 2002. Ellipsis and higher-order unification. *Linguistics and Philosophy* 14:399–452.

Dekker, Paul. 1993. *Transsentential Meditations. Ups and Downs in Dynamic Semantics*. Ph.D. thesis, ILLC/Department of Philosophy, University of Amsterdam, Amsterdam.

Dekker, Paul. 2001. On *if* and *only*. In R. Hastings, B. Jackson, and Z. Zvolenszky, eds., *Proceedings from SALT XI*. Ithaca, NY: CLC Publications.

Dekker, Paul. 2002a. Meaning and use of indefinite expressions. *Journal of Logic, Language and Information* 11:141–194.

Dekker, Paul. 2002b. Something else. In G. Alberti, K. Balogh, and P. Dekker, eds., *Proceedings of the Seventh Symposium of Logic and Language*, pages 17–26. Pécs: University of Pécs.

Dekker, Paul. 2003. A proper architecture for presupposition and quantification. Manuscript, ILLC, University of Amsterdam.

Dekker, Paul. 2004. Satisfying questions. In C. Meier and M. W. (eds.), eds., *Proceedings of the Eighth Annual Meeting Sinn und Bedeutung*, pages 83–94. Konstanz: Universität Konstanz.

Diesing, Molly. 1992. *Indefinites*. Cambridge, MA: MIT Press.

van Eijck, Jan. 1993. Axiomatizing Dynamic Predicate Logic with Quantified Dynamic Logic. In J. van Eijck, ed., *Course Material of the Fifth European Summerschool in Logic, Language and Information*. ESSLLI.

van Eijck, Jan and Fer-Jan de Vries. 1995. Reasoning about update logic. *Journal of Philosophical Logic* 24:19–45.

É. Kiss, Katalin. 1998. Identificational focus versus information focus. *Language* 74(2):245–273.

Evans, Gareth. 1977. Pronouns, quantifiers and relative clauses. *The Canadian Journal of Philosophy* 7:467–536 and 777–797. Reprinted in: Evans, G., 1985, *Collected papers*, Dordrecht: Foris, pp 76–152.

Feferman, Solomon. 1999. Logic, logics and logicism. *Notre Dame Journal of Formal Logic* 40:31–54.

von Fintel, Kai. 1997a. Bare plurals, bare conditionals, and *only*. *Journal of Semantics* 14:1–56.

von Fintel, Kai. 1997b. A minimal theory of adverbial quantification. In H. Kamp and B. Partee, eds., *Context-dependence in the Analysis of Linguistic Meaning. Volume I: Papers*, pages 153–193. IMS, Stuttgart.

Fries, Charles C. 1964. On the intonation of *yes-no* questions in English. In D. Abercrombie, D. B. Fry, P. A. D. McCarthy, N. C. Scott, and J. L. M. Trim, eds., *In Honour of Daniel Jones*. Longmans.

Gardent, Claire. 1991. *Gapping and VP-ellipsis in a unification-based grammar*. Ph.D. thesis, Cognitive Science, University of Edinburgh.

Gawron, Jean Mark. 1996. Quantification, quantificational domains and dynamic logic. In S. Lappin, ed., *The Handbook of Contemporary Semantic Theory*, pages 247–267. Oxford: Blackwell.

Gazdar, Gerald. 1979. *Pragmatics. Implicature, Presupposition, and Logical Form*. New York: Academic Press.

Gerbrandy, Jelle. 1999. *Bisimulations on planet Kripke*. Ph.D. thesis, ILLC, University of Amsterdam.

Geurts, Bart and Robert van der Sandt. 2004. Interpreting focus. *Theoretical Linguistics* 28:1–44.

Ginzburg, Jonathan. 1995. Resolving questions, I & II. *Linguistics and Philosophy* 18:459–527, 567–609.

Ginzburg, Jonathan. 1996. Interrogatives: questions, facts, and dialogue. In S. Lappin, ed., *The Handbook of Contemporary Semantic Theory*. Oxford: Blackwell.

Ginzburg, Jonathan and Ivan Sag. 2000. *Interrogative Investigations: the form, meaning, and use of English interrogatives*. Stanford: CSLI.

