

Book Review

Gennaro Chierchia and Sally McConnell-Ginet, *Meaning and Grammar: An Introduction to Semantics* *

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1. Introduction

Many of the central problems in AI, such as natural-language understanding, image understanding, plan recognition, and diagnosis, involve interpreting observations drawn from some source. All these problems have the following elements: on the basis of a certain set of *observations*, construct a *theory* (sometimes called a *model*) that describes the *world* that is revealed by the observations.¹ The observations, of course, generally present only a partial, and even partly incorrect, picture of the world. The observer may have access to other information about the world (the *context*) which can be used to complete and correct the theory.

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¹To avoid a clash of the terminologies used in logic and in AI, I will use the terms *theory*, *model*, and *interpretation* as they are used in logic. For lack of a better term, I will use *understanding* to mean the process of building a theory from observations.

So, for example, in image understanding, the observation (say, an image) licenses a theory (say, a collection of 3D solids) describing some aspect of the world (say, a jumble of parts on a worktable). The world could contain parts that are not reflected in the theory, for example, because they are occluded in the image. The theory could also be less detailed than the world, for example, by not capturing the surface details of the objects. The observations could be marred by imperfect observation conditions, say through an aberrant lens, and knowledge of the nature of the aberration, or of the nature of the objects expected in the scene, might be used to arrive at a (more) correct theory.

The metatheory of these problem areas thus has the task of providing a framework in which one can specify and relate observer, observations, background knowledge, theories, and the world.

In most areas of AI, attention has been focused primarily on the relation between observation and theory, for example, by formalizing the intuition that the theory should be a “best explanation” of the observations, taking into account contextual factors. In this class fall, for example, Reiter and Mackworth’s theory of depiction [25], Kautz’s theory of plan recognition [16], Reiter’s theory of diagnosis [24], and the interpretation methods based on Bayes’ rule (as used in speech recognition [15]) and on minimum-length encoding [20].

When the theories are relatively concrete and simple (as is the case with some of the simple geometric structures used in image understanding, or with word sequences in speech recognition), there is relatively little to be learned by analyzing their relation to the world. But when the concepts they represent can be abstract and complex (as those that arise, for example, with the plan inference problem, which relies on notions of state, action, and even intention), it becomes useful to be able to ask questions such as when theories are consistent, and what logical consequences follow them.

For theories that can be expressed in a logical language, *model-theoretic semantics* provides a useful tool to explore these questions. Properties of theories and models, such as the consistency and completeness of a theory with respect to a model, can then be studied. These methods have been successfully applied to many artificial languages of interest to computer science, including programming languages, temporal logic, and dynamic logic. Much of our understanding of nonmonotonic logic is a result of applying semantic techniques (e.g., [19,27]).

Although in image understanding and in diagnosis one seldom talks about the *meaning* of observations, in linguistics, meaning is central (at least to those who agree that there is life beyond syntax). Sharp differences of opinion remain, however, over what meanings are, or even what there are meanings of. Sentences, utterances (i.e., sentences in context), and speakers are all candidates.

Following on some of his (and others') early successes with the model theory of artificial languages, Tarski [29] took linguistic meaning to be a property of sentences, and proposed that it should be taken to be the conditions under which they would be true in given circumstances. The sentence *John walks* is true (in the current world at the present time) if and only John walks (in this world, now).

In a series of papers in the 1960s culminating in *The proper treatment of quantification in English* (PTQ) [18], Montague began applying the Tarskian approach to natural language: he showed for the first time how to define precisely the syntax and denotations of a fairly complex fragment of English. Emphasizing, as Chomsky had for syntax, that the analysis should apply to unbounded languages, Montague proposed a treatment based on a strong assumption of *compositionality*: the meaning of a complex phrase should be given only in terms of the meanings of its parts.

