The Intertwining Influences of Logic, Philosophy, and Linguistics in the Development of Formal Semantics and Pragmatics

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Acknowledgements

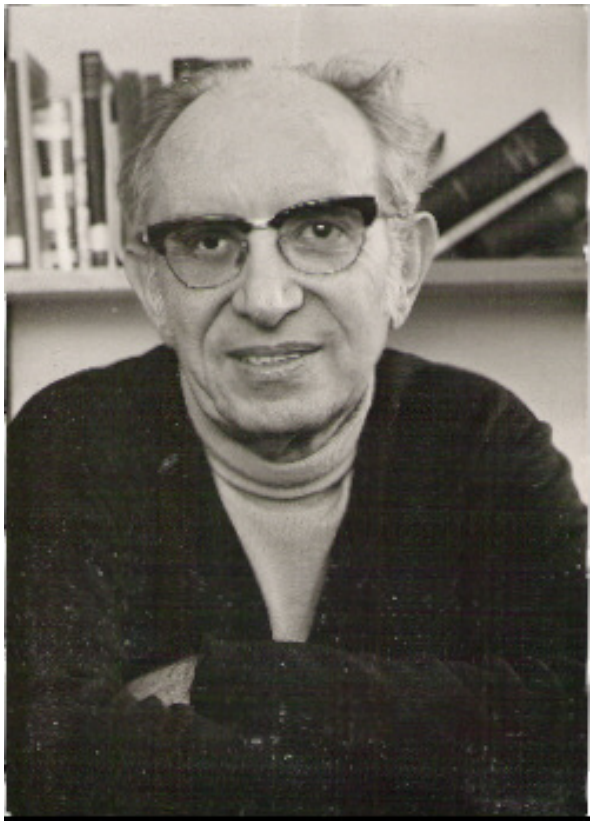
- This talk overlaps with and builds on (Partee 2011, 2013a, 2013b), which provide background for the issues discussed here. All are part of my work for a book in progress on the history of formal semantics.
- For the early history of quantification, I have made great use of (Westerståhl 2011) and (Peters & Westerståhl 2006), and for everything related to Tarski and his students and colleagues and to antecedents and early years of the Program in Logic and the Methodology of Science at UC Berkeley, I have made great use of (Feferman and Feferman, 2004).
- I am grateful for comments and discussion to numerous colleagues, especially Hans Kamp, Nino Cocchiarella, Richmond Thomason, Martin Stokhof, Solomon Feferman, and Ivano Caponigro.

1. Introduction

- Formal semantics and pragmatics have developed since the 1960's through interdisciplinary collaboration among linguists, philosophers, and logicians, and have affected developments in linguistics, philosophy of language, and cognitive science.
- I'll first describe the environment in which formal semantics was born and took root. I'll start around 1957, the year of the founding of the Group in Logic and Methodology of Science, and the year that Montague defended his dissertation at Berkeley under Tarski.
- I'll focus on Montague's contributions to the founding of formal semantics, since he came directly out of the Group whose anniversary we're celebrating, and he epitomizes its interdisciplinarity with his study at Berkeley of logic, mathematics, philosophy, and Near Eastern languages, including his motivations for and attitudes toward his work on natural language.
- I'll also say a little about the 'naturalizing' influence of linguists on developments after Montague's untimely death in 1971.

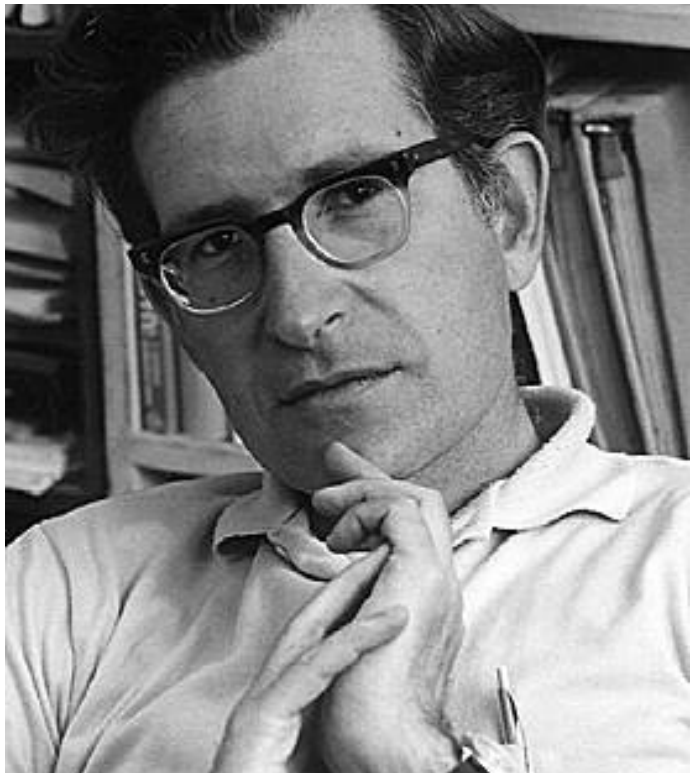
2. Semantics in linguistics in 50's and 60's

