

Language and Logic: Ideas and Controversies in the History of Formal Semantics

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0. Pre-Introduction

- Mini-bio to put my work in context:
- At Swarthmore College, torn between majoring in math and majoring in Russian; loved math and languages, saw no relation.
- Majored in math with minors in Russian and Philosophy – just the 3 things I loved best, still saw no connection.
- Discovered the existence of linguistics just in time to enter Chomsky’s first class of PhD students at MIT (1961-65). Heaven. Became a syntactician and Chomsky disciple.
- First job at UCLA (1965-72). Old friend David Lewis introduced me to Richard Montague, who was starting to do work on natural language. First sat in on Montague’s seminar in Fall 1968.
- Montague died in 1971; I soon started teaching “Montague grammar” and giving talks about it.
- Moved to UMass Amherst 1972, so did Terry Parsons, and Emmon Bach in 1973 – we became one of the centers of MG.

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Linguistic Institute, UMass Amherst, 1974. Parsons, Partee, Bach



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1. Introduction

- Formal semantics is an approach to semantics, the study of meaning, with roots in logic, philosophy of language, and linguistics.
- The word “formal” in “formal semantics” is opposed to “informal” and reflects the influence of logic and mathematics in the rise of scientific approaches to philosophy and to linguistics in the 20th century.
- Distinctive characteristics of this approach:
 - truth conditions and entailment relations as a central part of meaning;
 - (usually) a model-theoretic conception of semantics;
 - and a guiding methodological principle is the **Principle of Compositionality**: “The meaning of a whole is a function of the meanings of its parts and their mode of syntactic combination.”

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“Semantics” can mean many different things

- “Semantics” traditionally meant quite different things to linguists, philosophers, and psychologists, since different fields have different central concerns and different methodologies.
 - Philosophers have long been concerned with truth and reference, with logic, with compositionality, with how meaning is connected with thought, with the analysis of philosophically important terms.
 - Linguists influenced by Chomsky care about what’s “in the head” of a speaker of a language, and how it’s acquired.
 - Psychologists have experimentally studied concept discrimination, concept acquisition, emphasis on lexical level.
 - Syntax has influenced linguists’ notions of “logical form”; ‘structure’ of meaning suggests ‘tree diagrams’ of some sort.
 - Logicians build formal systems, axioms, model theoretic interpretation. ‘Structure’ suggests inferential patterns or algebraic structures.

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The principal sources of formal semantics

Formal semantics has roots in several disciplines, most importantly logic, philosophy, and linguistics.

The most important figures in its history were Richard Montague (1930-1971), whose seminal works date from the late 1960’s and the beginning of the 1970’s, and David Lewis (1941-2001), whose major contributions span the 1970’s.

There were many other important contributors; none will get their fair treatment today, because the story is big and time is short.



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Introduction, *cont’d.*

- Formal semantics as it has developed over the last 50+ years has been shaped by fruitful interdisciplinary collaboration among linguists, philosophers, and logicians, among others.
- There have been centuries of study of logic and of language. And until the late 19th century, the disciplines logic, psychology and linguistics were not yet separated, and issues of logic, thought, and language were often discussed together and closely intertwined.
- Today, drawing on a book project in progress, I’ll trace some of the background and history of formal semantics, describing some pivotal advances and controversies that have shaped the field.
- I’ll talk about some of the important contributions by logicians as formal semantics and pragmatics developed after Montague’s untimely death in 1971, as well as the “naturalizing” influence that linguists have had on the field as it has become more and more a branch of linguistics, and the ongoing collaborations between them.

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2. Semantics in linguistics

- **Before Chomsky’s *Syntactic Structures* (1957) --**
- In the 19th century linguistics existed within philology in Europe and largely within anthropology in the U.S. Descriptive lexical semantics was important for philology, and semantic analysis of kinship terms etc. was important for anthropology, but there was little theoretical work, no syntax, and no semantics above the word level.
- In the 20th century, like so many other fields, linguistics emerged as a science. Part of the Chomskyan revolution was to view linguistics as a branch of psychology (cognitive science).
- There were negative attitudes to semantics in American linguistics in the 20th century, partly influenced by logical positivism and by behaviorism in psychology.
- In logic and philosophy of language there was great progress in semantics, but it was relatively unknown to most linguists.

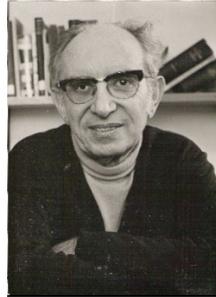
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Semantics in linguistics, *cont'd.*

- 1954: The philosopher and logician Yehoshua Bar-Hillel wrote an article in *Language* inviting cooperation between linguists and logicians, arguing that advances in both fields would seem to make the time ripe for an attempt to combine forces to work on syntax and semantics together.
- Bar-Hillel was a disciple of Carnap, also influenced by Ajdukiewicz, Norbert Wiener, and the linguist Zellig Harris, Chomsky's teacher.