Montague's ideas developed a loyal following among the theoretical (i.e., noncomputational) semanticists, but this popularity did not come easily. For a reader whose background is limited to an understanding of elementary syntax and of first-order logic, PTQ presents a number of rather formidable technical obstacles.² Several semantic problems are solved together, each contributing its share of machinery. In PTQ, these ideas are presented almost simultaneously, and it is not easy to distinguish their separate consequences.

2. *Meaning and Grammar*

Chierchia and McConnell-Ginet's *Meaning and Grammar* is a solid introduction to the model-theoretic semantics of English, aimed primarily at advanced undergraduate and graduate students in linguistics departments. For that audience, it should become the text of choice. Following the example of the first successful textbook in the area, Dowty, Wall, and Peters' *An Introduction to Montague Grammar* (IMG) [8], the authors introduce the main ideas of model-theoretic semantics by leading the reader through a series of progressively more comprehensive fragments of English. The core

²The syntax, based on an algebraic system called *categorial grammar*, was quite foreign to linguists familiar with context-free grammars and with the most widely accepted syntactic theory of the time, Chomsky's transformational grammars [4]. Because Montague attempts to give semantics to modal verbs such as *believe*, to (some) verb tenses, and to time-dependent expressions such as *the temperature*, the domains of his logical models are much more complex than those needed for first-order logic. Finally, compositionality requires that expressions such as *loves John* and *loves every man* each be given interpretations, as they are necessary to derive the interpretations of *Mary loves John* and *Mary loves every man*. These interpretations end up being complex functions on the domain, represented as lambda expressions.

of the book is what one could call *context-independent semantics*—the part that deals with interpretation of sentences with no reference to discourse setting. Although similar to IMG in structure, the presentation differs in many details.³

But the main interest of *Meaning and Grammar* is in its coverage of some of the major developments in model-theoretic semantics since PTQ. Still within the realm of context-independent semantics, Chapter 9 is an excellent introduction to *generalized quantifiers*. The conventional way of giving interpretations to quantifiers such as *some* and *every* is to state a separate rule for each quantifier. Barwise and Cooper [2] presented a very elegant treatment of quantification that deals uniformly with a large class of quantifiers (including, for example, *most*, *the*, and *two*, as well as *some* and *every*), and predicts their behavior with conjunctions and negations.

Readers familiar only with the general principles of model-theoretic semantics may be surprised by *Meaning and Grammar*'s forays in some areas of meaning that depend on context.⁴ But before entering this part of the discussion, it would perhaps be useful to say a few words about the relevance of model-theoretic semantics to *computational linguistics* and AI.

3. PTQ and computational linguistics

PTQ provoked a flurry of interest among computational linguists in the 1970s and early 1980s. The discipline of compositionality made it easier to deal with some aspects of the writing of context-independent “semantic interpretation rules”. PTQ's intermediate representation language, intensional logic (IL), was sufficiently rich to allow the encoding of complex concepts. But several problems remained.

The compositionality constraint forced *all* semantic differences to be reflected at the syntactic level. The two readings of (1)—one where a single woman is the object of every man's love and another where there may be more than one woman—needed to be *syntactically* different.

- (1) Every man loves a woman.

Theoretical linguists had trouble justifying the extra distinctions on syntactic grounds, and computational linguists found the computational costs

³For example, the syntactic foundation of *Meaning and Grammar* is context-free grammar, with a few transformations added, rather than categorial grammar. Readers seeking an exegesis of PTQ should still read IMG.

⁴The study of the aspects of meaning that depends on context is sometimes called *pragmatics*. The authors generally avoid the term, which is used in a great variety of ways, and so will I. For a good discussion of the issue, see [17].

of the extra syntactic ambiguities very high. This led to adaptations of Montague's semantic ideas to different syntactic models (e.g., GPSG [10]), and to theories that allowed for more modularity. Woods [31] and Cooper [7], for example, showed how a storage mechanism operating in parallel with the compositionally constructed denotations makes it possible to deal with quantifier ambiguities outside the syntax.⁵

But the main deficiency of PTQ, in the eyes of computational linguists, is that it did not address the effect of context on meaning, or at least of that part of context that is not controlled by syntax. PTQ has nothing to say about the fact that in (2a) *they* refers to the city counselors while in (2b) it refers to the demonstrators, that in (2c) the relation between *oil* and *filter* is different from that between *oil* and *tank*, that *bank* in (2d) is a financial institution, and that (2e) is a request even if it looks like a question.