- 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.



Semantics in linguistics, *cont'd.*

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



Semantics in linguistics, *cont'd.*

- Later note: Bar-Hillel in 1967 wrote to Montague, after receipt of one of Montague's pragmatics papers: "It will doubtless be a considerable contribution to the field, though I remain perfectly convinced that without taking into account the recent achievements in theoretical linguistics, your contribution will remain one-sided." I.e., Bar-Hillel hadn't given up trying to get the logicians and linguists together.
- Frits Staal also tried on many occasions to get linguists, logicians, and philosophers together, including Chomsky and Montague. He founded the journal *Foundations of Language* with that aim. And he also edited the transcript from the symposium on "The Role of Formal Logic in the Evaluation of Argumentation in Natural Languages" that Bar-Hillel organized in 1967 at the 3rd International Congress for Logic, Methodology and Philosophy of Science in Amsterdam.

The Katz-Postal hypothesis and the Garden of Eden

- 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 (1), arguing that there was independent syntactic motivation for doing so, and then the meaning could be determined on the basis of Deep Structure alone instead of via a "Negation transformation".
- (1) [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

- A surprising historical accident was 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. This historical accident was one of the causes of the "Linguistic Wars" of the late 1960's.
- In the 'standard theory', (3a-6a) would be derived from deep structures associated with (3b-6b). Such derivations had seemed meaning preserving, considering only pairs like (2a-2b) with proper names.

(2) a. John voted for himself. FROM:

b. John voted for John.

(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:

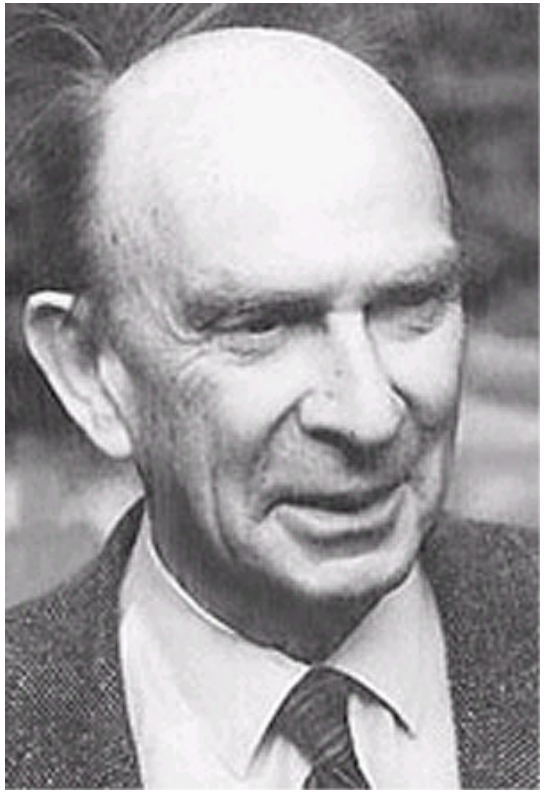
b. No number is even and no number is odd.

The Linguistic Wars of the Late 1960's

- The Katz-Postal hypothesis, and hence Chomsky's *Aspects*, incorporated the Compositionality Principle: the meaning of a whole is a function of the meanings of its parts and of how they are syntactically combined. In *Aspects, t*he relevant syntactic structure was Chomsky's Deep Structure.
- Generative Semanticists (Lakoff, McCawley, Ross) 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.
- The Interpretive Semanticists (Jackendoff and some others) held on to a Chomskyan Deep Structure, and proposed semantic rules that interpreted both Deep and Surface structure in a complex architecture.
- Linguistic wars. And even now, continuing debates about solutions.

