The History of Formal Semantics: Evolving Ideas about Logical Form, Linguistic Form, and the Nature of Semantics

Lecture 1: Logic and Language: A History of Ideas and Controversies

Barbara H. Partee
partee@linguist.umass.edu
Baggett Lecture 1, University of Maryland

1. Introduction

- Formal semantics and formal pragmatics as they have developed over the last 50 years have been shaped by fruitful interdisciplinary collaboration among linguists, philosophers, and logicians, among others, affecting and affected by developments in linguistics, philosophy, cognitive science, and computational linguistics.
- As part of a larger project on the history of formal semantics, in this talk I'll emphasize aspects of the pre-history and history of formal semantics that concern the relation between language and logic.
- 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 I'll trace some of the history of these issues, including the history of claims that "natural language has no logic", and how joint work of linguists, logicians, and philosophers have taken that claim from a majority opinion to a minority opinion.

"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.

The principal sources of formal semantics

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

The most important figure in its history was Richard Montague (1930-1971), whose seminal works date from the late 1960's and beginning of the 1970's.

There were of course many other important contributors; not all will get their fair treatment today, just because the story is too big and time is too short.

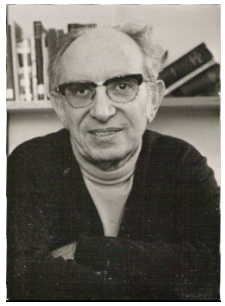
-- Now let me back up to some pre-history.

2. Semantics in linguistics

- **Before *Syntactic Structures (1957)* --**
- In the 19th century linguistics existed within philology in Europe and in large part within anthropology in the U.S.
- 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. Neglect of semantics in early American linguistics also because of fieldwork tradition: start with phonetics, then phonology, then morphology, occasionally a little syntax …
- Semantics in logic and philosophy of language: much progress, but relatively unknown to most linguists.

Semantics in linguistics, *cont'd.*

- 1954: 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.
- He was arguing against logicians who considered natural language too unruly to formalize, and appealing to linguists to make use of some of the logicians' methods.



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.)
- Bar-Hillel didn't give up, though. In 1967 he wrote to Montague, after receipt of one of Montague's 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."
- Also in 1967, during the 3rd Intl. Congress for Logic, Methodology and Philosophy of Science, Bar-Hillel organized a symposium in Amsterdam on 'The Role of Formal Logic in the Evaluation of Argumentation in Natural Languages', with Katz, Montague, Hintikka, Max Black, Staal, Stenius, Lyons, Dummett, others …
- But back to our history …

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 has been ambivalent about semantics.
- He has been skeptical about the possibility of including semantics in a formal grammar, and has insisted on the "autonomy of syntax".
- But he has held that one test of a syntactic theory is that it should provide a basis for a good semantics (if only we had any idea how to study semantics).

Chomsky and semantics

- He argued early on that deep structure reveals semantically relevant structure that is obscured in surface structure.

(1) a. John is easy to please (surface structure)

b. (for someone) to please John is easy (deep structure)

- From *Syntactic Structures,* p.93: In proposing that syntactic structure can provide a certain insight into problems of meaning and understanding we have entered onto dangerous ground. There is no aspect of linguistic study more subject to confusion and more in need of clear and careful formulation than that which deals with the points of connection between syntax and semantics. The real question that should be asked is: "How are the syntactic devices available in a given language put to work in the actual use of this language?"

Chomsky and semantics, *cont'd*

- Chomsky's *LSLT* (1955/1975) includes extended arguments about why grammar shouldn't be based on meaning (as Quine had argued it would need to be), using the *Colorless green ideas sleep furiously* example, and making analogies to speaker intuitions of possible but non-actual phonetic forms of English.
- He emphasizes here, as in *Syntactic Structures*, that that doesn't mean that semantics isn't a serious thing, to be pursued as well but separately.
- "But it is important to distinguish sharply between the *appeal* to meaning and the *study* of meaning. The latter is an essential task for linguistics. It is certainly important to find some way of describing **language in use** (my emphasis – BHP). But this is not the study of grammatical structure. When these parallel studies are sufficiently advanced, it will be possible to explore the many indisputable connections between them."

Semantics in early generative grammar: Katz & Fodor

- Katz and Fodor (early 60's) added a semantic component to generative grammar. They addressed the Projection Problem, i.e. compositionality: how to get the meaning of a sentence from meanings of its parts.
- At that time, "Negation" and "Question Formation" were transformations of declaratives: prime examples of meaning-changing transformations.
- So meaning depended on the entire transformational history. "P-markers" were extended to "T-markers", to which semantic Projection rules applied.
- Katz and Fodor's idea of computing the meaning on the basis of the whole T-marker can be seen as aiming in the same direction as Montague's derivation trees.
- (2a) [The airplanes [will [fly]]] (deep structure)
  $\Rightarrow_{\text{T-NEG}}$ (2b) [The airplanes [will not [fly]]]
- (3) T-marker for (2b) includes P-marker for its deep structure (2a) plus a graph showing what transformations have been applied in its derivation.

Katz & Fodor, *cont'd.*

- But their semantics was very primitive. Katz and Fodor worked with "semantic features", and their semantic representations were "bundles of features" – suitable at best for decompositions of one-place predicates.
- Quine (1970):"Logic chases truth up the tree of grammar"; Katz and Fodor's position might be characterized: "Semantic projection rules chase semantic features up the tree of grammar."
- What they were trying to capture had nothing to do with truth-conditions, but rather properties like ambiguity, synonymy, anomaly, analyticity, characterized in terms of 'how many readings' a sentence has, whether two sentences 'share a reading', etc.

Philosophers' reactions to linguists' "semantic representations"

David Lewis (1970, p.1):

- "But we can know the Markerese translation of an English sentence without knowing the first thing about the meaning of the English sentence: namely, the conditions under which it would be true. Semantics with no treatment of truth conditions is not semantics."
- "Translation into Markerese is at best a substitute for real semantics, relying either on our tacit competence (at some future date) as speakers of Markerese or on our ability to do real semantics at least for the one language Markerese."

Philosophers' reactions to linguists' "semantic representations", *cont'd.*

- But linguists *did* presuppose tacit competence in Markerese; they took it – or some kind of representation language -- to be universal and innate, and many still do (e.g. Jackendoff; also Jerry Fodor).
- To philosophers and logicians doing formal semantics, the language of Markerese looked empty, since it was uninterpreted.
- To linguists in 1970, concern with *truth* looked puzzling. Linguists were trying to figure out mental representations that would underlie linguistic competence. "Actual truth" was (correctly) considered irrelevant, and truth *conditions* were not really understood.
- When the linguistic relevance of truth conditions finally penetrated (later), the very nature of linguistic semantics changed – not just in terms of the tools used, but also in the questions asked and the criteria of adequacy for semantic analyses.

From *Syntactic Structures* to *Aspects*: Katz & Postal

- In a theoretically important move, separable from the "Markerese" issue, and related to the problem of compositionality, Katz and Postal (1964) made the innovation of putting such morphemes as Neg and a Question morpheme Q into the Deep Structure, as in (4), arguing that there was independent syntactic motivation for doing so, and then the meaning could be determined on the basis of Deep Structure alone.
- (4) a. [NEG [Mary [has [visited Moscow]]]] $\Rightarrow_{\text{T-NEG}}$ [Mary [has not [visited Moscow]]]

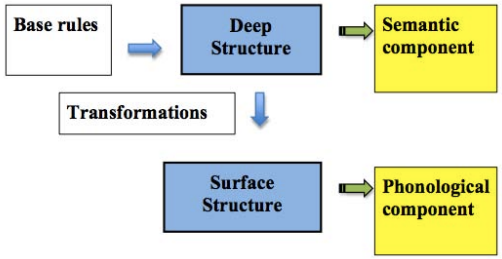
  b. [Q [Mary [has [visited Moscow]]]] $\Rightarrow_{\text{T-Q}}$ [Has [Mary [visited Moscow]]]

From *Syntactic Structures* to *Aspects*: Katz & Postal, *cont'd.*

- This led to a beautiful architecture, which Chomsky laid out in his *Aspects of the Theory of Syntax* (1965).
- Phrase structure rules generate Deep Structures.
- Deep Structure is the input to semantics.
- Transformations map Deep Structure to Surface Structure.
- Surface Structure is the input to phonology.

Chomsky 1965 – Aspects of the Theory of Syntax

Architecture of the theory:



Katz & Postal and *Aspects*: the Garden of Eden period

- This big change in architecture rested on Katz and Postal's claim that transformations should be meaning-preserving.
- It was an interesting and provocative claim, and even without any 'real semantics' at the foundation, it led to interesting debates.
- And the architecture of the theory, with syntax mediating between semantics and phonology, was elegant and attractive.
- Chomsky in *Aspects* (1965) had added to the elegance of the architecture by combining all the 'kernel' sentences underlying a sentence into a single Deep Structure.
- During the brief period when *Aspects* held sway, there was a rosy optimism that the form of syntactic theory was more or less understood and we could start trying to figure out the "substantive universals".