Goodman, Nelson. 1961. About. *Mind* 70:1–24.

Grice, Paul. 1989. *Studies in the way of words*. Cambridge, Mass.: Harvard University Press.

Groenendijk, Jeroen. 1998. Questions in update semantics. In J. Hulstijn and A. Nijholt, eds., *Formal Semantics and Pragmatics of Dialogue*. University of Twente.

Groenendijk, Jeroen. 1999. The logic of interrogation. Classical version. In T. Matthews and D. L. Strolovitch, eds., *The Proceedings of the Ninth Conference on Semantics and Linguistic Theory*, pages 109–126. Ithaca NY: CLC Publications.

Groenendijk, Jeroen and Martin Stokhof. 1984. *Studies on the Semantics of Questions and the Pragmatics of Answers*. Ph.D. thesis, University of Amsterdam, Amsterdam.

Groenendijk, Jeroen and Martin Stokhof. 1989. Type-shifting rules and the semantics of interrogatives. In G. Chierchia, B. Partee, and R. Turner, eds., *Properties, Types and Meaning*. Kluwer.

Groenendijk, Jeroen and Martin Stokhof. 1990a. Dynamic Montague Grammar. In L. Kálmán and L. Pólos, eds., *Papers from The Second Symposium on Logic and Language*, pages 3–48. Budapest: Akadémiai Kiadó.

Groenendijk, Jeroen and Martin Stokhof. 1990b. Two theories of dynamic semantics. In J. van Eijck, ed., *Logics in AI*, pages 55–64. Berlin: Springer.

Groenendijk, Jeroen and Martin Stokhof. 1991a. Dynamic predicate logic. *Linguistics and Philosophy* 14(1):39–100.

Groenendijk, Jeroen and Martin Stokhof. 1991b. Dynamic predicate logic. *Linguistics and Philosophy* 14(1):39–100.

Groenendijk, Jeroen and Martin Stokhof. 1997. Questions. In J. van Benthem and A. ter Meulen, eds., *Handbook of Logic and Language*. Elsevier Science Publishers.

Gunlogson, Christine. 2001. *True to Form: Rising and Falling Declaratives and Questions in English*. Ph.D. thesis, UCSC.

Gussenhoven, Carlos. 1984. *On the Grammar and Semantics of Sentence Accents*. Foris, Dordrecht.

Gussenhoven, Carlos. 2004. *The Phonology of Tone and Intonation*. Cambridge University Press.

Halpern, Joseph Y. and Yoram Moses. 1985. Towards a theory of knowledge and ignorance: Preliminary report. In *Proceedings of the AAAI Workshop on Non-Monotonic Reasoning*, pages 165–193. American Association for Artificial Intelligence, New Paltz, NY.

Hamblin, Charles L. 1958. Questions. *Australasian Journal of Philosophy* 36:159–68.

Hamblin, Charles L. 1973. Questions in Montague English. *Foundations of Language* 10:41–53. Reprinted in B. Partee (ed.), 1976, *Montague Grammar*, Academic Press, NY.

Haspelmath, Martin. 1997. *Indefinite Pronouns*. Oxford: Oxford University Press.

Heim, Irene. 1982. *The Semantics of Definite and Indefinite Noun Phrases*. Ph.D. thesis, University of Massachusetts, Amherst. Published in 1988 by Garland, New York.

Heim, Irene. 1983a. File change semantics and the familiarity theory of definiteness. In R. Bäuerle, C. Schwarze, and A. von Stechow, eds., *Meaning, Use, and Interpretation of Language*. Berlin: de Gruyter.

Heim, Irene. 1983b. On the projection problem for presuppositions. In M. Barlow, D. Flickinger, and M. Wescoat, eds., *Proceedings of WCCFL II*. Stanford, California.

Heim, Irene. 1987. Where does the definiteness restriction apply? In A. ter Meulen and E. Reuland, eds., *The Representation of (In)definiteness*. Cambridge, Mass.: MIT Press.