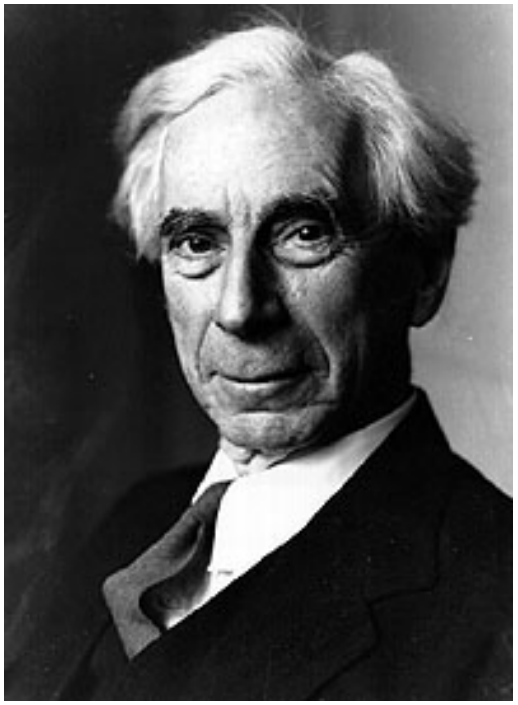
3. The Ordinary Language – Formal Language Wars

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



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

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



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.

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

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

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

- The answer is that it is distributed over the whole formula – in fact everything except the predicate *walk* in the formula can be traced back to *every man*. The treatment is *syncategorematic* – the expression *every man* does not belong to any category.
- 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.

The origins of generalized quantifiers

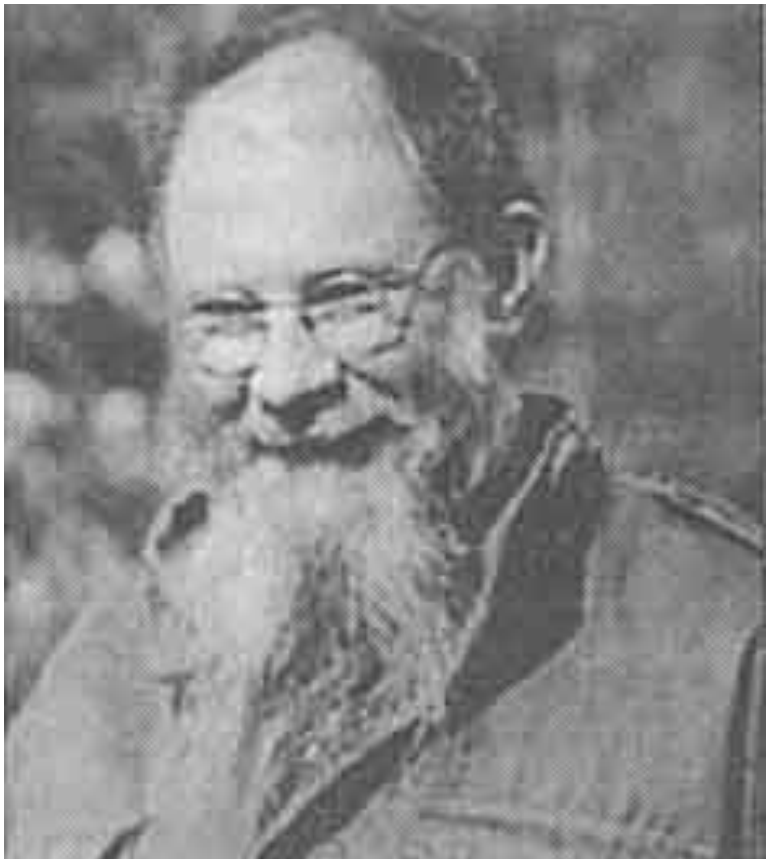
- According to Peters and Westerståhl (2006), the logical notion of quantifiers as second-order relations is "discernible" in Aristotle, full-fledged in Frege, then forgotten until rediscovered by model theorists under the influence of Tarski.
- Tarski's first PhD student was Andrzej Mostowski; he got his Ph.D. in 1938, but Tarski could not sign the dissertation because he was not a full professor; someone else signed as the official supervisor, a bitter pill for Tarski.
- Mostowski 1957 introduced unary generalized quantifiers, sets of sets: 'everything', 'something', 'an infinite number of things', 'most things'. But not relational 'most', 'every' ("binary GQs").

Tarski and Andrzej Mostowski (1913-1975)

The origins of generalized quantifiers, *cont'd*.