Garden of Eden period, *cont'd.*

- In that period, roughly the mid-60's, before the linguistic wars broke out in full force, I think generative grammarians generally believed the Katz and Postal hypothesis.
- The idea that meaning was determined at this "deep" level was undoubtedly part of the appeal of the notion of Deep Structure beyond linguistics (cf. Leonard Bernstein's Norton Lectures, *The Unanswered Question*) and probably contributed to the aura surrounding the notion of "language as a window on the mind."
- So around 1965, there was very widespread optimism about the Katz-Postal hypothesis that semantic interpretation is determined by deep structure, and the syntax-semantics interface was believed to be relatively straightforward (even without having any really good ideas about the nature of semantics.)

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

- What upset that lovely view? Linguists discovered quantifiers! Transformations that preserved meaning (more or less) when applied to names clearly did not when applied to some quantifiers.
- "Equi-NP Deletion"
  - With names: John wants John to win ⇒ John wants to win.
- But: Everyone wants everyone to win ⇒ Everyone wants to win ??
- This and similar problems led to the well-known Linguistic Wars between Generative Semantics and Interpretive Semantics. Slightly caricaturing, Generative Semanticists put "logical form" first, insisting on semantically interpretable deepest structures, whereas the Interpretive Semanticists put "linguistic form" first, insisting on an autonomous syntax.
- So with the battles of the late 60's and early 70's raging in linguistics, let's turn to philosophy and logic.

3. Semantics in Logic and Philosophy

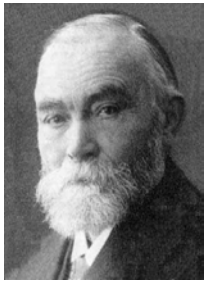
- The relevant history in philosophy goes back at least to Aristotle, but for today I'll start with just brief mentions of Descartes and Leibniz before turning to the central figures of the 19th and 20th centuries.
- The history of the formally oriented approach towards the philosophy of language goes back at least to Rene Descartes (1596-1650) and Gottfried Leibniz (1646-1716). [Cocchiarella 1997]
- Descartes, like the medieval speculative grammarians, believed that underlying all speech there exists a *lingua universalis*, but what it represented was the form of human reason and not the nature of things in the world.
- Leibniz agreed with Descartes that there exists a *lingua universalis* underlying all speech and that such a language represented the form of human reason. Leibniz was more programmatic in his approach, however.

Leibniz, *cont'd.*

- Leibniz called the general framework for such a universal language a *characteristica univeralis,* based on an *ars combinatoria*, a system of symbolization that would have simple forms for simple concepts, and unambiguous logical forms displaying the logical structure of all complex expressions, together providing a logical analysis of all the actual and possible concepts that might arise in science.
- And the framework should include a *calculus ratiocinator*, a complete system of deduction that would allow new knowledge to be derived from old. Leibniz aimed to encompass the three relationships between language and reality, language and thought, and language and knowledge.
- In the 19th century, 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" (*Begriffschrift*), a "logically perfect language" to satisfy Leibniz's goals. (more on quantifiers in Lecture 2)
- 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 semantics for variable-binding, more compositionally than what Tarski did 50 years later.
- Frege rejected the psychologism of many of his predecessors, e.g. John Stuart Mill (a complex figure – see Kusch 2011, "Psychologism", Stanf. Encyc of Philosophy).

The background of psychologism in logic

- From Mill, *Logic,* 1865:
- 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.
- One kind of argument for Psychologism in the 19th century German *Psychologismus-Streit* (from Kusch 2011):
  1. Psychology is defined as the science which studies *all (kinds of) laws of thought.*
  2. Logic is a field of inquiry which studies *a subset of all laws of thought.*

  Ergo, logic is a part of psychology.

Frege's anti-psychologism in logic.

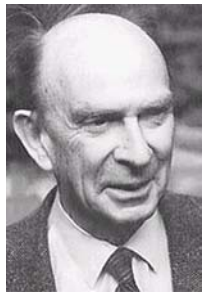
- One of Frege's main theses is that mathematics and logic are not part of psychology, and that the objects and laws of mathematics and psychology are not defined, illuminated, proven true, or explained by psychological observations and results. One of Frege's central arguments for this thesis is the 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'.

Some key 20th century developments in logic/ semantics

- Russell 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'.
- Later Carnap developed a *semantic* approach, where meaning = truth conditions, an idea he got from Wittgenstein.
- Carnap introduced possible worlds as state-descriptions, and analyzed intensions as functions from possible worlds to extensions.
- 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.

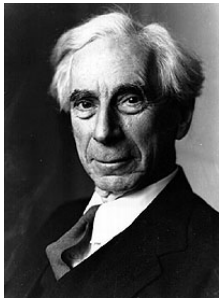
The Ordinary Language – Formal Language war.

- Around this time 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 and its uses. Late Wittgenstein (1889-1951), 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."



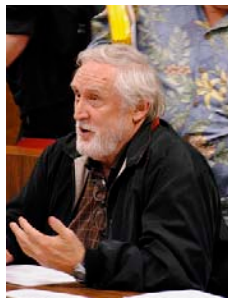
The Ordinary Language – Formal Language war.

- 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."
- So both sides in this 'war' (like Chomsky later) were in agreement that logical methods of formal language analysis do **not** apply to natural languages.



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.



The OL– FL war and responses to it

- In some quarters, that war continues. But the interesting response of some formally oriented philosophers 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.

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 treated both worlds and times as components of "indices", and intensions as functions from indices to extensions.
- Strategy of "add more indices" comes from Dana Scott's "Advice on modal 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 to extensions.

Montague's work, *cont'd.*

- In 'Pragmatics and Intensional Logic' (written in 1967), Montague distinguished between 'possible worlds' and 'possible contexts', and applied his logic to the analysis of a range of philosophically important notions (like *event, obligation*); this was just before or just as he started working on the analysis of natural language.
- That work, like most of what had preceded it, still followed the tradition of not formalizing the relation between natural language constructions and their logico-semantic analyses or 'reconstructions': the philosopher-analyst served as a bilingual speaker of both English and the formal language used for analysis, and the goal was not to analyze natural language, but to develop a better formal language. (Montague in an article in Staal (ed.) 1969 continued to maintain the latter goal as the more important one.)

A note on the Kalish and Montague textbook.

- The first edition of Kalish and Montague's logic textbook (1964, but drafted much earlier) contains the following passage:
- "In the realm of free translations, we countenance looseness...To remove this source of looseness would require systematic exploration of the English language, indeed of what might be called **the 'logic of ordinary English', and would be either extremely laborious or impossible. In any case, the authors of the present book would not find it rewarding**." (p.10)
- On page 10 of the 2nd ed., 1980, the passage is altered:
- "In the realm of free translations, … would be extremely laborious or perhaps impossible. **In any case, we do not consider such an exploration appropriate material for the present book (however, see Montague [4 [*Formal Philosophy*]] and Partee [1 [*ed., Montague Grammar*]])**."
- Thanks to Nick Drozd (p.c.) for alerting me to this quotation and its revision.
- So Montague's attitude evidently underwent a change in the late 60's.

Montague's turn to "linguistic" work.

- A new clue about Montague's motivations: from an early talk version of "English as a Formal Language", July 31, 1968, UBC, Vancouver:

(I think I'm deciphering 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 many 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.

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.

Montague's turn to "linguistic" work, *cont'd.*

- 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 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.

Montague's work, *cont'd.*

- 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.
- 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, both the linguistic wars and the philosophy of language wars could be peacefully resolved by removing their presuppositions.

Montague's work, *cont'd.*

- Details of Montague's own analyses of the semantics of English have in many cases been superseded, but in overall impact, PTQ was as profound for semantics as Chomsky's *Syntactic Structures* was for syntax.
- Emmon Bach (1989) 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 minimal data that have to be accounted for to reach "observational adequacy". That principle, inherited from the traditions of logic and model theory, is at the heart of Montague's semantics and is one of the defining principles of formal semantics.

Montague's work, *cont'd.*

- The adoption of truth conditions and entailment relations as basic semantic data is not innocuous from a foundational perspective. Among philosophers the main concern is that truth conditions are not *enough.* But 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 remember or 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.
- Most agree that truth conditions are not *enough*; proposals for richer notions of meaning go back at least as far as David Lewis's 1970 proposal for 'structured meanings'. This is an active topic of research both for foundational studies and for 'doing' semantics. But the goal of formal semanticists is to enrich, not abandon, the truth-conditional conception of meaning.

5. Joint work by linguists and philosophers: Montague Grammar and the development of 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.

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.

Joint work by linguists and philosophers, cont’d.

- Recall the consequences of the analysis in (5b) 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 make 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.

Joint work by linguists and philosophers, cont’d.