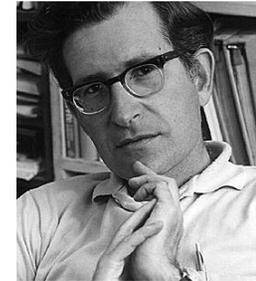
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Semantics in linguistics, *cont'd.*

- 1955: Chomsky, then a Ph.D. student, wrote a reply in *Language* arguing that the artificial languages invented by logicians were so unlike natural languages that the methods of logicians had no chance of being of any use for linguistic theory. (Chomsky and Bar-Hillel remained friends.)
- It took another 15 years or so for the synthesis to begin.



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Semantics in linguistics, *cont'd.*

- Later note: Bar-Hillel in 1967 wrote to Montague, after receipt of one of Montague's pragmatics papers: "It will doubtless be a considerable contribution to the field, though I remain perfectly convinced that without taking into account the recent achievements in theoretical linguistics, your contribution will remain one-sided." Bar-Hillel never gave up trying to get the logicians and linguists together.
- The philosopher Frits Staal also tried on many occasions to get linguists, logicians, and philosophers together, including Chomsky and Montague. He founded the journal *Foundations of Language* with that aim. And he also edited the transcript of the symposium on "The Role of Formal Logic in the Evaluation of Argumentation in Natural Languages" that Bar-Hillel organized in 1967 at the 3rd International Congress for Logic, Methodology and Philosophy of Science in Amsterdam.

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Chomsky's *Syntactic Structures* (1957)

- Chomsky concentrated on the native speaker's ability to produce and understand a potentially infinite class of sentences.
- His conclusion: linguistic competence must involve some finite description of an infinite class of sentences.
- His formulation of the goals of linguistic theory revolutionized the field.
- Chomsky's syntax has been extremely influential; he has been ambivalent about semantics.
- He has been skeptical about the possibility of including semantics in a formal grammar.
- But he has held that one test of a syntactic theory is that it should provide a basis for a good semantics.



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The Katz-Postal hypothesis and the Garden of Eden

- In a theoretically important move within a Chomskyan approach, aiming for compositionality, Katz and Postal (1964) made the innovation of putting such morphemes as Neg into Deep Structure, as in (1). Then the meaning could be determined on the basis of a Chomskyan Deep Structure alone and a “Negation transformation” wouldn’t change meaning as it had in Chomsky (1957).
- (1) [NEG [Mary [has [visited Moscow]]]] ⇒_{T-NEG} [Mary [has not [visited Moscow]]]
- In *Aspects of the Theory of Syntax* (1965), Chomsky tentatively accepted Katz and Postal’s hypothesis of a syntax-semantics connection at Deep Structure.
- The architecture of the theory (syntax in the middle, with semantics on one side and phonology on the other) was elegant and attractive.
- This big change in architecture rested on the claim that transformations should be meaning-preserving.
- “Garden of Eden” period, when *Aspects* = “the standard theory”.

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Expulsion from Garden of Eden and the roots of the linguistic wars

- A surprising historical accident is that the behavior of quantifiers with respect to transformational rules familiar from *Syntactic Structures* and *Aspects* was not really noticed until the Katz-Postal hypothesis had for most linguists reached the status of a necessary condition on writing rules.
- I believe that this historical accident was one of the major causes of the “linguistic wars” between Generative Semantics and Interpretive Semantics.
- On the next slide I give a few examples of derivations that would have been given in the *Aspects* theory, where the examples given typically involved proper names like *John* and *Mary*, not quantifier phrases like *every man*.
- We see that in examples with names, the transformations are meaning-preserving. But in the corresponding examples with quantifier phrases, the transformations radically change the meaning (and it may change in different ways with different quantifiers).
- I suspect that the Katz-Postal hypothesis would never have been suggested if such quantifier examples had been noticed earlier, and the history of syntax and semantics would have been different.

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Expulsion from the Garden of Eden, *cont’d.*

- REFLEXIVIZATION
John voted for John. → John voted for himself.
Every man voted for every man. → Every man voted for himself.
- EQUI-NP DELETION
Mary wanted Mary to win. → Mary wanted to win.
Every candidate wanted every candidate to win. → Every candidate wanted to win.
- CONJUNCTION REDUCTION
3 is even and 3 is odd. → 3 is even and odd.
No number is even and no number is odd. → No number is both even and odd.
- RELATIVE CLAUSE FORMATION
The pacifist fought. The pacifist was inconsistent. → The pacifist who fought was inconsistent.
All pacifists fight. All pacifists are inconsistent. → All pacifists who fight are inconsistent.

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The Linguistic Wars of the Late 1960’s

- The Katz-Postal hypothesis, and hence Chomsky’s *Aspects*, incorporated the Compositionality Principle: the meaning of a whole is a function of the meanings of its parts and of how they are syntactically combined. In *Aspects*, the relevant syntactic structure was Chomsky’s Deep Structure.
- When that failed, Generative Semanticists kept the goal of compositionality and pushed the ‘deep’ structure “deeper”, making it a kind of logical form. But they knew only first-order logic.
- Chomsky had been tentative about adopting the K-P hypothesis, and valuing syntactic autonomy more highly, he and the Interpretive Semanticists abandoned the K-P hypothesis and kept their syntax.
- The linguistic wars concerned the relation of syntax to semantics, though linguists had relatively primitive ideas about semantics.
- So with the linguistic wars of the late 60’s and early 70’s raging, let’s turn to philosophy and logic.