- Lindström 1966 introduced binary generalized quantifiers like 'most', 'every', 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.
- Lindström was a follower of Lars Svenonius, the first Swedish model theorist, who was influenced by Tarski and his students, and who was named a Visiting Associate Professor at UC Berkeley for 1962-1963. (Lindström was in turn the teacher of Dag Westerståhl.)
- For formal semanticists the sources of generalized quantifiers were Tarski's student Montague and David Lewis.
- Those two did groundbreaking work in showing the importance of generalized quantifiers for making a formal semantics of natural language possible.

Richard Montague and David Lewis



4. Montague's work leading to his language papers

- Montague's early work was philosophical and logical rather than explicitly natural-language oriented, as was true of Frege, Carnap, Tarski.
- The three papers that were crucial for formal semantics were his last three papers: EFL (English as a formal language, 1970), UG (Universal grammar, 1970), and PTQ (The proper treatment of quantification in ordinary English, 1973).
- But he would have contributed greatly to the foundations of formal semantics even without those three papers, with his development of intensional logic and his combination of pragmatics with intensional logic in the immediate precursors to his three language papers.
- The three precursors, developed in seminars and talks from 1964 to 1968, were 'Pragmatics and Intensional Logic' ('P&IL', 1970), 'Pragmatics' (1968), and 'On the nature of certain philosophical entities' ('NCPE', 1969).

Montague's pre-"linguistic" work, *cont'd.*

- The three earlier papers still followed the tradition of not formalizing the relation between natural language constructions and their logico-semantic analyses or 'reconstructions': the goal was not to analyze natural language, but to develop a better formal language. Only the last three papers offered such formalization.
- NCPE (1969), the paper that's devoted to philosophical applications, contains a great deal that can be considered as much a matter of semantics as of philosophy, and foreshadows some of his work in his three final "language" papers.

Montague's pre-"linguistic" work, *cont'd.*

- There is an important credit in the first footnote of NCPE: "I should like to express gratitude … to Professor Benson Mates, whose talk "Sense Data", given before the UCLA Philosophy Colloquium on November 18, 1966, largely provoked the present considerations.

Montague's pre-"linguistic" work, *cont'd.*

- The main concern of NCPE is the status of such entities as pains, events, tasks, and obligations. The Mates problem about 'sense data', which 'provoked' this paper, is described on pp 169-170.
  - Now Benson Mates … raised the interesting problem of describing in an exact way such situations as that about which we might ordinarily say
  - (19) 'Jones sees a unicorn having the same height as a table actually before him';
  - It was this problem that gave rise to the present paper, as well as to the construction of the intensional logic which it contains. In the light of that logic, the treatment of (19) is fairly obvious. Since we have decided to use 'sees' only in the veridical sense, we must first reformulate (19) as
  - 'Jones seems to Jones to see a unicorn having the same height as a table actually before him'.

Montague's pre-"linguistic" work, *cont'd.*

- 'Jones seems to Jones to see a unicorn having the same height as a table actually before him'.
- And this can be represented as follows:
- (20) ∃*x* (Table [*x*] & Before [*x*, Jones] & Seems [Jones, Jones, ^λ*u*∃*y* (Unicorn [*y*] & Sees [*u,y*] & *y* Has-the- same-height-as *x*)]).

- So Montague realized that Mates had considered a nice solution but rejected it because it would require "quantifying into" indirect contexts (here with *a table*), which before P&IL it seemed could not be done intelligibly. Thus Montague was motivated to further develop his intensional logic and to demonstrate that it had useful applications in the domain of such problems.
- He goes on to note that we *can* provide for sense data if we wish – he has already considered the nature of pains, which are one class of sense data – but quantifying into *seems* contexts is now possible and therefore examples like Mates's do not *force* the admission of sense data as entities.

5. Montague's turn to "linguistic" work.

- No one seems to know for sure why exactly Montague decided to turn his attention to the task of explicitly constructing a formal framework for the syntactic and semantic description of language.
- Everyone agrees that what Montague most valued intellectually were logical and philosophical results. He considered the empirical description of natural language a matter of secondary importance.
- But he was not satisfied with what linguists were doing, felt he could do better, and thought it was probably worth the small amount of effort he believed it would require.

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

- His change of direction came as a surprise to some of his colleagues; Solomon Feferman, for instance, had been working with Montague on a book on the method of arithmetization of metamathematics, incorporating results of both of their dissertations under Tarski. To Feferman, Montague's work on formal semantics of natural languages came "out of the blue" (p.c. January 10, 2011).