- As Fred Landman (p.c.) notes, it was Montague’s innovative use of lambda abstraction as the active variable-binding operator in PTQ that enabled a unified treatment of variable binding in connection with quantification, relative clauses, and interrogatives.
- In retrospect, we can see that it was trying to do all recursion on closed sentences was what made transformational rules cast in terms of “identical NPs” break down when quantifiers were discovered, which led to the expulsion from the Garden …
- In Chomskyan syntax, a corresponding change was eventually made, replacing the “identical NP” by the special null element PRO, interpreted as a bound variable. Other syntactic theories, including modern versions of Categorial Grammar, were developed after the quantifier issues had become well known, so they were designed from the start not to run into those problems.

Joint work by linguists and philosophers, cont'd.

- **Function-argument structure** as semantic glue was largely unknown to linguists before Montague's work.
- Before Montague, linguists knew nothing about lambdas or semantic types, and had no clear idea about how to combine meanings above the lexical level. That's why the usual attempts involved "semantic representations" in a hypothesized "language of thought", which looked very much like natural language. No one had entertained the idea that the things *denoted* by expressions could have a natural way of combining.
- The appreciation of the importance of function-argument structure also helped linguists understand much more of the original motivation of categorial grammar, invented and developed by Polish logicians (Lesniewski 1929, Ajdukiewicz 1935; then also Curry and Lambek) but dismissed by linguists as soon as it was proven to be equivalent in generative power to context-free phrase-structure grammar. Revival in linguistics after Montague: Bach and others.

Linguistic-philosophy interactions – east and west

- 1967-69 -- Davidson and Harman both at Princeton, intensely interacting, both optimistic about potential fruitfulness of linguistics-philosophy interactions. Optimistic about generative semantics. Influenced each other's work; and together they produced some exciting conferences and influential edited collections – more on that in Lecture 3.
- David Lewis and Montague both at UCLA then, also interacting; David introduced me to Montague and I first sat in on a seminar of Montague's at UCLA (with David and Frank Heny) in 1968. I had a lot of dumb questions at the beginning, and David was the one I could ask them to; he always answered patiently and well.
- 1968 – circulation of first version of Terry Parsons' "A Semantics for English"

Chomsky's skepticism about all this.

- It turned out that Chomsky was deeply skeptical of formal semantics and of the idea of compositionality in any form.
- I have never been able to satisfactorily explain his skepticism; it has seemed to me that it was partly a reaction to a perceived attack on the autonomy of syntax, even though syntax is descriptively autonomous in Montague grammar.
- But syntax is not "explanatorily autonomous" in Montague grammar, or in any formal semantics, and I do not see any rational basis for believing that it should be.
- Maybe also because of puzzles about the nature of our knowledge of semantics (raised in my 1979 "Semantics: mathematics or psychology?").
- Chomsky 1986: mental representations – fine; but embedding them into models that include the actual world, dubious.
- In any case, 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 Fintel, in 1994, and (ironically) quickly became one of the leading programs in formal semantics as well as syntax.

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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The History of Formal Semantics: Evolving Ideas about Logical Form, Linguistic Form, and the Nature of Semantics

Lecture 2: The Starring role of Quantifiers in the History of Formal Semantics

Barbara H. Partee
partee@linguist.umass.edu
Baggett Lecture 2, University of Maryland

1. Introduction

- This is the second of three talks about how formal semantics has developed, especially over the last 40+ years, shaped by fruitful interdisciplinary collaboration among linguists, philosophers, and logicians.
- The history of formal semantics as described in Lecture I features quantifiers at several points. In this talk I'll look more closely at crucial turning points in the history of semantics where quantifiers have played a major role.
- One example illustrated yesterday was how linguists' 'discovery' of quantifiers led to expulsion from the 'Garden of Eden' period associated with Chomsky's 1965 *Aspects of the Theory of Syntax*. I'll say more about that today, and about some other developments, both earlier and later.
- Of course the history of formal semantics is much more than the history of treatments of quantifiers, but their story is an important and fascinating chapter.

2. Quantifiers in linguistics up to the linguistic wars

- Chomsky 1957 in *Syntactic Structures*:
- Sometimes transformations change meaning: The following active-passive pair have different meanings, with the first quantifier having wider scope in each case:

(1) a. Everyone in this room speaks two languages.

b. Two languages are spoken by everyone in this room.

- Scope issues came to the fore only later, in the late 60's; Then those judgments about (1) came to be questioned; some argued that (1b) is ambiguous, some argued that both are. Linguists had no good methodologies for settling such debates.

The Katz-Postal hypothesis

- In a theoretically important move, related to the problem of compositionality, Katz and Postal (1964) made the innovation of putting such morphemes as Neg into the Deep Structure, as in (2), arguing that there was independent syntactic motivation for doing so, and then the meaning could be determined on the basis of Deep Structure alone.
- (2) [NEG [Mary [has [visited Moscow]]]] $\Rightarrow_{\text{T-NEG}}$ [Mary [has not [visited Moscow]]]
- In *Aspects* (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".

Quantifiers and expulsion from the Garden of Eden

- Partee 1971, (at UMD): The surprising historical accident … is that the behavior of quantifiers was not really noticed until the Katz-Postal hypothesis had for most linguists reached the status of a necessary condition on writing rules. I think this historical accident is one of the major causes of the state of turmoil in the theory today. Let me give a few examples of derivations that would have been given in the standard theory, and leave you to reflect on whether the Katz-Postal hypothesis would have even been suggested if these had been noticed beforehand.
- (3) a. Every man voted for himself. FROM:
- b. Every man vote for every man.
- (4) a. Every candidate wanted to win. FROM:
- b. Every candidate wanted every candidate to win.
- (5) a. All pacifists who fight are inconsistent. FROM:
- b. All pacifists fight. All pacifists are inconsistent.
- (6) a. No number is both even and odd. FROM:
- b. No number is even and no number is odd. (pp 655-656)

Quantifier scope ambiguity and compositionality

- When linguists did start worrying about quantifiers, in the 60's, one big puzzle concerned quantifier scope ambiguities. A sentence like (7) is generally judged ambiguous.
- (7) Every student read one book.
- But there is little or no independent evidence that (7) is syntactically ambiguous.
- The Katz-Postal hypothesis, and hence *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. The relevant syntactic structure was Deep Structure.
- Generative Semanticists held onto the goal of compositionality and pushed the 'deep' structure deeper, making it a kind of logical form.
- Chomsky had been tentative about adopting the K-P hypothesis, and valuing syntactic autonomy more highly, abandoned it.
- Linguistic wars. And even now, continuing debates about solutions.

Early linguistic notions of 'logical form'

- **Generative semantics** (Lakoff, Ross, McCawley, Postal, early Dowty, Larry Horn, Pieter Seuren, sometimes Bach): In order for deep structure to capture semantics, it needs to be deeper, more abstract, more like "logical form" (first-order-logic).
- The syntax seemed implausible to some; but Lakoff's "Quantifier Lowering" was later reintroduced "upside down" as "Quantifier Raising" by Bob May, and the interpretivists gradually articulated a syntactic level of "logical form" or LF, with much (of course not all) in common with Generative Semantics proposals.
- Robin Cooper and Terry Parsons in the mid-1970's wrote an elegant short paper laying out algorithms for converting among schematized variants of Generative Semantics, Interpretive Semantics, and Montague Grammar with respect to quantifier scope and bound variable pronouns (Cooper and Parsons 1976). (What is "logical form" in Montague Grammar? The analysis trees that trace the steps of syntactic derivation.)

Early linguistic notions of 'logical form', *cont'd.*

- I noted that one consequential historical accident was that linguists did not notice quantifiers until they had already accepted the hypothesis that meaning is determined at Deep Structure.
- Another important 'accidental' historical fact was that both linguists and philosophers who worried about the semantics of quantified sentences thought of "logical form" in terms of first-order logic.
- But given that generalized quantifiers were only developed starting in the late 1950's, that could hardly have been otherwise.
- We'll return in Part 4 to generalized quantifiers and their role in reconciling the apparent mismatches between "linguistic form" and "logical form". But first let's take a quick tour of some of the crucial developments from Aristotle to Frege and Tarski.

3. Developments in Logic -- Aristotle

- Aristotle (384–322 B.C.E.) invented logic, and he focused on quantification. (Operators like *and* and *or* were added by the Stoics.)
- Aristotle's syllogisms formalize certain inferential properties – i.e. certain aspects of the meanings -- of the four expressions *all, some, no, not all.* See Peters & Westerståhl, ch.1.
- For Aristotle, *all* and *no* carried a presupposition of non-emptiness of their domains. Later logicians changed that, so there are two versions of the Square of Opposition, with periods of confusion. See Terry Parsons on the history of the Square of Opposition in the *Stanford Encyc. of Philosophy.*
- Foundational and hugely influential work. Proof-theoretic approach to semantics. Everything he did was great. But only sentences of the form Q A B were studied; no names, no relational predicates, no sentences with more than one quantifier.
- Little progress on quantification between Aristotle and 19th century.