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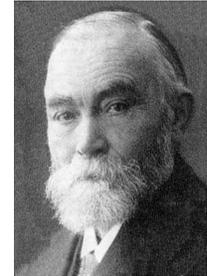
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3. Semantics in Logic and Philosophy

- The relevant history in philosophy goes back at least to Aristotle.
- For today all I'll say about Aristotle was that his logic was so elegant that his syllogistic treatment of quantifier sentences became like a bible for centuries. And that left sentences with more than one quantifier ignored until the 19th century.
- The history of the formally oriented approach towards the philosophy of language goes back at least to Rene Descartes (1596-1650) and Gottfried Leibniz (1646-1716).
- And George Boole (1815-64) had an algebraic conception for a system governing the "Laws of Thought", a *calculus ratiocinator* independent from the vagaries of natural language. (Boolean algebra turns out to have widespread application to natural language semantics, whether Boole would like that or not.)

Frege

- The greatest foundational figure for formal semantics is Gottlob Frege (1848-1925). His crucial ideas include the idea that *function-argument* structure is the key to semantic compositionality.
- Frege is also credited with **the Principle of Compositionality**: The meaning of a complex expression is a function of the meanings of its parts and of the way they are syntactically combined.
- And Frege introduced the distinction between *sense* and *reference* (*Sinn* and *Bedeutung*), which philosophers and semanticists have tried to formalize adequately ever since.

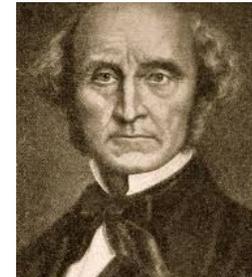


Frege, cont'd.

- One of Frege's great contributions was the logical structure of quantified sentences. That was part of the design of a "concept-script" (*Begriffsschrift*), a "logically perfect language" to satisfy Leibniz's goals.
- He did not see himself as offering an analysis of natural language, but a tool to augment it, as the microscope augments the eye.
- Frege also figured out a systematic and compositional semantics for variable-binding, prefiguring something Tarski did 50 years later.
- Frege rejected the psychologism of many of his predecessors, including John Stuart Mill (1806-1873).
- This is an interesting issue that arose again in a different form when linguists began to import logicians' tools into linguistics – we'll return to it at the end.

Psychologism and anti-psychologism in Logic

- Mill: Logic is a branch of psychology.
- So far as it is a science at all, [Logic] is a part, or branch, of Psychology; differing from it, on the one hand as the part differs from the whole, and on the other, as an Art differs from a Science. Its theoretical grounds are wholly borrowed from Psychology, and include as much of that science as is required to justify its rules of art (Mill, *Logic*, 1865, 359).



Frege's anti-psychologism in logic.

- One of Frege's main theses is that mathematics and logic are not part of psychology, and that the objects and laws of mathematics and philosophy are not defined, illuminated, proven true, or explained by psychological observations and results. One of Frege's central arguments for this thesis is the consideration that whereas mathematics is the most exact of all sciences, psychology is imprecise and vague (1884, 38). (Kusch 2011)
- Frege claims that in the realm of logic we find both descriptive and prescriptive laws, with the former being the foundation for the latter.
 - ...every law that states what is can be apprehended as prescribing that one ought to think in accordance with it ... This holds of geometrical and physical laws no less than logical laws (Frege 1893, XV).
- Frege's main criticism of psychological logic is that it conflates 'true' and 'being-taken-to-be-true'.
- "Psychologism" is a foundational issue in semantics – more later.

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Some key 20th century developments in logic/ semantics

- Bertrand Russell (1872-1970) introduced *logical types* to avoid paradox, using them to impose restrictions on well-formed function-argument expressions.
- Early Carnap used the theory of types syntactically for the 'logical construction of the world' and 'the logical construction of language'.
- Tarski developed *model theory* based in set theory and with it made major advances in providing a **semantics** for logical languages, including his semantical definition of truth.
- Later Carnap, influenced in part by Tarski, developed a *semantic* approach, where meaning = truth conditions, an idea he got from early Wittgenstein.
- Carnap introduced possible worlds as state-descriptions, and analyzed intensions as functions from possible worlds to extensions.
- Carnap and Tarski both had major influence on Montague's work.

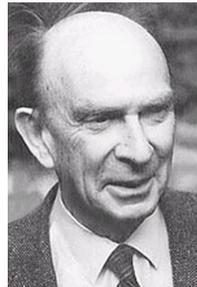
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The Ordinary Language – Formal Language Wars

- In the late 1940's, a war began within philosophy of language, the "Ordinary Language" vs "Formal Language" war.
- Ordinary Language Philosophers rejected the formal approach, urged attention to ordinary language, its uses, context-dependence. Late Wittgenstein (1889-1951), Ryle (1900-1996), Austin (1911-1960), Strawson (1919-2006).
- Strawson 'On referring' (1950): "The actual unique reference made, if any, is a matter of the particular use in the particular context; ... Neither Aristotelian nor Russellian rules give the exact logic of any expression of ordinary language; for ordinary language has no exact logic."