Heim, Irene. 1994. Interrogative semantics and Karttunen's semantics for *know*. In R. Buchalla and A. Mittwoch, eds., *Proceedings of the 9-th Annual Conference Ben Gurion University of the Negev 1993 and of the Workshop on Discourse Hebrew Unversity of Jerusalem 1993*. Israel Association for Theoretical Linguistics.

Hendriks, Petra. 2005. Explaining production/comprehension asymmetries at the semantics/pragmatics interface. Ms. University of Groningen.

Hendriks, Petra and Jennifer Spenader. 2004. A bidirectional explanation of the pronoun interpretation problem. In P. Schlenker and E. Keenan, eds., *Proceedings of the ESSLLI'04 Workshop on Semantic Approaches to Binding Theory*. Nancy, France.

Henkin, Leon. 1963. An extension of the craig-lyndon interpolation theorem. *Journal of Symbolic Logic* 28:201–216.

Higginbotham, James. 1996. Questions. In S. Lappin, ed., *Handbook of Contemporary Semantic Theory*. Oxford: Blackwell.

Higginbotham, James and Robert May. 1981. Questions, quantifiers and crossing. *The Linguistic Review* 1:41–80.

Hirschberg, Julia. 1985. *A Theory of Scalar Implicature*. Ph.D. thesis, University of Pennsylvania, Published in 1991 by Garland, New York.

Hirschberg, Julia. 2000. A corpus-based approach to the study of speaking style. In M. Horne, ed., *Prosody: Theory and Experiment*, pages 335–350. Kluwer Academic Press.

Hirschberg, Julia and Gregory Ward. 1995. The interpretation of the high-rise contour in English. *Journal of Pragmatics* 24:407–412.

Hoeksema, Jack and Frans Zwarts. 1991. Some Remarks on Focus Adverbs. *Journal of Semantics* 8:51–70.

Honcoop, Martin. 1998. *Dynamic Excursions on Weak Islands*. Ph.D. thesis, Leiden University/HIL.

de Hoop, Helen and Irene Krämer. 2004. Children's optimal interpretation of indefinite subjects and objects. Manuscript, University of Nijmegen.

Horn, Laurence R. 1969. A presuppositional analysis of *only* and *even*. *CLS* 5:97–108.

Horn, Laurence R. 1972. *On the semantic properties of logical operators in English*. Ph.D. thesis, UCLA, Los Angeles, CA.

Horn, Laurence R. 1992. The said and the unsaid. In *Proceedings of SALT II*, pages 163–192.

Horn, Laurence R. 1996. Exclusive company: *Only* and the dynamics of vertical inference. *Journal of Semantics* 13:1–40.

Horn, Laurence R. 2002. Assertoric inertia and NPI licensing. *CLS* 38:55–82.

Hulstijn, Joris. 1997. Structured information states. Raising and resolving issues. In A. Benz and G. Jäger, eds., *Proceedings of MunDial97*. University of Munich.

Hulstijn, Joris. 2000. *Dialogue Models for Inquiry and Transaction*. Ph.D. thesis, University of Twente.

Jackendoff, Ray. 1972a. *Semantic Interpretation in Generative Grammar*. Cambridge, Massachusetts: MIT Press.

Jackendoff, Ray. 1972b. *Semantic Interpretation in Generative Grammar*. Cambridge, Massachusetts: MIT Press.

Jacobs, Joachim. 1983. *Focus und Skalen, zur Syntax und Semantik von Gradpartikelen im Deutschen*. Tübingen: Niemeyer.

Jäger, Gerhard. 1996. Only updates. On the dynamics of the focus particle *only*. In M. Stokhof and P. Dekker, eds., *Proceedings of the Tenth Amsterdam Colloquium*, pages 387–405. Amsterdam: ILLC, University of Amsterdam.

Jäger, Gerhard. 1997. Common grounds, questions and relevance. Manuscript, University of Munich.

Jäger, Gerhard. 2002. Some notes on the formal properties of bi-directional optimality theory. *Journal of Logic, Language and Information* 11:427–451.

Kadmon, Nirit. 1990. Uniqueness. *Linguistics and Philosophy* 13:273–324.

Kadmon, Nirit. 2001. *Formal Pragmatics*. Massachusetts: Blackwell.