Post-Aristotle

- Implicit in Aristotle's syllogistic is a semantics for the quantifiers, although not explicitly. Each of the four quantifier expressions can be seen as standing for a binary relation between properties:
- (i) *all* (A,B) $\Leftrightarrow$ $A \subseteq B$ (ii) *some* (A,B) $\Leftrightarrow$ $A \cap B \neq \varnothing$, etc.
- In hindsight, this is close to the idea of Generaized Quantifiers. But the idea of giving a semantic value to the quantifiers themselves was not explicitly developed until much later, really not until Frege.
- In the Middle Ages there was a lot of work trying to figure out meanings for expressions like *all men* or *some man*, sometimes syncategorematically (Albert of Saxony analyzed *all* and *some* via conjunctions and disjunctions), sometimes categorematically (giving them independent meanings) with convoluted theories.
- For instance, it's natural to suggest that "all men" denotes the set of all men. But then what? They were especially unsuccessful with the 'negative' quantifiers *no* and *not all*.

Leibniz

- Leibniz (1646-1716) dreamed of a *characteristica univeralis,* a system of symbolization with simple forms for simple concepts, and unambiguous logical forms displaying the logical structure of all complex expressions, together with a *calculus ratiocinator*, a complete system of deduction that would allow new knowledge to be derived from old.
- Leibniz also may have been the first to use bound variables, but in his integral calculus, not in his logic. Those variables were intrinsically bound, not replaceable by constants.
- (8) $$\int_a^b f(x)\,dx$$

Leibniz, de Morgan, Peirce

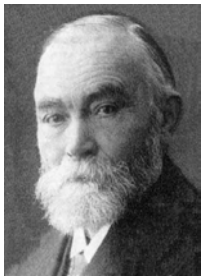
- A different use of variables was already in use in algebra, in formulas like (9), implicitly bound by universal quantifiers.

(9) $x + (y + z) = (x + y) + z$ Law of Associativity

- They could be substituted for by constants: implicit Universal Instantiation. But no explicit quantifiers anywhere, and no existential quantifiers even implicitly. (Peters &Westerståhl, ch. 1)
- Those two uses were not united and generalized until Frege's work.
- The word 'quantifier' appears first in De Morgan (1862), as an abbreviation for Hamilton's 'quantifying phrase'. (from Wilfrid Hodges' web page: http://wilfridhodges.co.uk/)
- The American philosopher and logician C.S. Peirce (1839-1914) added further operations and is often credited with developing the theory of relations (Burris 2009).

Frege

- The greatest foundational figure for formal semantics is Gottlob Frege (1848-1925). His crucial ideas include the Compositionality Principle and the idea that *function-argument* structure is the key to semantic compositionality.
- One of Frege's great contributions was the logical structure of quantified sentences. That was part of the design of a "concept-script" (*Begriffschrift*), 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.

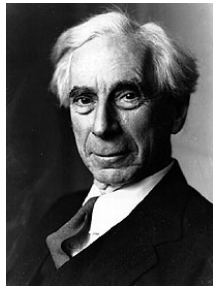


Frege, *cont'd.*

- **Hodges (2010)**: Myth Two: Frege invented mathematical logic.
- Difficulty: Giuseppe Peano (c. 1890) coined the name 'mathematical logic' and devised a programme for it.
  - Mr G. Frege, a professor at the University of Jena, to whom many interesting works in mathematical logic are due, of which the first dates from 1879, has arrived in turn, and by a quite independent path, in his book Grundgesetze der Arithmetik (1893) at the expression in symbols of a series of propositions concerning the concept of number. . . . The works of Frege are independent of those of the numerous authors of mathematical logic.
  - Peano lists the authors he used: Boole, Schröder, Peirce, Jevons, MacColl, Grassmann and Dedekind.
- Advances often credited to Frege include Quantifiers. In fact Frege did have universal quantifiers (not existential), but the universal and existential quantifiers in use today trace back to Peirce via Schröder and Peano.
- Source of the myth: Frege was a much deeper and much more rigorous thinker than any of his contemporaries in logic. Today we recognise this.

Russell on quantifiers in logic and language

- "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 favorite 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.



Quantifiers in logic and language, *cont'd.*

- An exercise I often give my students: where in Russell's formula (8), symbolizing *Every man walks*, is the meaning of *every man*?

(8) $\forall x\,(\,\mathrm{man}\,(x) \rightarrow \mathrm{walk}\,(x)\,)$

- 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*.
- 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 reportedly 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.

More on Frege, and Tarski

- Frege worked out the semantics of free and bound variables, and developed the syntax and semantics of quantifiers as variable-binding operators. And he did it more compositionally than Tarski.
- In Tarski's semantics for quantified sentences, standard in logic textbooks, the quantifier symbols ∀and ∃ are not themselves given a semantic interpretation. They are treated *syncategorematically*: we are given semantic interpretation rules for formulas *containing* quantifiers. Tarski's semantics is thus not strictly compositional (Tarski, p.c.)
- Tarski does not get the interpretation of (8)
- (8) $\forall x\,(\,\mathrm{man}\,(x) \rightarrow \mathrm{walk}\,(x)\,)$

  by combining the interpretation of the quantifier with the interpretation of the rest of the formula; instead he has a schema that gives the interpretation of (8) by considering satisfaction of the open formula by all possibly values of the variable x.

More on Frege, *cont'd..*

- Frege treated the quantifier symbols as categorematic, standing for certain second-order objects (P&W, p35-40). Although his notation was quite different from modern notation, he treated the universal quantifier as a unary second-level operator that applies to a first-level predicate to give a truth-value. P&W observe that Frege thus invented a kind of generalized quantifier, though it was forgotten until reinvented in a model-theoretic context.
- Frege's universal quantifier was "everything" rather than "every". We can represent it as a set of sets as in (9) (where D is the universe):

(9) $\lambda P\,[\forall x\,P(x)]$ or $\{P: D \subseteq P\}$

- Then a sentence like *Every boy walks* would have to be paraphrased into something like "Everything is such that if it is a boy, it walks." Thus Frege's analysis of universal quantifiers had some things in common with later generalized quantifiers, but like Russell, he did not directly analyze NP constituents like *every boy.*

Tarski

- Tarski (1902-1983) developed *model theory* based in set theory and with it made major advances in providing a semantics for logical languages, including a semantical definition of truth. Frege had had an absolute notion of truth, and a single domain of all objects; all non-variables had fixed interpretations. Even Tarski 1935 had symbols with fixed interpretations. It was only late Tarski (1950's) who introduced interpretation relative to models.
- Model theory revolutionized semantics. This comes out most clearly (for linguists) when we look at the cascade of advances that came with the study of generalized quantifiers.
- There was work on generalized quantifiers by Mostowski and Lindstrom before Montague, but for formal semanticists the source of generalized quantifiers (probably independently conceived) was Montague and David Lewis.

4. Generalized Quantifiers

…

Montague's work on quantifiers: background

- The Fregean principle of compositionality was central to Montague's theory and remains central in formal semantics.
- **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.
- Montague showed that one could give a model-theoretic semantics for ordinary English, with a syntax rather close to surface structure.
- Details of Montague's own analyses of the semantics of English have in many cases been superseded, but in overall impact, PTQ was as profound for semantics as Chomsky's *Syntactic Structures* was for syntax.
- Emmon Bach (1989) 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

Montague and generalized quantifiers

- According to Peters and Westerståhl, the logical notion of quantifiers as second-order relations is "discernible" in Aristotle, full-fledged in Frege, then forgotten until rediscovered by model theorists.
- Mostowski 1957: unary generalized quantifiers, sets of sets: 'everything', 'something', 'an infinite number of things', 'most things'
- Lindström 1966: binary generalized quantifiers, without which one can express 'most things walk', but not 'most cats walk'. (What we are accustomed to calling 'generalized quantifiers', e.g. the denotation of 'most cats', represents the application of a Lindström quantifier to its first argument, giving a unary generalized quantifier.)
- Montague 1973 (and David Lewis 1970): English NPs like *every man, most cats* can be treated categorematically, uniformly, and compositionally if they are interpreted as generalized quantifiers. This was a big part of the refutation of the point Russell and Strawson were agreed on, that there is no logic of natural language.

Generalized quantifiers and English syntax

- One of the first big things that impressed linguists about Montague's work (and David Lewis had the same idea on this point) was how with a higher-typed logic and the lambda-calculus (or other ways to talk about functions), NPs could in principle be uniformly interpreted as generalized quantifiers (sets of sets).
- And Determiners could in principle 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 (8), the first-order formalization of *Every man walks*?"

(10)

every student	$\lambda P \forall x[\mathbf{student}(x) \rightarrow P(x)]$
every student walks	$\lambda P \forall x[\mathbf{student}(x) \rightarrow P(x)]\ (\mathbf{walk})$
	$= \forall x[\mathbf{student}(x) \rightarrow \mathbf{walk}(x)]$

- So now we have a semantic type, <<e,t>,t>, sets of sets of entities, to correspond to English NPs. NP is function, VP is <e,t> argument.