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

- For many years, I had thought that Montague's interest in formalizing the syntax and semantics of natural language had come from his work with Kalish on their joint textbook, which was unusual among logic textbooks for the degree of explicitness with which they treated the matter of translating from logic to English and vice versa.
- In 2009 and 2010 I asked Montague's students Hans Kamp and Nino Cocchiarella what they thought. Condensing their replies:
- From Kamp (e-mail, October 2009): In developing a model-theoretic semantics for NL the focus is naturally on conditions of truth and reference; that is not the same thing as defining a translation function from NL to Predicate Logic. However, a model-theoretic account of NL meaning can be used as a criterion for adequate translation. And as became plain in Richard's later papers on NL semantics (not EFL, but UG and PTQ), a translation function could also be useful as a way of articulating a model-theoretic treatment.

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

- From Cocchiarella (December 2010):
  - [Montague's] early work on pragmatics and intensional logic had not yet [in the mid 60's] affected [his] basic philosophical view: namely, that all philosophical analyses can be carried out within a definitional extension of set theory, which explains why in "English as a Formal Language" Montague uses set theory to construct the syntax and semantics of a fragment of English in a way that resembles the construction of the syntax and semantics of a first-order modal predicate calculus.
  - But Montague did not remain satisfied with set theory as a *lingua philosophica*, nor with unprincipled 'paraphrasing' between natural language and logical language, and in the end he proposed instead the construction of an intensional logic as a new theoretical framework within which to carry out philosophical analyses … .
  - Once Montague moved on to an intensional logic we have a distinctive new tone about English and natural language in his papers ... .
- But then in 2011 I found a new clue in the Montague archives.

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

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

6. Generalized quantifiers

- One of the first things that impressed linguists like me about Montague's (and Lewis's) work was this idea about how with a higher-typed logic and the lambda-calculus (or other ways to talk about functions), DPs could be uniformly interpreted as generalized quantifiers (sets of sets).
- And Determiners could be interpreted as functions that apply to common noun phrase meanings (sets) to make generalized quantifiers.
- Recall how we asked "Where's the meaning of *every man* in (10), the first-order formalization of *Every man walks*?"

(12)

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 DPs. DP is function, VP is <e,t> argument.

Generalized quantifiers, *cont'd.*

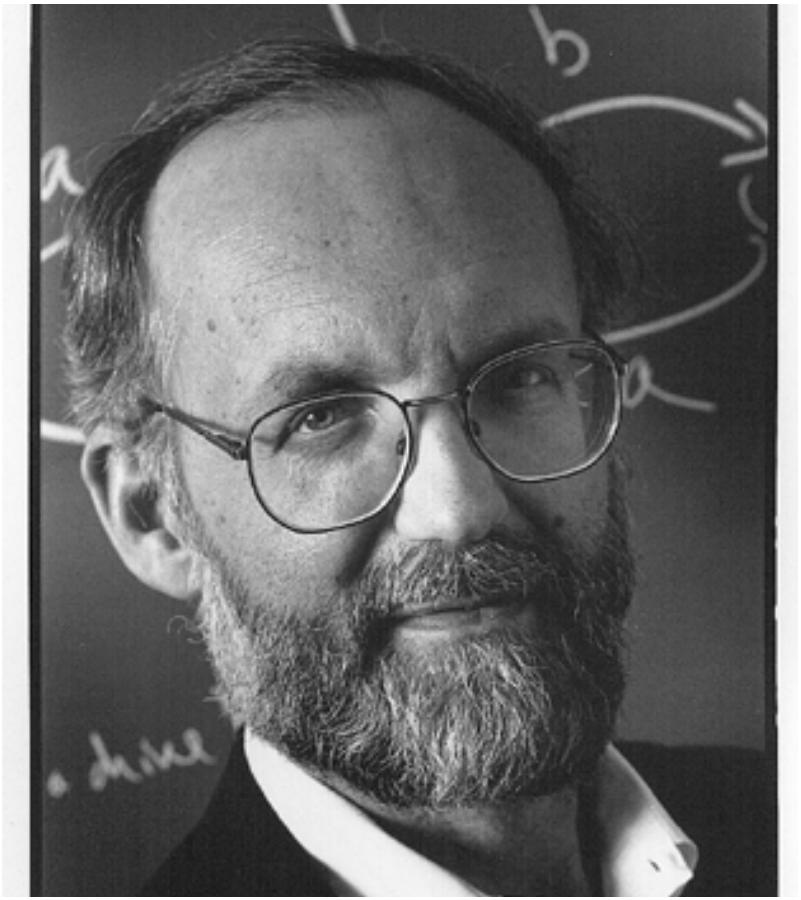
(13)