Kamp, Hans. 1981. A theory of truth and semantic representation. In J. Groenendijk, T. Janssen, and M. Stokhof, eds., *Formal Methods in the Study of Language*, pages 277–322. Amsterdam: Mathematical Centre. Reprinted in J. Groenendijk, T. Janssen, and M. Stokhof (eds.), 1984, *Truth, Interpretation and Information*, Foris, Dordrecht, pp. 1–41.

Kamp, Hans and Uwe Reyle. 1993. *From Discourse to Logic*. Dordrecht: Kluwer.

Karttunen, Lauri. 1974. Presupposition and linguistic context. *Theoretical Linguistics* 1:181–194.

Karttunen, Lauri. 1977. Syntax and semantics of questions. *Linguistics and Philosophy* 1:3–44.

Kasper, Walter. 1992. Presupposition, composition and simple subjunctives. *Journal of Semantics* 9:307–331.

Keenan, Edward. 1992. Beyond the Frege boundary. *Linguistics and Philosophy* 15:199–221.

Kratzer, Angelika. 1989. An investigation of the lumps of thought. *Linguistics and Philosophy* 12(5):607–653.

Krifka, Manfred. 1991. A compositional semantics for multiple focus constructions. In S. Moore and A. Wyner, eds., *Proceedings from SALT I*, pages 127–158. Cornell.

Krifka, Manfred. 1992. A compositional semantics for multiple focus constructions. In J. Jacobs, ed., *Informationsstruktur und Grammatik*. Linguistische Berichte, Sonderheft 4. Also appeared in S. Moore and A. Wyner (eds.) *Proceedings from SALT I*, pages 127–158, Cornell Working Papers in Linguistics 10, 1991.

Krifka, Manfred. 1993. Focus, presupposition, and dynamic interpretation. In K. Bimbó and A. Máté, eds., *Proceeedings of the Fourth Symposium on Logic and Language*, pages 31–59. Budapest: Áron.

Krifka, Manfred. 1995. The semantics and pragmatics of polarity items. *Linguistic Analysis* 25:209–258.

Krifka, Manfred. 1999. Additive particles under stress. In *Proceedings from SALT 8*. Cornell.

Krifka, Manfred. 2001. For a structured meaning account of questions and answers. In C. Fery and W. Sternefeld, eds., *Audiatur Vox Sapientia. A Festschrift for Arnim von Stechow*, pages 287–319. Berlin: Akademie Verlag.

Krifka, Manfred. 2003. Quantifiers in questions. *Korean Journal of English Language and Linguistics* 3:499–526.

Kripke, Saul. 1972. Naming and necessity. In D. Davidson and G. Harman, eds., *Semantics of Natural Languages*, pages 254–355, 763–769. Dordrecht: Reidel.

van Kuppevelt, Jan. 1991. *Topic en Comment. Expliciete en Impliciete Vraagstelling in Discourse*. Ph.D. thesis, University of Nijmegen, Nijmegen.

Lakoff, George. 1971. Pronouns and reference. In *Syntax and Semantics*, vol. 7, pages 275–335. New York: Academic Press.

Lambrecht, Knud. 1994. *Information Structure and Sentence Form*. Cambridge.

Lambrecht, Knud and Laura Michaelis. 1998. Sentence accent in information questions: Default and projection. *Linguistics and Philosophy* 21:477–544.

Lascarides, A. and N. Asher. 1993. Temporal interpretation, discourse relations and common sense entailment. *Linguistics and Philosophy* 16:437–493.

Lewis, David. 1988. Relevant implication. *Theoria* 18:161–174.

Mann, William C. and Sandra A. Thompson. 1988. Rhetorical structure theory: Toward a functional theory of text organization. *Text* 8(3):243–281.

Mathieu, Eric. 1999. French WH in situ and the Intervention Effect. In C. Iten and A. Neeleman, eds., *UCL Working Papers in Linguistics*, pages 441–472. University College London.

McCarty, J. 1980. Circumscription - a form of non-monotonic reasoning. *Artificial Intelligence* 13:27–39.