Generalized quantifiers, *cont'd.*

(11)

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

Generalized quantifier theory and model theory

- Barwise and Cooper, a logician and a linguist, 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.
- They found a first good approximation to a formalization of the distinction between "weak" determiners, which can occur in *there*-sentences, and "strong" determiners, which cannot.
- Key definitions:
- A determiner D is *positive strong* if D(A)(A) is true whenever D(A) is defined (A any subset of the universe).
- D is *negative strong* if D(A)(A) is false whenever D(A) is defined.
- D is *weak* if it is neither positive strong nor negative strong.
- Subsequent improved definition by Keenan (several), improvements to the definitions and to the analysis of *there*-sentences by Comorvski, Zucchi, Francez, Hazout, Landman, McNally.

Generalized quantifier theory & model theory: NPI's.

- Another property which applies to generalized quantifiers (but not only those concerns *negative polarity items*.
- An NP like *no boy* in subject licenses polarity items as in (12).

(12) No boy had *ever* seen *any* problem *at all* in *any* of her proposals.

- A fascinating debate went on in the 1980's between Bill Ladusaw, who proposed a model-theoretic explanation, and Marcia Linebarger, who proposed an account in terms of the position of a NEG morpheme in Logical Form.
- Ladusaw's account was probably the first case of a formal semantic analysis where the model theory was absolutely crucial; his account could not be recast in terms of 'LFs' or semantic representations.
- Crucial concept: NPI's are licensed inside the argument of a monotone decreasing function.
- Later: Michael Israel: close to Ladusaw's core account, plus some pragmatic constraints, as suggested by Linebarger.

5. Quantifiers and pragmatics – (i) NPIs

- Quantifiers also played an important role in the development of formal pragmatics and the recognition of the necessarily close connection between formal semantics and formal pragmatics.
- We just alluded to the role of pragmatics in the licensing and interpretation of negative polarity items.
- Ladusaw's classic work on the licensing of NPI's by monotone decreasing functions ("downward-entailing contexts") looked at the formal properties of the licensing contexts, but treated the NPIs themselves as having basically simple existential meanings.
- Kadmon and Landman argued for a unified treatment of NPI *any* and free choice *any*, and for the need to supplement Ladusaw's account with more about the meaning of *any* itself. They argued that the the meaning of *any* is like that of *a* plus semantic/pragmatic conditions that reduce tolerance for exceptions: "widening", "strengthening". Israel extends that with further explicit pragmatics.

Quantifiers and pragmatics – (ii) indefinites

- Indefinites like *a student* have been puzzling for a long time. Frege didn't treat them. Russell analyzed sentences containing indefinites as quantified sentences with an existential quantifier.
- Early work in formal semantics – Montague, Barwise and Cooper, and others – absorbed that view of indefinites into Generalized Quantifier theory.

(13) *a student* $\lambda P \exists x[\mathbf{student}(x) \,\&\, P(x)]$

- But indefinites did not behave like other quantifier phrases.
- (i) Singular indefinites permit discourse anaphora, unlike *every boy, no boy.*

(14) a. A boy came in. He was whistling.
b. #No/every boy came in. He was whistling.

- (ii) Singular indefinites have 'variable quantificational force', as in donkey sentences. More tomorrow on the Kamp/Heim theory and the move to **dynamic semantics.**

Quantifiers and pragmatics – (iii) domain restriction

- From the start, it was recognized that quantifier domains are understood as "restricted" in ways not always linguistically explicit.

(15) When I looked in on the experiment, everyone was asleep.

(16) Only one class was so bad that no student passed the exam. (Heim 1991)

- In much early work, before the mid-to-late 80's, it was presumed that something like a "universe of discourse" would provide a natural implicit domain restriction. If we ask "Is everybody happy?", we are asking about everybody "here", not in the whole universe.
- That went along with a view that one could do semantics autonomously from pragmatics:
  - Syntax is autonomous; semantics interprets syntactically structured expressions. Pragmatics accounts for the use in context of semantically interpreted expressions.
- But examples like (15) and (16) showed that things are more complex, and sparked debates that still go on.

Quantifiers and pragmatics, *cont'd*

- Related to the issue of quantifier domain restriction is the whole matter of "implicit arguments" or "implicit variables". These are implicit arguments or parameters connected with words like *local, enemy, notice, left* and *right*.
- They are not themselves quantifiers, but what made people realize that something probably had to be done about them in the semantics and maybe even in the syntax was their occurrence in "bound variable contexts" (Partee 1989):

(17) a. John was at a local bar.

b. Every sports fan in the country was at a local bar watching the playoffs.

- Philosophers as well as linguists have gotten involved in debates about how semantics and pragmatics (and maybe syntax) interact here; the issues relate to philosophical debates about 'contextualism.'

6. Quantifiers, universals, and typology

- Formal semantics has made advances in the study of universals and typology in recent decades, and there have probably been more advances in the study of quantification than in any other area.
- Bach, Jelinek, Kratzer, and Partee (eds.) (1995) *Quantification in Natural Languages* was the first major work on typology from the perspective of formal semantics.
- One of the questions that motivated our work was whether all natural languages have NPs that are interpreted as generalized quantifiers. Barwise and Cooper had hypothesized "Yes"; we marshalled our colleagues to help us answer the question, and it turned out to be "No".
- At least as widespread, but maybe also not universal, is "adverbial quantification", first studied by David Lewis.

(18) A quadratic equation usually has two distinct roots.

Quantifiers, universals, and typology, *cont'd*

- Function vs content word universal (Chierchia 1984): Three related properties of function words:
  - (i) Functional categories (like Determiner quantifiers) have high semantic types, whereas content words have the simple types of entities and predicates.
  - (ii) Natural languages do not quantify over function words; do not have interrogative forms for function words, and do not have anaphora in the domain of function words.
  - (iii) Each language has only a small finite number of function words; their range of possible meanings is constrained, and some of them are very widespread cross-linguistically,
- The significance of Chierchia's universal is that language acquisition for content words and for function words is very different. The function words are of high type, but it seems that the child does not have to consider all possible meanings of those types; the function words seem to be nearly innate, or at least very highly constrained.

Quantifiers, universals, and typology, *cont'd*

- DET is one of the categories where the most work has been done, and very interesting universals have been proposed. Here is one of the most famous from Barwise and Cooper's work.
- **Conservativity universal: Natural language determiners are conservative functions.** (Barwise and Cooper 1981)
- Definition: A determiner meaning D is conservative iff for all A,B, D (A)(B) = D(A)(A ∩ B).
- Examples: No solution is perfect = No solution is a perfect solution. Exactly three circles are blue = Exactly three circles are blue circles. Every boy is singing = every boy is a boy who is singing.
- "Non-example": *Only* is not conservative; but it can be argued that *only* is not a determiner.
- Only males are astronauts (F) ≠ only males are male astronauts (T).
- **Consequence:** When evaluating D(A)(B), one only needs to consider A's, never non-A's.

7. Quantifier scope ambiguity

- Quantifier scope ambiguity is a major challenge for compositionality.
- A sentence like *Every student read one book* is semantically ambiguous, but there isn't much evidence for it being syntactically ambiguous. There were at least six kinds of solutions proposed from the 60's to the 80's, even before the introduction of choice functions and various non-quantificational analyses of indefinites. More now.
- 1. Generative semantics (Lakoff, McCawley et al): Underlying structures similar to first-order logic structure, plus a transformation of Quantifier Lowering. The perceived need to constrain derivations so that scope corresponded to surface c-command led to Transderivational Constraints.
- 2. Interpretive semantics (mainly Jackendoff): separate mechanisms; see Cooper and Parsons 1976 for a reformulation as an indexing mechanism. (They proved intertranslatibility among approaches 1, 2, and 3.

Quantifier scope ambiguity, *cont'd.*

- 3. Montague's Rule-by-rule approach, with a rule of Quantifying In. Generate one syntactic structure via distinct derivations; compositionality is homomorphism between syntactic and semantic **derivations**.
- 4. Cooper storage – Cooper 1973. Modified compositionality: compositionally derive a SET of interpretations for each syntactic structure. When you hit a quantifier phrase, optionally "store" it, then "retrieve it" from storage when you hit a suitable higher node, like an S or a VP. (Scope islands represent points in the derivation where the store must be empty.) Also used in GPSG.
- 5. Quantifier Raising (May 1977). A syntactic rule, roughly inverse of Quantifier Lowering, produces a derived syntactic structure dubbed LF; that's the syntactic level that gets compositionally interpreted.
- 6. Type-shifting – Hendriks 1988. No 'movement'; alternative readings via type-shifting of verbs and other functors so as to change relative 'function-argument command' relations.