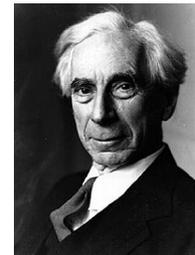
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Does ordinary language "have no logic"?, *cont'd.*

- Russell 1957, 'Mr. Strawson on referring': "I may say, to begin with, that I am totally unable to see any validity whatever in any of Mr. Strawson's arguments. ... I agree, however, with Mr. Strawson's statement that ordinary language has no logic."
- Russell was not the first philosopher to complain about the illogicality of natural language. One of his complaints was the way English put phrases like "every man", "a horse", "the king" into the same syntactic category as names like "Smith".
- He considered the formulas of his first-order logic a much truer picture of 'logical form' than English sentences.



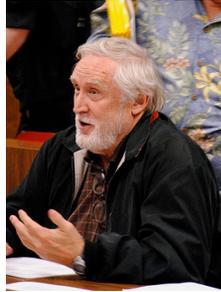
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On the claim that ordinary language has no logic

- Terry Parsons reports (p.c.) that when he started thinking about natural language in the late 60's, he was very much aware of the tradition from Russell that "the grammar of natural language is a bad guide to doing semantics".
- But in 'On denoting', he realized, Russell had produced an *algorithm* for going from this 'bad syntax' to a 'good semantics'.
- That would suggest that the grammar of natural language was not such a bad vehicle for expressing meaning, including the meaning of sentences with quantifiers, definite descriptions, etc.



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The OL- FL war and responses to it

- The interesting response of some formally oriented philosophers to the OL-FL war was to try to analyze ordinary language better, including its context-dependent features.
- The generation that included [Prior](#), [Bar-Hillel](#), [Reichenbach](#), [Curry](#), and [Montague](#) gradually became more optimistic about being able to formalize the crucial aspects of natural language.
- Along with Bar-Hillel's calls for linguistics-philosophy cooperation, Frits Staal and several colleagues launched the journal *Foundations of Language* in 1965 calling for broader interdisciplinary cooperation. (Its successor is *Linguistics and Philosophy*.)
- Arthur Prior (1914-1969) made great progress on the analysis of tense, one central source of context-dependence in natural languages, which had been omitted from earlier logical languages. He visited UCLA in 1965; he and Montague influenced each other.

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Some people and groups

- Polish logicians – Leśniewski, Łukasiewicz, Ajdukiewicz, Tarski
- Rudolf Carnap – Vienna Circle > Prague > Chicago > UCLA
- Evert Beth – Amsterdam. Also Johan van Benthem.
- Yehoshua Bar-Hillel – disciple of Carnap; connections to Reichenbach, Ajdukiewicz, Carnap, Montague, Chomsky.
- Haskell Curry – Birkhoff, Schönfinkel, Bernays, Hilbert, Feys; Penn State College, Amsterdam
- Hans Reichenbach – physics, math, phil. - Berlin Circle, UCLA
- Jaakko Hintikka – von Wright. Helsinki > Stanford > U of Florida > Boston U.
- Donald Davidson – infl. by A.N. Whitehead, Quine, Suppes. Started as an English major, then classics and philosophy.
- A.N. Prior – N.Z. – JN Findlay, JJC Smart. Oxford. Visited UCLA.
- Max Cresswell – N.Z. – Prior. Victoria Univ. Wellington, many visits.
- WVO Quine, Hilary Putnam, David Lewis, Dana Scott.

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4. Montague's work

- Montague, a student of Tarski's, was an important contributor to these developments. His Higher Order Typed Intensional Logic unified tense logic and modal logic (extending Prior's work) and more generally unified "formal pragmatics" with intensional logic.
- Montague also generalized the intensional notions of property, proposition, individual concept, etc., into a fully **typed intensional logic**, extending the work of Carnap (1956), Church (1951), and Kaplan (1964), putting together Frege's function-argument structure with the treatment of intensions as functions from world-time indices to extensions.
- What made his approach daunting also made it powerful; the rich type structure made it possible to have semantic types not just for sentences, predicates, and terms, but for determiners, DPs, modifiers, degree phrases That made it much easier to work compositionally with an independently motivated syntax.

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Why did Montague turn to “linguistic” work?

- A clue about Montague’s motivations: I found in the Montague Archives the preamble to an early talk version of “English as a Formal Language”, July 31, 1968, UBC, Vancouver:
- (I’m now sure I’ve deciphered RM’s shorthand (for small words only) right.)
- “This talk is the result of 2 annoyances:
 - The distinction some philosophers, esp. in England, draw between “formal” and “informal” languages;
 - The great sound and fury that nowadays issues from MIT under the label of “mathematical linguistics” or “the new grammar” -- a clamor not, to the best of my knowledge, accompanied by any accomplishments.
 - I therefore sat down one day and proceeded to do something that I previously regarded, and continue to regard, as both rather easy and not very important – that is, to analyze ordinary language*. I shall, of course, present only a small fragment of English, but I think a rather revealing one.”
 - *Montague’s inserted note: Other creditable work: Traditional grammar, Ajdukiewicz, Bohnert and Backer, JAW Kamp.
 - Later notes (1970) suggest he eventually found it not entirely easy.