McCawley, James D. 1981. *Everything that Linguists have always Wanted to Know about Logic* *but were ashamed to ask*. Oxford: Basil Blackwell.

McLemore, Cynthia. 1991a. The interpretation of L*H in English. In *Texas Linguistic Forum - Discourse*, vol. 32. University of Texas, Austin.

McLemore, Cynthia. 1991b. *The Pragmatic Interpretation of English intonation: Sorority Speech*. Ph.D. thesis, University of Texas, Austin.

Merin, Arthur and Christine Bartels. 1997. Decision-theoretic semantics for intonation. Tech. Rep. Bericht Nr. 88, Univ. Stuttgart and Univ. Tübingen.

Milsark, Gary. 1974. *Existential sentences in English*. Ph.D. thesis, Cambridge, Massachusetts.

Moltmann, Friederike. 1992. *Coordination and Comparatives*. Ph.D. thesis, MIT, Cambridge Mass.

Moltmann, Friederike. to appear. Presuppositions and quantifier domains. *Synthese* .

Monz, Christof. 2003a. *From Document Retrieval to Question Answering*. Ph.D. thesis, ILLC, University of Amsterdam, Amsterdam.

Monz, Christof. 2003b. *From Document Retrieval to Question Answering*. Ph.D. thesis, ILLC, University of Amsterdam.

Muller, Philippe and Laurent Prévot. 2003. An empirical study of acknowledgement structures. In *Proceedings of Diabruck*. Saarbrücken.

Nilsen, Øystein. 2003. *Eliminating Positions*. Ph.D. thesis, Utrecht University.

Obenauer, Hans-Georg. 1976. *Etudes de la Syntaxe Interrogative du Français*. Tübingen: Niemeyer.

Ohala, John J. 1984. An ethological perspective on common cross-language utilization of FO of voice. *Phonetica* 41(1):1–16.

Otto, Martin. 2000. An interpolation theorem. *Bulletin of Symbolic Logic* 6:447–462.

Ouhalla, Jamal. 1996. Remarks on the binding properties of WH-pronouns. *Linguistic Inquiry* 27:676–707.

Palmer, Frank R. 1986. *Mood and Modality*. Cambridge University Press.

Paul, Hermann. 1880. *Prinzipien der Sprachgeschichte*. Leipzig: Niemeyer.

Pesetsky, David. 2000. *Phrasal Movement and its Kin*. Cambridge, Mass.: MIT Press.

Pierrehumbert, Janet. 1980. *The Phonology and Phonetics of English Intonation*. Ph.D. thesis, MIT, distributed by the Indiana University Linguistics Club.

Pierrehumbert, Janet and Julia Hirschberg. 1990. The meaning of intonational contours in the interpretation of discourse. In P. R. Cohen, J. Morgan, and M. E. Pollack, eds., *Intentions in Communication*, chap. 14, pages 271–311. MIT Press.

Postal, Paul. 1998. *Three Investigations of Extraction*. Cambridge, Mass.: MIT Press.

Prince, Alan and Paul Smolensky. 1997. Optimality: from neural network to universal grammar. *Science* 275:1604–1610.

Prüst, Hub, Remko Scha, and Martin H. van den Berg. 1994. Discourse grammar and verb phrase anaphora. *Linguistics and Philosophy* 17:261–327.

Reinhart, Tanya. 1981. Pragmatics and linguistics: An analysis of sentence topics. *Philosophica* 27(1):53–94.

Reinhart, Tanya. 1997. Interface economy: Focus and markedness. In C. Wilder, H. M. Gaertner, and M. Bierwisch, eds., *The Role of Economy Principles in Linguistic Theory*. Berlin: Akademische Verlag.

Reyle, Uwe. 1993. Dealing with ambiguities by underspecification: Construction, representation and deduction. *Journal of Semantics* 10:123–179.

Rizzi, Luigi. 1990. *Relativized Minimality*. Cambridge, Mass.: MIT Press.

Roberts, Craige. 1995. Domain restriction in dynamic interpretation. In E. Bach, E. Jelinek, A. Kratzer, and B. H. Partee, eds., *Quantification in Natural Languages*. Dordrecht: Kluwer.