Closing with a reminiscence

- When I was a PhD student at MIT in the early 1960's, I had a chance one summer to teach a voluntary evening course in linguistics for bright high school students from the Boston area. To introduce them to syntax, I got them to discover the "Affix-Hopping" transformation from Syntactic Structures. However you reformulate it now, it's still a great thing – you've known it all your life but never realized what a cool thing it is you know.
- And when I had a chance to give a one-afternoon lecture on semantics in a program of math for high school students at Hampshire College in the 1970's, I picked generalized quantifiers and the monotonicity properties that explain the distribution of Negative Polarity Items. Also really cool.
- Larson's introductory "case study" in semantics in the Gleitman and Liberman *Invitation to Cognitive Science* is all about generalized quantifiers and some of their cool properties. And we even put a chapter about them in the Partee, ter Meulen and Wall *Mathematical Methods in Linguistics.*
- Maybe part of the attention to quantifiers in formal semantics is because its practitioners are generally people who like both logic and language. But I think it's also because quantifiers turn out to have such rich properties, and to generate endless interesting research questions.

Selected references

- Here are a few key references relating to the history of quantifiers and their treatment in logic, philosophy, and linguistics.
- Bach, Emmon, Jelinek, Eloise, Kratzer, Angelika, and Partee, Barbara H. eds. 1995. *Quantification in Natural Languages*. *SLAP*. Dordrecht: Kluwer.
- Hodges, Wilfrid. 2010. Traditional versus modern logic. Ms., *Slides for a lecture for the Edinburgh University Philosophy Society, November 2010*. Okehampton. http://wilfridhodges.co.uk/history17.pdf .
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- Peters, Stanley, and Westerståhl, Dag. 2006. *Quantifiers in Language and Logic*. Oxford: Oxford University Press.
- Westerståhl, Dag. 2011. Generalized quantifiers. In *The Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta. http://plato.stanford.edu/archives/sum2011/entries/generalized-quantifiers/ .

Selected references, *cont'd*

- More references and links relating to quantifiers, their history, and their treatment in logic, philosophy, and linguistics.
- Barwise, Jon, and Cooper, Robin. 1981. Generalized quantifiers and natural language. *Linguistics and Philosophy* 4:159-219. Reprinted in Portner and Partee, eds., 2002, *Formal Semantics: The Essential Readings*. Oxford: Blackwell. 75-126.
- Keenan, Edward L., and Paperno, Denis, eds. 2012. *Handbook of Quantifiers in Natural Language*: Springer.
- Montague, Richard. 1973. The proper treatment of quantification in ordinary English. Repr. in Montague 1974, *Formal Philosophy*, Yale UP, 247-270.
- Szabolcsi, Anna. 2010. *Quantification*: Research Surveys in Linguistics. Cambridge: Cambridge University Press.
- Course websites: see under http://people.umass.edu/partee/Teaching.htm .
- **Partee, Spring semester 2011**: MGU, Moscow. Formal Semantics and Semantic Universals
- **Partee, Spring semester 2012:** RGGU, Moscow. The History of Formal Semantics.

The History of Formal Semantics: Evolving Ideas about Logical Form, Linguistic Form, and the Nature of Semantics

Lecture 3: Pivotal Moments in the "Naturalization" of Formal Semantics

Barbara H. Partee
partee@linguist.umass.edu
Baggett Lecture 3, University of Maryland

1. Introduction

- This is the third of three talks about how formal semantics has developed, especially over the last 40+ years, shaped by fruitful interdisciplinary collaboration among linguists, philosophers, and logicians.
- Philosophers and logicians like Montague were central to the beginnings of formal semantics, but linguists have also played major roles in its development (as well as in raising challenges to some of its central tenets.)
- Logicians' earlier work on the logical structure of various natural language locutions was sometimes linguistically unrealistic. It took more work by linguists and linguistically sophisticated philosophers and logicians to develop formal tools that offered a better fit with the structures that linguists ascribe to natural languages.
- I'll trace some of the important contributions, including a few "personal vignettes" along the way.

2. Relative clauses – Montague to Rodman

- Montague's treatment of restrictive relative clauses in PTQ was semantically insightful (like Quine's in *Word and Object*). A relative clause is a 1-place predicate, semantically a set to be intersected with the noun set.
- Syntactically, he made his work easier by considering only relative clauses like "such that Mary loves him", not "WH-relatives" like "whom Mary loves".
- Bob Rodman (1976) wrote a nice paper on WH-relative clauses in my first Montague seminar at UCLA in the spring of 1972. He showed how constraints on extraction in relative clauses paralleled constraints on quantifier scopes. That was one of the first demonstrations of parallel constraints on movement and interpretation, and suggested that formal semantics could be useful for finding hypotheses of interest to normal linguists.

3. Indefinites and the introduction of dynamic semantics.

- The preface to Irene Heim's 1982 dissertation begins:

> In November 1978, a workshop was held at the University of Massachusetts whose title was "Indefinite Reference" and whose topic Barbara Partee described in a circular that started as follows:
>
> > One standard view among logicians is that indefinite noun phrases like 'a tall man' are not referring expressions, but quantifier phrases, like 'every man', 'no man', and 'most men'. Yet in many respects, indefinite noun phrases seem to function in ordinary language much like definite noun phrases or proper names, particularly with respect to the use of pronouns in discourse. This may be simply a matter of sorting out semantics from pragmatics, but there is not to our knowledge any currently available theory that simultaneously characterizes the logical or truth-functional properties of indefinite noun phrases and accounts for their 'discourse-reference' properties....

3. Indefinites and the introduction of dynamic semantics, *cont'd.*

- A family of five problems:

Discourse anaphora.

(1) a. John/the man/a man walked in. He looked tired.
b. #Every man/ no man/ more than one man walked in. He looked tired.

Different "discourse" behavior of logically equivalent sentences.
(This argues against a purely pragmatic account of the differences in (1a-b).)

(2) a.One of the ten marbles is not in the bag. It is probably under the sofa.
b. Nine of the ten marbles are in the bag. ??It is probably under the sofa.
(Example in Heim's 1982 dissertation, from Partee)

Indefinite introduces a "discourse referent" with limited lifespan.

(3) a. John wants to catch a fish and eat it. (Karttunen)
b. Maybe he would share it with me. (Modal subordination, Roberts)
c. #It's probably under the boat now.

3. Indefinites and dynamic semantics, *cont'd.*

The two connected problems of "donkey sentences"

(4) a. *Every man who owns a donkey beats it.*
b. *If a man owns a donkey, he always beats it.*

- Problem 1: How to explain that *it* can be anaphoric to *a donkey* in these sentences?
- Problem 2: How to explain that *a donkey* seems like a *universally* quantified NP in these sentences? (And in (4b), same for *a man.*

The quantificational variability of indefinites.

(5) An equation like this *always/often/sometimes/never* has more than one solution. -- paraphrases with '*all/many/some/no equations* like this'.

- **Solution** (Heim/ Kamp): Indefinite NPs are not quantifier phrases.
- An indefinite "introduces a new file card/ a new discourse referent".
- Heim 1982 file change semantics, Kamp 1981 DRT are ***dynamic*** theories: replace truth conditions by "context change potential".
- Truth of a file: embeddability of the file ('partial model') in a model.

3. Indefinites and dynamic semantics, *cont'd.*

- Irene Heim and Hans Kamp came up with their theoretical innovations in response to this family of problems virtually simulatneously and independently.
- Heim's dissertation is a classic. One important thing she did is to treat indefinites and definites both, treating both as "variables" of type e with no independent quantificational force of their own.
- The difference between indefinites and definites consists in two things:
  - (i) for an indefinite, pick a new variable, for a definite pick an old one. (This is the core of the "anaphoric theory of definites").
  - (ii) the NP content of an indefinite enters into asserted content; the NP content of a definite is presupposed.
- Both Heim and Kamp had accounts of the "lifespan" of a discourse referent, with crucial differences between simple sentences or sequences thereof vs. quantified sentences.

3. Indefinites and dynamic semantics, *cont'd.*

- Both Heim and Kamp built on Stalnaker's theory of how assertions update the "common ground".
- Dynamic semantics: The interpretation of sentences not only depends on the context, it also affects the context.
- Heim: the semantic content of a sentence is its "context change potential" (CCP). And this change goes down to the smallest parts, so the contribution of each part is its contribution to the context change potential of the whole. Big theoretical change.
- Truth conditions are still there, derivatively. CCP primary.
- In Heim's "file change semantics", a "file" is true w.r.t. a model if it is embeddable in that model (disc. referents mapped onto entities in the model, etc). A formula is true if updating a true file with it makes a true file, false if updating a true file with it makes a false file.
- Where does the apparent existential quantifier in the interpretation of an indefinite come from? "File is true if *there is a way* to embed it."