John	$\lambda P[P(\mathrm{j})]$ (the set of all of John's properties)
John walks	$\lambda P[P(\mathrm{j})]\ (\mathbf{walk}) = \mathbf{walk}\ (\mathrm{j})$
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. (B&C 1981)
- 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). [*every*]
- D is *negative strong* if D(A)(A) is false whenever D(A) is defined. [*neither*]
- D is *weak* if it is neither positive strong nor negative strong. [*no, 3*]
- Subsequent improvements to the definitions and to the analysis of *there*-sentences by Keenan and others.

Jon Barwise and Robin Cooper



Recursion on open sentences: relative clauses

- And doing recursion on open sentences together with Frege's idea of using function-argument application as a principal means of semantic composition, together led to a far better semantic analysis of relative clauses than had been achieved linguists before or during the semantic wars. (Quine actually presented this solution in *Word and Object*; Montague didn't invent it.)
- I want to recall how impossible it had been to do justice to relative clauses in quantified noun phrases in earlier linguistic work.

(16) a. The man who won the men's race was a Kenyan.

b. Every child who carved a pumpkin got a prize.

c. Some child who carved a pumpkin got a prize.

- Combining 'kernel Ss' containing "Identical NP" can't be right.

a. The man won the men's race. The man was a Kenyan.

b. Every child carved a pumpkin. Every child got a prize.

c. Some child carved a pumpkin. Some child got a prize.

Relative clauses and quantifiers, *cont'd.*

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

Relative clauses and quantifiers, *cont'd.*

(17) Every boy who loves Mary is happy

[[boy who loves Mary]] = [[boy]] ∩ [[who loves Mary]]

[[boy]] is the set of boys

[[who loves Mary]] is the set of individuals x such that x loves Mary

- *boy, who loves Mary,* and *boy who loves Mary* are all of type <e,t>.
- On Generalized Quantifier theory, all determiners are functions that first combine with the <e,t> NP argument, and then combine with the rest of the sentence, which will also be of type <e,t>.
- (In the simplest case, the 'rest of the sentence' is just a VP. But if the Generalized Quantifier is not in subject position, it gets "quantified in" by one mechanism or another, and the 'rest of the sentence' is an <e,t>-type lambda abstract. See Heim & Kratzer or other textbooks.)

7. From puzzles about intensional verbs to Generalized Quantifiers in Montague's work

- Montague's primary motivation was always logic and the use of logic in philosophical arguments, and he explained why that merited some attention to natural language semantics.
- But Montague's interest in language seems to have gone beyond what was "required", even if he didn't value that interest highly. In high school, he studied Latin, French, and Spanish. In college besides mathematics and philosophy he studied French, Arabic, Hebrew, some Polish, some Greek (p.c. Ivano Caponigro).
- He continued graduate work in mathematics, philosophy, and Semitic languages, especially with Walter Joseph Fischel in classical Arabic, with Paul Marhenke and Benson Mates in philosophy, and with Tarski in mathematics and philosophy, receiving an M.A. in mathematics in 1953 and a Ph.D. in philosophy in **1957** (the year the Program in Logic and Methodology of Science became official, also the year of Feferman's Ph.D.)

From intensional verbs to GQs, *cont'd.*

- Montague's earliest concentrated work on language-related topics seems to have taken place in the spring of 1966, much of which he spent in Amsterdam, where he gave a seminar on the philosophy of language. Notes from that period show an occupation with pragmatics and indexicality, and with problems of intensional contexts.
- He gave a talk on "Pragmatics" as early as December 1964, which fits with what Cocchiarella told me (p.c. 2010):
  - "Prior spent the 1964-65 academic year at UCLA, incidentally, and, according to Montague, it was then that Prior, as a result of Montague's influence, began to have a greater interest in a more rigorously formal approach to the analysis of language. Prior, of course, also influenced Montague, especially about pragmatics and intensional logic."
- Montague was also corresponding with Bar-Hillel in those early years, when Bar-Hillel was advocating that pragmatics should provide a formal theory of indexical terms.