- (2) (a) The city counselors denied the demonstrators a permit because they feared violence.
- (b) The city counselors denied the demonstrators a permit because they advocated violence.
- (c) Sam changed the oil filter of the oil tank.
- (d) John went to the bank to get money.
- (e) Can you tell me my grade?

Some context-dependent constructions have been given interpretations in model-theoretic semantics. Chapter 6 of *Meaning and Grammar* presents Bar-Hillel's suggestion [1] that *indexicals*, such as *I* and *now*, could be given denotations by adding to the valuation function extra parameters that take on the value of the current speaker and time.⁶ One of the most interesting parts of *Meaning and Grammar* is its treatment of a number of other aspects of context-dependent meaning, such as presuppositions, within the framework of model-theoretic semantics.

But the fact remains that the context dependencies given in the examples in (2) are not among those addressed within model-theoretic semantics, and hence within *Meaning and Grammar*. The reason is simple: in none of these examples does the context *determine* what resolutions should take place. Some choices may be *preferred*, but it is not until they have been *assumed* and that meanings have been made determinate that the interpretation rules

⁵Recently, a syntactic theory quite close to the one used in PTQ, unification categorial grammar [32], has been getting much attention, primarily for its ability to deal with a set of difficult interactions between syntax and semantics, but it is wisely still not being used to reflect quantifier scoping in the syntax.

⁶The semantics of indexicals is much more complex than hinted at here, and well covered in Chapter 6. Work in situation semantics, not covered in *Meaning and Grammar*, is also concerned with this issue [3].

of model-theoretic semantics can assign denotations. In (2e), it is logically possible for John to have dug up his money from a spot by the river. In fact, this reading would become preferred (although still not necessary) if (2e) were followed by (2f).

- (2) (f) He almost fell into the river.

So, let us return to the picture, sketched in the first section, of a relation between observation, theory, and the world. Although, in the natural language case, one traditionally thinks of meaning as a direct relation between sentences—the observations—and the world (including agents, as discussed further in the next section), I believe it is more helpful to think of a theory, also incorporating assumptions about the context, acting as an intermediary between observations and (models of) the world. And, of course, this assumption process is nonmonotonic.

Under this perspective, most of the work on natural-language understanding done in the context of AI (e.g. [14,30]) can be seen as addressing the problem of what assumptions to make. Model-theoretic semantics still helps to clarify the structure of the underlying domain and the contribution of syntactic constraints. What role compositionality should play in the assumption process is far from settled. Pereira and Pollack [21] offer one promising avenue.

4. Speech act theory

The aspect of *Meaning and Grammar* I was most surprised by, and pleasantly so, was its attention to the action-based perspective on linguistic meaning, generally referred to as *speech act theory*. It is awkward at best, within a semantic account based on truth values, to deal with sentences such as questions and imperatives, which cannot be easily assigned truth values, and with actions, such as gestures, that may be used communicatively, but are not performed linguistically.

For Grice [12], meaning was fundamentally a property of *speakers*—of communicators. A sentence's meaning (its *timeless meaning*, as he called it) arises as a consequence of its being used conventionally to convey speaker meaning. The heart of Grice's analysis of a speaker's meaning some proposition *p* (e.g., that the hearer should close the door) rests on the speaker's intending that the hearer recognize his intention that *p*. Extending Grice's analysis, Searle [26] proposed definitions of several *illocutionary acts*, such as informing, requesting, and promising, and suggested that the (literal) meaning of an utterance be taken to be the illocutionary act performed by the speaker. Grice and Searle thus showed the way to an analysis of meaning that, by linking it to mental state and action, allowed meaning to

be assigned, not only to statements, but to other speech acts, and potentially even to nonlinguistic communicative acts such as gestures. Because of its natural connection to planning and plan recognition, this idea has been useful in AI, particularly in language generation and in the understanding of dialogues.