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Montague’s view of his “linguistic” work.

- From Staal’s edited proceedings of Bar-Hillel’s 1967 symposium:
- Montague: “As far as the main points are concerned, let me say first that I deplore the distinction customarily drawn between formal and informal languages. The syntax and semantics of certain not insignificant fragments of English can be treated just as formally and precisely as those of the first-order predicate calculus, and in very much the same manner. No adequate treatment of this sort has yet been published; one has, however, been recently developed by my student J. A. W. Kamp and myself.
- “I might add that our treatment [relies on] certain recent developments in intensional logic ... Thus the methods developed in connection with artificial languages can be employed to yield completely precise ... notions of truth and logical consequence for significant fragments of natural language.
- “Yet, although I have myself devoted some time to this goal, I somewhat question its importance. ... Is it really so important ... to be able to establish conclusively that a given argument in a natural language is invalid? I believe that as the scope of exact artificial languages is enlarged, people will begin to use them for argumentation; witness the gradual abandonment of ordinary language by mathematicians between 1875 and the present.”

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- Montague’s first work on natural language was the provocatively titled “English as a Formal Language” (Montague 1970b, “EFL”). He had taught the material at UCLA in spring 1965 (Kamp was there) and at UvA in Spring 1966.
- EFL famously begins “I reject the contention that an important theoretical difference exists between formal and natural languages.”
- As noted by Emmon Bach (1989), the term “theoretical” here must be understood from a logician’s perspective and not from a linguist’s.
- What Montague was denying was the central presupposition of the formal language – ordinary language wars: a mismatch between linguistic form and ‘logical form’ for natural languages.
- What he was proposing, here and in his “Universal Grammar”, was a framework for describing syntax and semantics and the relation between them that he considered compatible with existing practice for formal languages and an improvement on existing practice for the description of natural language.

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- The Fregean principle of compositionality was central to Montague’s theory and remains central in formal semantics.
- Montague’s syntax-semantic interface: Syntax is an algebra, semantics is an algebra, and compositionality is the requirement that there be a homomorphism mapping the former into the latter.
- The nature of the elements of the syntactic and semantic algebras is left open; what is constrained is the relation between them.
- The differences between Montague’s higher-order typed Intensional Logic and first-order predicate logic made a crucial difference for the possibility of giving a compositional semantics based on a relatively “conservative” syntax for English.
- Let me give an example that made a big impact on me and on many linguists.

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Quantifiers in logic and language

- An exercise I often give my students: where in Russell's formula (10), symbolizing *Every man walks*, is the meaning of *every man*?

$$(10) \forall x (\text{man}(x) \rightarrow \text{walk}(x))$$

- The answer is that it is distributed over the whole formula – in fact everything except the predicate *walk* in the formula can be traced back to *every man*. The treatment is *syncategorematic* – there is no constituent in the logical formula corresponding to *every man*.
- One way to answer Russell is to devise a logic in which the translation of *every man* is a constituent in the logical language. Terry Parsons did it with a variable-free combinatoric logic, Montague did it with a higher-order typed intensional logic.
- Both were influenced by seeing how to devise algorithms for mapping from (parts of) English onto formulas of first-order logic, thereby realizing that English itself was not so logically unruly.
- First-order logic has many virtues, but similarity to natural language syntax is not one of them.

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Generalized quantifiers

- One of the first things that impressed linguists about Montague's (and Lewis's) work was how with a higher-typed logic and lambdas or other ways to talk about functions, DPs ("Determiner phrases" – *the man, every linguist, no logician, John*) can be uniformly interpreted as generalized quantifiers (sets of sets).
- And Determiners (*the, every, some, no, most, ...*) could be interpreted as functions that apply to common noun phrase meanings (sets) to make generalized quantifiers.
- Recall how we asked "Where's the meaning of *every man* in (10), the first-order formalization of *Every man walks*?"

$$(12) \begin{array}{ll} \text{every student} & \lambda P \forall x [\text{student}(x) \rightarrow P(x)] \\ \text{every student walks} & \lambda P \forall x [\text{student}(x) \rightarrow P(x)] (\text{walk}) \\ & = \forall x [\text{student}(x) \rightarrow \text{walk}(x)] \end{array}$$

- So now we have a semantic type, $\langle\langle e, t \rangle, t \rangle$, sets of sets of entities, to correspond to English DPs. DP denotes a function, VP its $\langle e, t \rangle$ argument.