From intensional verbs to GQs, *cont'd.*

- The other main topic that seems to have concerned Montague from very early on is modal and intensional contexts, including the puzzles about intensionality raised by Quine (1960) (and by Buridan, as Montague notes in NCPE).
- That family of problems was under active discussion among a number of philosophers Montague was influenced by, including Mates, Carnap, and Church, and is reflected in Montague's first two papers in the 1974 collection, from 1959 and 1960.
- Montague was clearly interested for some time in the problem of intensional verbs like *seeks* and *conceives*; Michael Bennett (1974) notes that we find a suggestion from Montague to Geach about how to treat intensional verbs reported in Geach's *Reference and Generality* (1965, p.432).

From intensional verbs to GQs, *cont'd.*

- The problem of intensional transitive verbs seems to have occupied Montague's attention as he was developing his intensional logic.
- Some puzzles by Benson Mates provided an impetus for his 1969 paper, "On the nature of certain philosophical entities", which preceded all his explicitly language-related papers (talk: 1967).

(19) Jones sees a unicorn having the same height as a table actually before him. (Mates, with non-veridical 'see'.)

- Montague handled that via *seems to see*, which his intensional logic let him treat, but needed something else for *seeks* or *conceives.*
- In NCPE he analyzes sentences with *seeks* via paraphrase. He wants to show why, as Quine (1960) had noted, the argument in (9) is not valid, although the analogous argument with *finds* is valid.

(9) 'Jones seeks a unicorn; therefore there is a unicorn'

From intensional verbs to GQs, *cont'd.*

- He first describes a solution that rests on analyzing *seek* as *try to find*, symbolizing (9) as (10), which puts the existential quantifier for *a unicorn* in the premise under the scope of an intensional operator.

(10) Tries [Jones, ^λ*u* ∃*x* (Unicorn [*x*] & Finds [*u*, *x*])]

- He gives a similar paraphrase analysis of Buridan's examples with *owe.*
- Then he raises the question of whether resorting to these paraphrases is necessary.
- **We may wonder whether it is possible to approximate English more closely within our intensional language.** What we can do in the case of 'seeks'—and that of 'owes' would be completely analogous—is to introduce *several* predicate constants; and it would be possible to define them by means of the following equivalences: [emphasis added, BHP]

(15) □∀*x*∀*P*(*x* Seeks-a *P* ↔ Tries [*x*, ^λ*u* ∃*y* (*P*[*y*] & finds [*u*, *y*])]).

(16) □∀*x*∀*P*(*x* Seeks-the *P* ↔ Tries [*x*, ^λ*u* ∃*y* (∀*z* (*P*[*z*] ↔ *z* = *y*) & Finds [*u*, *y*])]).

(17) □∀*x*∀*P*(*x* Seeks-two-objects-having *P* ↔ Tries … [similarly]

From intensional verbs to GQs, *cont'd.*

- But he rejects that solution on several grounds, including the need for infinitely many predicate constants, something he had criticized Quine for when Quine suggested treating *seeks a unicorn* as an unanalyzed predicate constant. Then we find:
- "If, however, we were to pass to a *third-order*, rather than a *second-order*, language, the situation would change: we should then be able to introduce a single predicate constant in terms of which all notions analogous to those introduced by (14)-(17) could be expressed; I shall give a more detailed account of the situation in a later paper."
- So he had evidently gotten the GQ idea before NCPE was published in 1969. The GQs first appear in print in UG (1970, talks in 69, 70).
- One of my 'history' puzzles is who was first, Montague or Lewis? Both published papers with GQs in 1970, with talks in 1969.
- I've found the birth of the idea for Montague in 3 pages of notes from September 1, 1968, and a letter from DKL suggesting that Montague had priority.

From intensional verbs to GQs, *cont'd.*

- In the Montague archives in Box 1, Folder 7, "Intensional verbs and Berkeley's argument", three pages of notes from September 1, 1968 seem to record his first idea about solving the problem of intensional transitive verbs by giving them "third order" arguments, properties of properties of entities, i.e. intensional versions of generalized quantifiers.
- I now suppose that that is the source of the comment in NCPE that such a thing could be done, an idea that came after the "talk" version of NCPE (early 1967) but before the final manuscript was submitted (presumably sometime in the fall of 1968). I quote from these pages in my SuB paper to show both that the proposal is explicitly there and that it appears to be new to him at that time. Here are tiny extracts.
- Page 1 begins with "We can improve on 25 Apr 68"; the second half of the page begins with "Try:"