The authors devote most of Chapter 4 to speaker meaning and the dynamics of discourse. Following the practice common in model-theoretic semantics, they avoid enlisting actions and mental concepts as critical participants in their enterprise. They thereby escape from having to explicate these notoriously difficult notions and their interactions, as attempted, for example, by various authors in [6]. Instead, they try to get around the assimilation of meaning to illocutionary acts by adopting a very abstract view of the contribution of action to sentence meaning. They take the sentential meaning of a declarative sentence such as *There is a bull in the field*, to be the *statement* of the proposition that there is a bull in the field, which, following Stalnaker [28], they define as the function that adds the stated proposition to a context. Sentential meaning has thus become dynamic.

This approach (the “meaning as locutionary act” approach) leaves open several questions. First, what are the analogous rules for sentences of other moods, such as imperatives and interrogatives? What do they add to context? Second, what happens when new information conflicts with old?

The obvious answer to the first question is that what is added to the context is not just any kind of proposition, but specifically one that characterizes the speaker’s relation to another proposition, indicated by linguistic content—for example, that the speaker believes a proposition, in the case of a declarative, or that he intends some action to be done, in the case of an imperative or interrogative. This would already help account for the fact that the use of *It is red* is appropriate in (3), but not in (4) and (5).

- (3) I bought a car. It is red.
- (4) Did you buy a car? *It is red.
- (5) (a) A: Did you buy a car?
(b) B: No.
(c) A: *Is it red?

This solution, obviously, does not entirely avoid the introduction of mental vocabulary, although it does not require that meaning explain illocutionary acts.

The second issue—how to deal with revisions in the context—is, of course, the problem of theory revision. Nonmonotonicity is a key issue here, and it is hardly mentioned in the book (but see [9,22]).

There is a third problem with the meaning-as-locutionary-act approach. Searle's main reason for postulating the equation between sentence meaning and illocutionary acts was to account for the so-called explicit performative sentences, such as *I hereby find you guilty*, that *make* something true (at least in the right circumstances), not just *assert* it as true. The sentence *I hereby lie to you that p*. should be self-defeating. Even if one were to argue that explicit performative sentences had a truth value, the correct circumstances with respect to which it could be determined would not be those at the beginning of the utterance but rather those *created* by the utterance. The authors simply avoid the question of explicit performatives by asserting that they do not see them as "an insuperable problem for a program that places illocutionary force outside the realm of semantics proper". An alternative view is presented by Cohen and Levesque [5], who propose treating illocutionary acts as attempts to achieve changes in mental state.

5. Conclusion

The objectives of model-theoretic semantics and of "computational semantics" are largely complementary. No matter what happens to linguistics, computational or otherwise, in the next 20 years, PTQ, like Chomsky's *Aspects*, will have been on the critical path. Chierchia and McConnell-Ginet have been remarkably successful in pulling together in one book the elements of Montague's program, several extensions, and a foray of model-theoretic semantics into speech act theory. The barriers between semantics and pragmatics are falling, and that is something to rejoice about.

The book is generally well-written, although there are enough stylistic differences between chapters to make the reader conscious of its being the work of two authors. And for the reader who can't guess, they say up front who was responsible for what.

The prerequisites—elementary syntax and no logic—are minimal. The bibliography is well-balanced but not encyclopedic; the authors have modestly resisted the temptation to include everything they have written. The bibliography is also the best evidence for the gap that remains in this area between theoretical linguists and philosophers on the one hand and computational linguists on the other—I could find only one reference to an article by a computational linguist. Each chapter contains a few exercises, but no solutions are given.

Linguistics, as Pullum points out, can be taught in two ways: through an eclectic survey or through "the enlisting of students into the single-minded pursuit of a research goal" [23]. *Meaning and Grammar* is an excellent example of the second route.

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