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Generalized quantifiers, *cont'd.*

(13)

$$\begin{array}{ll} \text{John} & \lambda P [P(j)] \quad (\text{the set of all of John's properties}) \\ \text{John walks} & \lambda P [P(j)] (\text{walk}) = \text{walk}(j) \\ \text{every student} & \lambda P \forall x [\text{student}(x) \rightarrow P(x)] \\ \text{every student walks} & \lambda P \forall x [\text{student}(x) \rightarrow P(x)] (\text{walk}) \\ & = \forall x [\text{student}(x) \rightarrow \text{walk}(x)] \\ \text{a student} & \lambda P \exists x [\text{student}(x) \& P(x)] \\ \text{the king} & \lambda P [\exists x [\text{king}(x) \& \forall y (\text{king}(y) \rightarrow y = x) \& P(x)]] \\ & (\text{the set of properties which the one and only king has}) \end{array}$$

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- Once Montague had shown what could be done with the use of model-theoretic techniques for compositional semantic interpretation, and with a higher-order intensional logic, linguists and philosophers set about coming up with extensions and modifications of his ideas to fit natural language phenomena even better.
- Many aspects of Montague's own analyses of the semantics of English have been superseded (with major linguistically motivated innovations by Kamp, Parsons, Heim, Chierchia, Kratzer, Rooth, Roberts, many others), but in overall impact, Montague's first works were as profound for semantics as Chomsky's were for syntax.
- Emmon Bach (1989) summed up their cumulative innovations thus: Chomsky's Thesis was that English can be described as a formal system; Montague's Thesis was that English can be described as an *interpreted* formal system.
- Truth-conditions** and **entailment relations** are basic.
- These are data that have to be accounted for to reach a minimal level of adequacy.

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- The advent of truth conditions and the tools of model theory made semantics an incomparably more powerful discipline than it had been before. It may be hard to realize how surprising and controversial an idea it was to linguists in the early 1970's that we should think about truth conditions rather than just ambiguity, semantic anomaly, and synonymy.
- Jon Barwise and Robin Cooper, a logician and a linguist (my first UMass PhD student, 1975), cooperated in the first major investigation of properties of determiners, studied from the perspective of the model-theoretic properties of generalized quantifiers and the determiners that help to build them. (Barwise & Cooper 1981)

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Recursion on open sentences: relative clauses

- And doing recursion on open sentences together with Frege's idea of using function-argument application as a principal means of semantic composition, together led to a far better semantic analysis of relative clauses than had been achieved linguists before or during the semantic wars. (Quine actually presented this solution in *Word and Object*; Montague didn't invent it.)
 - I want to recall how impossible it had been to do justice to relative clauses in quantified noun phrases in earlier linguistic work.
- (16)
- The man who won the men's race was a Kenyan.
 - Every child who carved a pumpkin got a prize.
 - Some child who carved a pumpkin got a prize.
- Combining 'kernel Ss' containing "Identical NP" can't be right.
 - The man won the men's race. The man was a Kenyan.
 - Every child carved a pumpkin. Every child got a prize.
 - Some child carved a pumpkin. Some child got a prize.

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Relative clauses and quantifiers, *cont'd.*

- Generative Semanticists, looking for deep structures that would capture the meanings of these sentences, proposed analyses resembling first-order logic.
- For (16b), where the determiner is *every*, they proposed that in underlying structure, the relative clause is an *if*-clause:
- Every $x \in \text{man}$: if x won the men's race, then x was a Kenyan
- For (16c), where the determiner is *some*, they proposed that in underlying structure, the relative clause is a conjoined with the matrix clause:
- Some $x \in \text{child}$: x carved a pumpkin and x got a prize
- With only first-order logic to work with, it's hard to see how else to get the semantics right. But in fact we don't need or want different interpretations for these relative clauses.
- All restrictive relative clauses can be understood as sentence-sized adjectival clauses. They are all of type $\langle e, t \rangle$, denoting sets, just like nouns and simple adjectives.

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Relative clauses and quantifiers, *cont'd.*

- (17) Every boy who loves Mary is happy
- $[[\text{boy who loves Mary}]] = [[\text{boy}]] \cap [[\text{who loves Mary}]]$
- $[[\text{boy}]]$ is the set of boys
- $[[\text{who loves Mary}]]$ is the set of individuals x such that x loves Mary
- *boy*, *who loves Mary*, and *boy who loves Mary* are all of type $\langle e, t \rangle$.
- On Generalized Quantifier theory, all determiners are functions that first combine with the $\langle e, t \rangle$ NP argument, and then combine with the rest of the sentence, which will also be of type $\langle e, t \rangle$.
- (In the simplest case, the 'rest of the sentence' is just a VP. But if the Generalized Quantifier is not in subject position, it gets "quantified in" by one mechanism or another, and the 'rest of the sentence' is an $\langle e, t \rangle$ -type lambda abstract. See Heim & Kratzer or other textbooks.)