3. Indefinites and dynamic semantics, *cont'd.*

- Heim did not build her approach into a whole research program, and soon afterward changed her views on definites, though many still like the approach in her dissertation better than her later approach, or consider that both are needed.
- Kamp did pursue his Discourse Representation Theory (DRT) and has made it into a large-scale research program. Asher and others have extended it to include more pragmatics, more text-coherence relations.
- Kamp argued that DRT was not straightforwardly compositional and shouldn't be.
- Groenendijk and Stokhof responded with a fully compositional new kind of logic, Dynamic Predicate Logic, extended to Dynamic Montague Grammar. Chierchia extended it and applied it to a lot of difficult anaphora problems in his 1995 book.
- Reinhard Muskens showed how to reconcile Kamp with Groenendijk and Stokhof with his 1993 "Compositional DRT".

4. Plurals and mass nouns: ontology and typology

- Montague's papers only treated singular count nouns – no plurals and no mass nouns. Notes left behind from when he was writing PTQ show that he had wanted to include lots of plural quantifier NPs, but did not find a treatment of plurals that satisfied him.
- A number of approaches to plurals were proposed, initially with the idea that *horse* is true of entities, *horses* true of sets of entities.
- Mass nouns were a bigger problem; earlier approaches by philosophers of language tended to be in terms of 'sets of portions of matter'.
- Linguists, like Stein (1981) working on Thai, and the typologist David Gil argued that mass should be *basic*, since many of the world's languages make no mass-count distinction and treat all nouns the way English treats mass nouns.
- In languages like Thai and Chinese, counting always requires the use of *classifiers*, as in English 'two drops/glasses/puddles of water'.

Plurals and mass nouns: ontology and typology, *cont'd.*

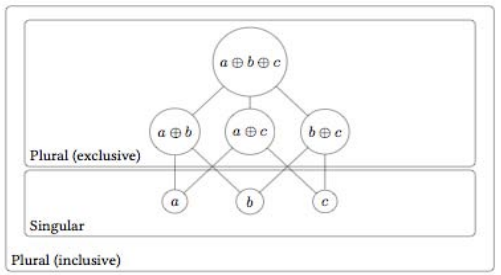
- Godehard Link, a philosopher and logician with a good linguistic education (who later did field work in Papua New Guinea), bulding on earlier work on mereology by Lesniewski, made a major breakthrough in his work on a logic for mass nouns and plurals.
- Link (1983) proposed a treatment of the semantics of mass and plural nouns whose principal innovations rest on enriching the structure of the model by treating the domain of entities as a set endowed with a particular algebraic structure.
- In the model Link proposes, the domain of entities is not simply an unstructured set but contains some subdomains which have the algebraic structure of semilattices. A distinction is made between *atomic* and *non-atomic* semilattices.
- Intuitively, atomic lattices have smallest discrete elements (their atoms), while non-atomic ones (really "not necessarily atomic") may not.

Plurals and mass nouns: ontology and typology, *cont'd.*

- Diagram from Lucas Champollion course handout: atomic join semilattice for singular *horse* and plural *horses*.

(6)

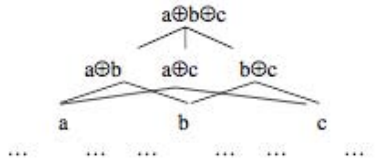
Figure 2.1: Different views on the plural.



Plurals and mass nouns: ontology and typology, *cont'd.*

- Diagram from Malte Zimmerman course handout:

(7)



- Potentially atomless join semilattice, for mass nouns like *water.* The individuals in the semilattice are 'portions of water'.

Plurals and mass nouns: ontology and typology, *cont'd.*

- These atomic and non-atomic join semilattice structures, when used to provide structures for the domains of count and mass nouns respectively, give an excellent basis for showing both what properties mass and plurals share and how mass and count nouns differ, as well as for formally elucidating the parallelism between the mass/count distinction and the process/event distinction (Bach 1986 "The algebra of events".)
- One of the most important features of this analysis is that the mass lattice structure emerges as unequivocally more general than the count noun structure, i.e. as the unmarked case.
- The domains of mass noun interpretations are simply join semilattices, unspecified as to atomicity. Atomic join semilattices are characterized as the same structures but with an added requirement, hence clearly a marked case.

Plurals and mass nouns: ontology and typology, *cont'd.*

- An important payoff is that these lattice structures also make it possible to give a unified interpretation for those determiners (and other expressions) that are insensitive to atomicity, i.e. which can be used with what is intuitively a common interpretation for mass and count domains, such as *the, all, some*, and *no*. *The*, for instance, can be elegantly and simply defined as a "supremum" operation that can be applied uniformly to atomic structures, both singular and plural, and non-atomic structures.
- "Count-only" determiners such as *three* and *every* have interpretations that inherently require an atomic semilattice structure.
- Link's work was not the last word, but it was a landmark event that set new standards: algebraic structure inside the entity domain opened up a way to capture the linguists' observation that mass is 'more basic' than count, and to capture the similarities and differences among mass and plural and among the different quantifiers and determiners that combine with them.

5. Type-shifting

- Montague required a single semantic type for each syntactic category, so for instance all NPs (our DPs) interpreted as generalized quantifiers, including proper nouns like *John*.
- In the 1970's, we bit the bullet and taught our courses that way.
- In the 1980's, evidence began to build up that category-type assignment was not so rigid and uniform.
- Early evidence from Partee and Rooth (1983) on conjunction; different inference patterns with extensional and intensional transitive verbs.

(8) a. John hugged and kissed two women ≠ John hugged two women and kissed two women.

b. John needs and wants a new secretary = John needs a new secretary and wants a new secretary.

- Right predictions **if** extensional verbs take e-type objects and intensional verbs take intensions of generalized quantifiers.

Type-shifting, *cont'd.*

- Partee (1986) built on and extended ideas about type-shifting.
- Montague's uniform treatment of NP's as generalized quantifiers, type (e→t)→ t :

(9) *John* λ***P***[***P***(**j**)]
a man λ***P*** ∃ ***x***[**man**(***x***) & ***P***(***x***)]
every man λ***P*** ∀ ***x***[**man**(***x***) → ***P***(***x***)]

- Intuitive type multiplicity of NP's:

(10) *John* "referential use": **j** (or **John)** type e
a fool "predicative use": **fool** type e→t
every man "quantifier use": as above type (e→t)→ t

- My 1986 resolution of the conflict: All NP's have meaning of type (e→t)→t; some also have meanings of types e and/or e→ t.
- Challenge: Find general principles for predicting what can shift and how.

Type-shifting, *cont'd.*

- ***Evidence for multiple types for NP's.***
- Evidence for type e (Kamp-Heim): While any singular NP can bind a singular pronoun in its (c-command or f-command) domain, only an e-type NP can normally license a singular discourse pronoun.

(11) John /the man/ a man walked in. He looked tired.

(12) Every man /no man/ more than one man walked in. *He looked tired.

- Evidence for type <e,t>: subcategorization for predicative arguments and conjoinablility of predicative NPs and APs in such positions.

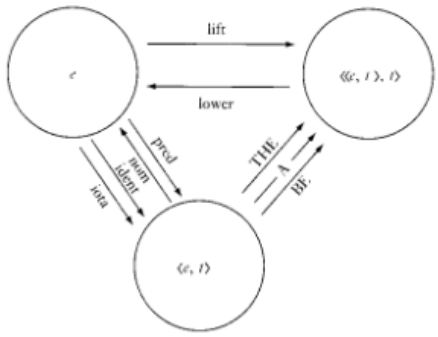
(13) Mary considers John competent in semantics and an authority on unicorns.

(14) Mary considers that an island /two islands / many islands / the prettiest island / the harbor / *every island / *most islands / *this island / *?Hawaii / Utopia.

Type-shifting, *cont'd.*

- In general, the possibility of an NP having a predicative interpretation is predictable from the model-theoretic properties of its interpretation as a generalized quantifier.
- Looking for "natural" type-shifting functors. Sometimes can find formal arguments for naturalness; see whether they we can predict empirical observations that some shifts are widespread (either universal or at least very common).
- Analogy: what might be a "natural" mapping from reals to integers? (Think about it; possible answers on another slide.)
- One natural shift: "Lift", the operation that takes you from "j" in type e to λ***P***[***P***(**j**)], Montague's (e→t)→ t interpretation for *John*.
- A family of proposed natural type-shifting functors on next slide, sometimes called the "Partee triangle".

Type-shifting, *cont'd.*: the Partee triangle (1986)



Type-shifting, *cont'd.*:

- "Natural" function from reals to integers? Some logicians may reply "Map every real number onto 0". Simple, but not natural.
  - Regular people more likely to say "rounding off".
  - That has the advantage of preserving order from one domain to the other, as much as possible.
  - Different versions of "rounding off" may have different further properties, and one can see that what's most natural or best may depend on one's purposes. (Shopkeeper vs. physicist, for instance)
- Some sample proposed type-shifting functors for English:
- *the* in all three types
- "A" and "THE" as type-shifting functors usable in languages without articles. (Blocking principle proposed by Chierchia: if a language has a dedicated word or morpheme for something, that language won't (can't) use type-shifting to accomplish the same thing.