From intensional verbs to GQs, *cont'd.*

- What follows, after some crossings-out, are essentially the GQs of UG and PTQ.
- *all-R = ^λQ∀x[R[x] → Q[x]]*
- *an-R = ^λQ∃x[R[x] & Q[x]]*
- *two-R's = ^λQ∃x∃y[x ≠ y & R[x] & R[y] & Q[x] & Q[y]]*
- *the-R = ^λQ∃x[{x} = {y: R[y]} & Q[x]]*
- *Jones = ^λQ[Q[Jones]] (with the "usual" denotation for the inner occurrence of 'Jones')*
- *Thus in general a term ζ of the sort above denotes the property of (being a property) applying to ζ.*

(Note that at this point he sometimes mixed set notation and lambda notation, and that he had plural as well as singular determiners.)

(There are more details in my 2013 *SuB* paper.)

From intensional verbs to GQs, *cont'd.*

- Then on page 2 of the pages dated 1 Sep 68, he works out '*u seeks an-R*' in this new third-order way and in his old *tries-to-find* way, and assuming as he did that *seek* is equivalent to *try to find,* he shows in three lines that they come out equivalent.
- And then he writes below that: "So this works." And then he checks the equivalences with *two-R*'s and with *all-R*'s.
- The "Try:" on page 1 and "So this works." on page 2 make it pretty clear that this was when intensional generalized quantifiers first occurred to him: they provided a solution to the problem of *seeks*.
- In other works one could see that he had been reluctant to go beyond second-order intensional logic.
- That initial reluctance may account for his choice of the title of PTQ; it hadn't been at all obvious to him that natural language quantification would need such a treatment.
- If Ede Zimmermann is right, *seek* does not require intensional GQ arguments; but GQ theory has been really fruitful whether GQs are 'right' in the long run or not.

From intensional verbs to GQs, *cont'd.*

- By the late 1960's, when he was putting a great deal of his energy into his work on natural language, he seems to have been treating it with more respect, and seems to have found it quite interesting.
- Hans Kamp writes, "From what I can remember from the many hours …, his interest in natural language was genuine. And even if he started out in the vein of 'it is all much simpler than you linguists think, if you only start out from the right premises and use the right methods', he was far too intelligent not to see the problems that come into focus once you sit down in an attempt to get the details …really right." (p.c., December 13, 2012)

From intensional verbs to GQs, *cont'd.*

- It's also interesting to compare how he introduces his three "linguistic" papers. Both EFL and UG start with variations on his contention that there is no important theoretical difference between formal and natural languages, and both emphasize the importance of the intensional logic he has developed.
- PTQ, on the other hand, starts right in about natural language: "The aim of this paper is to present in a rigorous way the syntax and semantics of a certain fragment of a certain dialect of English." (p. 247).
- In all of his philosophical writings, we see his desire to solve significant puzzles; in PTQ, we first see the honorific description "puzzle" applied to linguistic phenomena. "The present treatment is capable of accounting for … a number of other heretofore unattempted puzzles, for instance, Professor Partee's **the temperature is ninety but it is rising** and the problem of intensional prepositions." (p. 248).

8. The naturalization of formal semantics

- The earliest introduction of Montague's work to linguists came via Partee (papers 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.
- In this way, the growing awareness of Montague's work was one factor in the waning of the "linguistic wars": for many of us, the new "Montague grammar" (which evolved into "formal semantics") showed promise of meeting the most important goals of both sides.

The naturalization of formal semantics, *cont'd.*

- The puzzles of natural language semantics have inspired the development of new formal tools and techniques, either borrowed or invented.
- Quantifiers have often been at center stage in such developments, as with the work in the early 80's of Irene Heim on her "File Change Theory" of definites, indefinites, and quantifiers, and Hans Kamp's similar "Discourse Representation Theory". Both kinds of "Dynamic Semantics" build on Robert Stalnaker's insights into how conversational moves both depend on context and modify it.
- Emmon Bach worked in the late 80's on "Natural Language Metaphysics"; his work on the "algebra of events" and Godehard Link's algebraic work on the mereology of mass nouns and plurals showed the value of imposing some algebraic structure within the basic domains of entities and of events in the model structures underlying the semantics of natural languages.

The naturalization of formal semantics, *cont'd.*

- 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 our central questions was whether all natural languages have NPs that are interpreted as generalized quantifiers. Barwise and Cooper had hypothesized "Yes"; we marshaled 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.

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

- MUCH more work on quantification since then– theory, typology, fieldwork, experimental work, acquisition, processing, pragmatics, all influencing each other.

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