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5. Joint work by linguists and philosophers: from Montague Grammar to current formal semantics

- Montague was doing his work on natural language at the height of the "linguistic wars" between generative and interpretive semantics, though Montague and the semanticists in linguistics had no awareness of one another.
- The earliest introduction of Montague's work to linguists came via Partee (papers on "Montague Grammar" starting in 1973) and Thomason (who published Montague's collected works with a long introductory chapter in 1974).
- Partee and Thomason argued that Montague's work might allow the syntactic structures generated to be relatively conservative ("syntactically motivated") and with relatively minimal departure from direct generation of surface structure, while offering a principled way to address many of the semantic concerns that motivated some of the best work in generative semantics.

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Joint work by linguists and philosophers, cont' d.

- Let me review an obstacle I faced when I started trying to put MG and TG together, whose solution is related to a leading idea that came into linguistics from philosophy and logic in this period, namely the (Fregean) idea that recursion must be done on *open* sentences.
 - Obstacle: what to do about deletion rules? In classical TG, (5a) was derived from something like (5b) by "Equi-NP Deletion".
- (5) a. Mary was eager to win.
b. [_S Mary was eager for [_S Mary to win]]
- But given the principle of compositionality, and given the way MG works by building up the meanings of constituents from the meanings of their subconstituents, there is nothing that could correspond to "deleting" a piece of a meaning of an already composed subpart.

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Joint work by linguists and philosophers, cont' d.

- Recall the consequences of "Equi-NP Deletion" for a sentence like (6a). The presumed deep structure (6b) would clearly give the wrong meaning.
- (6) a. Everyone was eager to win.
b. [_S everyone was eager for [_S everyone Tns win]]
- MG-TG resolution suggested in (Partee 1973, 1975): what we want as "underlying" subject in the embedded sentence is a bindable variable; I followed Montague's line and bound it by lambda abstraction to give the complement a VP type. (Some kept an S type for the infinitive, with the variable bound by the higher quantifier.)
- (7) a. [[to win]] = λx [win(x)]
b. alternatively: 'everyone' (λx [x was eager for [x to win]])
- That solution is one illustration of the importance of the Fregean principle that wherever quantifiers may be involved, recursion must be allowed to work on *open* sentences.

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Joint work by linguists and philosophers, cont' d.

- It was Montague's use of lambda abstraction as the active variable-binding operator in PTQ that unified variable binding in connection with quantification, relative clauses, and interrogatives.
- Lambda abstraction creates compositional 'names' for **functions**; this is central to function-argument-centered type theory.
- In retrospect: it was doing all recursion on **closed** sentences ("kernel sentences") that made transformational rules that involved "identical NPs" break down when quantifiers were discovered.
- And Polly Jacobson has shown how to capture these properties within a variable-free semantics using combinators – see her work on that.

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Mass and plural

- Although Montague's last paper is called 'The proper treatment of quantification in ordinary English', the only quantifiers he actually treated there were *a/an, every, the*.
- Manuscript notes show that he originally wanted to include many more, but without a treatment of plurality he was very limited. Other singular determiners he thought about included *no* and *any*; but he was not prepared to treat negation other than simple sentential negation, and he saw problems with *any* that he did not have solutions for.
- Early attempts to treat plurals, like Michael Bennett's in his 1974 dissertation, put them in a higher type than singulars, which caused considerable complexity and non-uniformity in the grammar.
- The first relatively successful treatment of mass and plurals came in a 1983 paper by Godehard Link, who made a major innovation by positing algebraic structure inside the domain of type e entities.

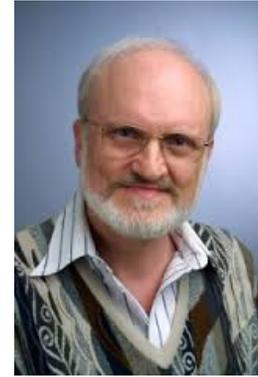
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Mass and plural, *cont'd.*

- Link proposed that a singular count noun denotes a set of atomic entities, while a plural count noun denotes a set of plural entities. No difference in *type*; both are type $\langle e, t \rangle$.
- The denotation of a plural noun forms an atomic semi-lattice structure.
- And the denotation of a mass noun is similar, but without presupposing that there are any atoms – 'divisibility' as well as 'cumulativity'.



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Other contributions by and with logicians

- Tense logic > semantics of tense and aspect. A very large area of active investigation, especially rich typologically. Foundational contributions by Hans Kamp, a student of Montague, who also interacted with Prior when Prior visited UCLA in Hans's first year. Many further logic-linguist collaborations in that area, including Bennett and Partee 1978, joint with my first UCLA philosophy PhD student (he would have been Montague's.)
- Modal logic and the logic of conditionals – important work by David Lewis, and by the linguist Angelika Kratzer, who spent a year in New Zealand studying with Max Cresswell.
- Dynamic logic (Groenendijk & Stokhof in Amsterdam; differently by Hans Kamp and by Irene Heim), to handle discourse anaphora and a family of related problems. Sentence meanings not truth conditions but 'context change potentials'.
- Property theory instead of type theory – Cocchiarella, Turner and Chierchia – for 'more intensional intensions'.

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Formal semantics as a subdiscipline of linguistics.