Roberts, Craige. 1996. Information structure in discourse. In J. H. Yoon and A. Kathol, eds., *Working Papers in Linguistics 49*, pages 91–136. Ohio State University.

Rochemont, Michael. 1986. *Focus in Generative Grammar*. John Benjamins.

van Rooij, Robert. 1997a. *Attitudes and Changing Contexts*. Ph.D. thesis, IMS, Stuttgart.

van Rooij, Robert. 1997b. The context-dependence of questions and answers. In P. Dekker, M. Stokhof, and Y. Venema, eds., *Proceedings of the Eleventh Amsterdam Colloquium*. Amsterdam: ILLC, University of Amsterdam.

van Rooij, Robert. 2002. Relevance implicatures. Manuscript, ILLC, Amsterdam.

van Rooij, Robert. 2003. Questioning to resolve decision problems. *Linguistics and Philosophy* 26:727–763.

van Rooij, Robert. 2004. Utility, informativity and protocols. *Journal of Philosophical Logic* 33:389–419.

van Rooij, Robert and Katrin Schulz. 2004. Exhaustive interpretation of complex sentences. *Journal of Logic, Language, and Information* 13:491–519.

Rooth, Mats. 1985. *Association with Focus*. Ph.D. thesis, University of Massachusetts, Amherst.

Rooth, Mats. 1992. A theory of focus interpretation. *Natural Language Semantics* 1(1):75–116.

Rooth, Mats. 1996. Focus. In S. Lappin, ed., *The Handbook of Contemporary Semantic Theory*, pages 271–297. Oxford: Blackwell.

Ross, John R. 1970. Gapping and the order of constituents. In M. Bierwisch and K. E. Heidolph, eds., *Progress in Linguistics*, pages 249–259. The Hague: Mouton.

Rullmann, Hotze. 1995. *Maximality in the Semantics of Wh-constructions*. Ph.D. thesis, University of Massachusetts, Cambridge, Massachusetts.

Šafářová, Marie. 2005. *Rises and Falls: Studies in the semantics and pragmatics of intonation*. Ph.D. thesis, University of Amsterdam.

Šafářová, Marie and Marc Swerts. 2004. On recognition of declarative questions in English. In *Proceedings of Speech and Prosody*. Nara, Japan.

Sauerland, Uli. 2004. Scalar implicatures in complex sentences. *Linguistics and Philosophy* 27:367–391.

Scha, Remko. 1981. Distributive, collective and cumulative quantification. In J. Groenendijk, T. Janssen, and M. Stokhof, eds., *Formal Methods in the Study of Language, Part 2*, pages 483–513. Amsterdam: Mathematical Centre.

Schulz, Katrin. 2005. A pragmatic solution for the paradox of free choice permission. To appear in *Synthese*.

Schulz, Katrin and Robert van Rooij. 2005. Pragmatic meaning and non-monotonic reasoning: The case of exhaustive interpretation. To appear in *Linguistics and Philosophy*.

Schwarzschild, Roger. 1994. The contrastiveness of associated foci. Hebrew University of Jerusalem.

Schwarzschild, Roger. 1999. GIVENness, avoid F and other constraints on the placement of focus. *Natural Language Semantics* 7(2):141–177.

Selkirk, Elisabeth. 1984. *Phonology and Syntax: The relation between sound and structure*. Cambridge, Mass.: MIT Press.

Seuren, Pieter A. M. 1985. *Discourse Semantics*. Oxford: Blackwell.

Shi, Dingxu. 1994. The nature of Chinese WH-questions. *Natural Language and Linguistic Theory* 12:301–333.

Spector, Benjamin. 2003. Scalar implicatures: Exhaustivity and Gricean Reasoning. In B. ten Cate, ed., *Proceedings of the ESSLLI 2003 Student Session*. Vienna.

Sperber, Dan and Deirdre Wilson. 1986. *Relevance: Commnication and Cognition*. Oxford: Blackwell. 2-nd edition 1995.

Stalnaker, Robert. 1978. Assertion. In P. Cole, ed., *Syntax and Semantics 9 – Pragmatics*, pages 315–332. New York: Academic Press.