Type-shifting, *cont'd.*:

- "Link" and "Delink" type-shifters – map between set and plural individual
- Cardinal numbers as adjectives or determiners.
  - Adjectival *three* is basic, applies to a plural entity, true of it if that plural entity has exactly three atoms.
  - Determiner *three* results from a type shift (or a raising & incorporation operation) that composes the meaning of adjectival *three* with the meaning of the indefinite article. (Hence in simple contexts the resulting "at least three" meaning.)
- Bittner and Hale (1995) give interesting semantic arguments for the claim that Warlpiri lacks the category of Determiner altogether, whereas Polish and Greenlandic Eskimo, which have determiners, have "null" articles. They argue that this difference can explain why the Warlpiri word for *many*, a noun, has a shifted interpretation as "all", while in languages with determiners such a shift will be impossible.
- The argument is slightly too long to repeat here, but it includes a plausible new constraint on type-shifting:

Type-shifting, *cont'd.*:

- Bittner and Hale (1995) , continued: Nouns in Warlpiri can be of type e or <e,t> -- some basically type e, others basically type <e,t>. Nouns typically can get three kinds of meanings (via shifts familiar from Partee 1986):

(15) a child (weak, type e)
the child (strong, type e)
[him/her,] who is a child (predicative, predicated of an implicit arg.)

- The noun *panu* 'many' is basically type <e,t>, but also has three meanings:

(16) a large group (i.e. 'many') (weak, type e)
the large group (i.e. 'all') (strong, type e)
[they,] who are a large group (predicative, type <e,t>)

- Their argument: because *panu* is a noun, it can shift to type e and get a strong reading which amounts to 'all'.
- Why can't determiner or adjectival *many* in other languages do that? Because e is usually a type only for nouns, and they propose that **Type-shifting rules cannot create any category-type correspondences not independently attested in a given language.**

Type-shifting, *cont'd.*:

- Continuing work on type-shifting – many applications, some efforts to identify constraints and implicational universals, etc.
- One lively area with many open questions: the distribution and interpretation of "bare plurals" (Dogs chase cats) and "bare singulars" in the world's languages, and the range of possible types for DPs and NPs. (Chierchia and others.)
- Another active area: aspectual properties and Aktionsarten, and ontological classes like events, processes, states.
- Slavic vs. English: no definite/indefinite article, vs no perfective/ imperfective verb distinction.
  - English: *eat the soup in 10 minutes* vs eat soup for 10 *minutes*
  - Slavic: *eat-Pf soup in 10 minutes* vs. *eat-Impf soup for 10 minutes*
  - Krifka, Filip, others: interaction of verbal aspectual properties and quantificational properties in determining properties of whole VP; different sorts of coerced type- (or sort-) shifting in different languages.
- Types are rather coarse-grained; need finer-grained "sorts" as well.

6. Situations

- Big topic, I will say very little. Another big change in the 80's.
- Another big splash in the early 80's: Barwise and Perry and their "Situation Semantics". Unprecedently large grant to Stanford to found CSLI, with Situation Semantics as a leading project.
- For various reasons, Situation Semantics as they developed it did not live up to its initial promise.
- But in the late 80's, Angelika Kratzer developed a different notion of situations, in which possible situations were parts of possible worlds, and her version has become extremely influential.
- Situations sometimes play the role of "events", e.g. with objects of perception verbs (*I saw John leave*), and sometimes play a role analogous to possible worlds.
- Propositions analyzed as sets of possible situations; since situations can be very small or as large as worlds, this gives a more fine-grained notion of propositions.
- See Kratzer on Situations in Stanford Encyc. of Philosophy.

7. A few more vignettes – ling-phil interactions 1970's

- Spring 1970 - There was a small conference of linguists and philosophers at UCLA in 1970, memorable in part because it was moved to the basement of a church after Reagan closed the University of California in the wake of protests over the bombing of Cambodia. Talks were by philosophers Montague, Julius Moravcsik, John Vickers, and Martin Tweedale, and linguists George and Robin Lakoff, George Bedell, and me; attendees included Bruce Vermazen, Lauri Karttunen, Bob Wall, and then-students Michael Bennett and Larry Horn.
- That was the time when I intervened in an argument between Lakoff and Montague about whether it was crazy to derive prenominal adjectives from relative clauses or crazy not to, explaining to each of them where the other's position was coming from, and during the coffee break got the closest to a compliment I ever got from Montague – "Barbara, I think that you are the only linguist who it is not the case that I can't talk to." (Larry Horn, already a budding negation specialist, also noticed that sentence and copied it down; our memories agree forty years later.)

Linguistic-philosophy interactions, *cont'd.*

- September 1970 – the Moravcsik, Hintikka and Suppes conference at Stanford at which Montague presented PTQ. (Volume published in 1973.)
- When "part 2" was held two months later, in November, we were all to make comments on as many of the other participants' papers as we wished. I decided to put all my efforts into commenting on Montague's paper.
- I commented on Montague's syntax, comparing it with transformational grammar. I recall David Kaplan saying that by listening 'inversely', he was able to understand something about how transformational grammars worked. And Montague didn't object to my description of what he was doing – that was reassuring.
- March 7, 1971 – Montague's death

Linguistic-philosophy interactions – timeline, cont'd

- Fall 1971 (I think): David Kaplan and I each taught a seminar at Stanford, one afternoon a week – we flew from the Ontario airport in the San Fernando Valley up to San Jose and back, talking all the way, and sat in on each other's seminars. I learned a lot from his seminar on demonstratives, and also from all the help I got from him, Jaakko Hintikka, and Julius Moravcsik as I struggled to understand Montague's intensional logic better.
- 1971 – publication of a couple of papers by Ed Keenan on what could well be called formal semantics:
- Keenan, Edward L. 1971. Names, quantifiers, and a solution to the sloppy identity problem. *Papers in Linguistics* 4.1. and
- Keenan, Edward L. 1971. Quantifier structures in English. *Foundations of Language* 7:225-284.
- 1972 – circulation of Terry Parsons's big fragment with his own way of doing formal semantics of English "An Outline of a Semantics for English", 2nd version
- Winter & spring quarters 1972: my first MG seminars, at UCLA. (Stockwell: "But when are you going to get back to doing linguistics?")

Linguistic-philosophy interactions – summer 1971.

- Summer 1971 -- Summer School in Semantics and Philosophy of Language at UC Irvine, organized by Donald Davidson and Gil Harman with funding from the Council for Philosophical Studies. A life-changing event for many of us, and an intense experience that forged lasting bonds among us.
- Two 3-week sessions, each with twice-a-week lecture+discussion (3 hours) by 3 philosophers and one linguist. Lecturers in the first session were Grice, Davidson, Harman, and me as the linguist; the second session (which I commuted to daily from home, together with Michael Bennett, which was another occasion for great discussions) had Strawson, Quine, Kaplan, and Haj Ross as the linguist. And there was a special evening series by Kripke on his just-completed "Naming and Necessity". The "students" were young philosophy professors, including Rich Thomason, Bob Stalnaker, Gareth Evans, Dick Grandy, Peter Unger, Steven Stich, Bill Lycan, Bob Martin, Oswaldo Chateaubriand, Carl Ginet, Sally McConnell-Ginet, James McGilvray, and many others; and many of them gave evening lectures. (Gil Harman reports "After intense discussions, we would spend time in Laguna Beach, where Davidson was teaching Quine to surf.")

Linguistic-philosophy interactions 1973

- Spring 1973 – Formal Semantics conference organized by Ed Keenan at Cambridge University – the first international conference on formal semantics. Included papers by David Lewis, Barbara Partee, R.D. Hull, Altham & Tennant, John Lyons, Pieter Seuren, Östen Dahl, Colin Biggs, Hans Kamp, Renate Bartsch, Carl Heidrich, Arnim von Stechow, Timothy Potts, George Lakoff, Stephen Isard, Petr Sgall, Theo Vennemann, Yorick Wilks, Joe Emonds, Maurice Gross, Ed Keenan, Haj Ross, and a few others. Collection *Formal Semantics of Natural Language* published in 1975. [The term 'formal semantics' (new then?) soon gained ground among like-minded semanticists who weren't all strictly Montagovian, Keenan being a prime example.]

Linguistic-philosophy interactions 1974

- Summer 1974 – Linguistic Institute at UMass Amherst, with my course on Montague Grammar and a large number of courses on semantics and philosophy of language – I was in charge of organizing that part of the Institute. The faculty in those areas heavily overlapped with those who participated in a seminar on Non-Extensional Contexts funded by MSSB that I organized, which included Rich Thomason, Bob Stalnaker, David Lewis, Emmon Bach, Terry Parsons, David Dowty, Ray Jackendoff, Janet Fodor, Ed Keenan, Hans Kamp, Lauri Karttunen, Michael Bennett, Enrique Delacruz, and two graduate students, Anil Gupta (Thomason's student) and Robin Cooper (mine).
- I'll end here for now. Please e-mail me with suggestions and comments and questions. partee@linguist.umass.edu
- Thank you – you've been a wonderful audience!

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