- The height of initial interaction on semantics between linguists and philosophers had passed by 1980, followed by the rise of cognitive science, including semantics, and then by a specialization of semantics inside of linguistics, with many individual scholars maintaining links of various kinds within and across the disciplines.
- By the middle of the 1980's the recognition of formal semantics as part of the core curriculum in linguistics was seen in the publication of textbooks and the growing number of departments with more than one semanticist.
- Formal semantics spread and became "mainstream semantics" in the US and Europe in spite of Chomsky's skepticism, and MIT hired its first formal semanticist, Irene Heim, in 1989, and its second, Kai von Stechow, in 1994, and quickly became one of the leading programs in formal semantics as well as syntax.

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Formal semantics within linguistics and philosophy.

- By the early 1990's, formal semantics (no longer "Montague grammar", though that's when "Montague grammar" made it into the Oxford English Dictionary) was a fully established field, and students were not conscious that the core fields hadn't always been 'phonology, syntax, semantics'.
- By the late 90's, linguistics-philosophy interaction was on the increase again, and more sophisticated, thanks in part to teaching and advising at MIT by Robert Stalnaker in Philosophy and Irene Heim in Linguistics.
- With the work of Irene Heim, Angelika Kratzer, Gennaro Chierchia and others, there was also greater integration of formal semantics with Chomskyan syntax. Now much important work is at the 'syntax-semantics interface.'



6. The foundational issue of semantic competence

- Before closing, I want to briefly mention an important foundational issue that has been with the field of formal semantics since linguists first became part of its history.
- The Chomskyan revolution in linguistics included putting human linguistic competence at the center of study: what's "in the head" of the speaker of a language, and how it's acquired.
- When some of us took on the challenge of combining Montague's approach to semantics with Chomsky's approach to syntax, technical and substantive progress was rapid and successful. But there was still the apparent incompatibility of Chomsky's view of linguistics as a branch of psychology and the anti-psychologist Fregean tradition viewing meanings as abstract objects.
- In hindsight, what I once saw as a problem I now see as a good thing: how semantics pushes us toward a less narrow view of competence and psychological reality.

The issue of semantic competence, *cont'd.*

- The foundational problems arise particularly for *lexical semantics*, where there are issues that have no counterparts in syntactic competence. The recursive compositional rules for combining meanings are psychologically (relatively) unproblematic.
- For the lexicon in syntax, there have seemed to be no worries-in-principle – the lexicon is finite, and at worst can be memorized.
- In semantics, on the other hand, some of the biggest worries have concerned the lexicon; it was on the basis of natural kind terms like 'tiger' that Putnam (1975) argued that "Meanings ain't in the head."
- Putnam argued, for instance, that even though he could not tell a beech tree from an elm tree, *beech* and *elm* in his language did not both just "mean" "some deciduous tree", but rather picked out the natural kinds 'beech' and 'elm', by virtue of his being a part of a language community with a certain history.
- There are *no comparable problems* in syntax!

Competence in semantics: lexicon, *cont'd.*

- Putnam:
 "So theory of meaning came to rest on two unchallenged assumptions:
 (i) That knowing the meaning of a term is just a matter of being in a certain psychological state.
 (ii) That the meaning of a term (in the sense of 'intension') determines its extension (in the sense that sameness of intension determines sameness of extension.)
 I shall argue that these two assumptions are not jointly satisfied by *any* notion, let alone any notion of meaning."
 (Putnam 1975, 219)



The issue of semantic competence, *cont'd.*

- A resolution to the tension between Chomskyan psychologism and formal semantics comes from arguments by Stalnaker and Burge about the need to revise what we take psychological realism to be.
- Stalnaker 1989: meanings **are** in the head, but like footprints are in the sand: the problem was in taking too narrow a view of “in the head”.
- “...a representational system is a system that is capable of being in a range of alternative internal states that tend to be causally dependent on the environment in a systematic way.”
- Tyler Burge (2010) argues that Chomsky’s view of grammar “in the mind” underestimates the degree to which “the natures of many mental states constitutively depend on relations to a subject matter beyond the individual.”
- Stalnaker’s and Burge’s work suggests that we should combine work on individual semantic representations with much more research on how those representations come to have the external relational content that makes reference possible.

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The issue of semantic competence, *cont'd.*

- If we think of “knowing a language” in a “hyper-intellectualized” way, then an interpreted language, as Montague understood it, cannot be “known” by a human, cannot be ‘in the head’.
- But if we follow Burge in drawing insight from perception and how it gives (fallible) veridical knowledge prior to any ‘reasoning’, we can see semantics, including the difficult area of lexical semantics, as a particularly important and fruitful branch of psychology.
- Perception involves a relation between perceiver and external objective reality. Perception is normally veridical but *can* be in error.
- Reference and truth conditions involve a relation between language user and external reality. Language is normally understood correctly but the language user *can* be mistaken.
- Language of course goes beyond objective representation, and there are other deep problems surrounding lexical meaning; but the puzzle of how to relate basic truth-conditional semantics to semantic competence is resolved, and cognitive science is the richer for it.

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Selected references

More material and fuller references can be found in several papers, versions of which are downloadable from my site, <http://people.umass.edu/partee/>.

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