Stalnaker, Robert. 1998. On the representation of context. *Journal of Logic, Language and Information* 7:3–19.

von Stechow, Arnim. 1982. Structured propositions. Tech. rep., Universität Konstanz, Konstant.

von Stechow, Arnim. 1991. Focusing and backgrounding operators. In W. Abraham, ed., *Discourse Particles: descriptive and theoretical investigations on the logical, syntactic and pragmatic properties of discourse particles in German*. Amsterdam: John Benjamins.

von Stechow, Arnim and Thomas E. Zimmermann. 1984. Term answers and contextual change. *Linguistics* 22:3–40.

Steedman, Mark. 2004. Information-structural semantics for English intonation. In *Proceedings of the LSA Workshop on Topic and Focus*.

Szabolcsi, Anna. 1981. The semantics of topic-focus articulation. In J. Groenendijk, T. Janssen, and M. Stokhof, eds., *Formal Methods in the Study of Language*. Amsterdam: Mathematical Centre.

Szendröi, Kriszta. 2003. Acquisition evidence for an interface theory of focus. In J. van Kampen, ed., *Proceedings of Generative Approaches to Language Acquisition*. Utrecht, The Netherlands.

Tarski, Alfred. 1956. The concept of truth in formalized languages. In *Logic, Semantics, Metamathematics*, pages 152–278. Oxford: Clarendon Press. Originally published as "Der Wahrheitsbegriff in der formalisierten Sprachen", 1936, *Studia Philosophica 1*, pp. 261–405.

Tarski, Alfred. 1986. What are logical notions? *History and Philosophy of Logic* 7:143–154.

Tomasello, Michael. 1999. *The Cultural Origin of Human Cognition*. Harvard University Press.

Tsai, Wei-Tien. 1994. *On Economizing the Theory of A-Bar Dependencies*. Ph.D. thesis, MIT, Cambridge, Mass.

Uldall, Elisabeth. 1962. Ambiguity: question or statement?, or, "Are you asking me or telling me?". In *Proceedings of IVth ICPhS*, pages 779–783.

Vallduví, Enric. 1992. *The informational component*. New York: Garland.

Velissaratou, Sophia. 2000. *Conditional questions and which-interrogatives*. Master's thesis, ILLC, University of Amsterdam.

Veltman, Frank. 1996. Defaults in update semantics. *Journal of Philosophical Logic* 25:221–261.

Watanabe, Akira. 1992. Subjacency and S-structure movement of WH-in-situ. *Journal of East Asian Linguistics* 1:255–291.

Westerståhl, Dag. 1995. Quantifiers in natural language. A survey of some recent work. In M. Krynicki and M. Mostowski, eds., *Quantifiers: Logic, Models and Computation, vol. 1*, pages 359–408. Dordrecht: Kluwer.

Williams, Edwin. 1994. *Thematic Structure in Syntax*. Cambridge, Mass.: MIT Press.

Wittgenstein, Ludwig. 1922. *Tractatus Logico-Philosophicus*. Oxford: Routledge and Kegan. Originally appeared in 1921 as Logisch-Philosophische Abhandlung in the "Annalen der Naturphilosophie, 14.

Wittgenstein, Ludwig. 1953. *Philosophical Investigations*. Oxford: Blackwell.

Zeevat, Henk. 1994a. Applying an exhaustivity operator in update semantics. In H. Kamp, ed., *Ellipsis, Tense and Questions*. Amsterdam: ILLC. DYANA2 deliverable R 2.2.b.

Zeevat, Henk. 1994b. Questions and exhaustivity in update semantics. In H. Bunt, R. Muskens, and G. Rentier, eds., *Proceedings of the International Workshop on Computational Semantics*, pages 211–221. University of Tilburg: ITK.

Zeevat, Henk. 2004. Contrastors. *Journal of Semantics* 21:95–112.

Zeevat, Henk and Remko Scha. 1992. Integrating pragmatics in update semantics. In A. Ortony, J. Slack, and O. Stock, eds., *Communication from an Artificial Intelligence Perspective: Theoretical and Applied Issues*, pages 17–34. Heidelberg: Springer.

Index