A Brief History of the Syntax-Semantics Interface in Western Formal Linguistics

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1. Before *Syntactic Structures*

– from linguistics within philology (Europe) /anthropology (US) + mathematics → linguistics as a science, particularly as psychology (cognitive science)

-- negative attitudes to semantics in American linguistics in the 20th century, probably influenced by logical positivism (cf. behaviorism in psychology). Rather little semantics in early American linguistics.

-- semantics in logic and philosophy of language: much progress, but relatively unknown to most linguists

2. In *Syntactic Structures*

We don't understand anything about semantics, but deep structure reveals semantically relevant structure that is obscured in surface structure

(1) a. John is easy to please < (for someone) to please John is easy
b. John is eager to please < John is eager (for John) to please (someone)

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

(2) a. Everyone in this room speaks two languages.
b. Two language are spoken by everyone in this room.

In later years, those judgments about (2) came to be questioned; a number of authors at different times claimed either that both (2a) and (2b) are ambiguous, or that (2a) unambiguous but the passive (2b) is ambiguous.

3. From *Syntactic Structures* to *Aspects*: Katz, Fodor, Postal

At the beginning of the 1960's, Jerrold Katz and Jerry Fodor, junior faculty at MIT, started developing proposals for how a semantic theory could be developed in a generative grammar framework. They were clearly concerned with what we now call compositionality, and which they called the Projection Problem.

Because such things as negation and question-formation were treated via transformations (T-NEG, T-Q) of affirmative declarative sentences, Katz and Fodor (Katz and Fodor 1963) figured that the meaning must depend on the entire transformational history. The transformations are sketched in a very oversimplified way in (3a-b).

(3) a. [Mary [has [visted Moscow]]] $\Rightarrow_{\text{T-NEG}}$ [Mary [has not [visited Moscow]]]
b. [Mary [has [visted Moscow]]] $\Rightarrow_{\text{T-Q}}$ [has [Mary [visited Moscow]]]

Their idea of extending phrase-markers to T-markers showing the transformational history of an expression, and 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.

(4) T-marker for (3a) = P-marker for the deep structure --- T_{NEG} --- T_{affix} ….

But their semantics was very primitive. Katz and Fodor worked with "semantic features", and their semantic representations had no real structure, just bundles of features – suitable at best for decompositions of one-place predicates. Later they added some bits of structure to handle transitive verbs and their two arguments, but with no attention at all to things like quantifiers.

And what they were trying to capture was restricted to things that could be expressed in terms of 'readings' – how many, and same or different. The three main things to be captured were (i) ambiguity – having more than one reading; (ii) semantic anomaly – having no reading; (iii) synonymy – sharing a reading (synonymy on a reading), or the stronger version, having all the same readings. The examples of what they could capture didn't seem very exciting, and the accounts were sometimes open to easy counterexamples[1].

Then Katz and Postal (Katz and Postal 1964) made the innovation of putting such morphemes as Neg and a Question morpheme into the Deep Structure, as in (5), arguing that there was independent syntactic motivation for doing so, and then the meaning could be determined on the basis of Deep Structure alone.

(5) a. [NEG [Mary [has [visted Moscow]]]] $\Rightarrow_{\text{T-NEG}}$ [Mary [has not [visited Moscow]]]
b. [Q [Mary [has [visted Moscow]]]] $\Rightarrow_{\text{T-Q}}$ [has [Mary [visited Moscow]]]

Surface Structure would then be the input to phonology.

Semantics ← Deep Structure → Surface Structure → Phonology

The claim that transformations should be meaning-preserving was an interesting and provocative one, and even without any 'real semantics' at the foundation, it led to interesting debates about apparent counterexamples. And the architecture of the theory (syntax in the middle, mediating between semantics on one end and phonology on the other) seemed elegant and attractive.

Chomsky's thinking was evolving from *Syntactic Structures* (Chomsky 1957) to *Aspects* (Chomsky 1965) while I was there, and he tentatively accepted Katz and Postal's suggestion of a systematic connection between syntax and semantics at the level of Deep Structure. (His continuing skepticism about semantics would still come out in such comments as "Well, I don't think anyone understands anything about semantics, but maybe what Fodor and Katz and Postal are doing has some promise.") But during the brief period when *Aspects* held sway and 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", roughly the mid-to-late 60's, before the linguistic wars broke out in full force, I think generative grammarians generally believed the Katz and Postal hypothesis. That was also the period when people entertained the "Universal Base Hypothesis", the conjecture that the grammars of all natural languages have the same base rules. (See brief discussion in (Partee et al. 1990, p.556) and more in (Peters and Ritchie 1973).) The idea that meaning was determined at this "deep" level was undoubtedly part of the appeal of the notion of Deep Structure beyond

[1] See (Partee 2004, Partee 2005) for more details on this and some of the other issues mentioned in this talk.

linguistics[2] 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.)

4. Expulsion from Garden of Eden: the linguistics wars

But at least among working linguists, that very appealing view fell apart when the behavior of quantifiers was noticed. The many differences between quantificational NPs and proper names (example (6) below) immediately created great conflicts between syntax and semantics, and in a sense kicked all of us generative grammarians out of our Garden of Eden.

4.1. Katz-Postal hypothesis in trouble.

(6) Example: *Everyone is eager to win first prize.*

(7) Chomsky's EQUI-NP transformation:

NP	be	ADJ_{eager}	for	NP	to	VP	
1	2	3		4	5	6	⇒
1	2	3		∅	∅	6	

Condition: 1 = 4

(8) Classic example: *John is eager for John to win⇒ John is eager to win.*

(9) Problematic: *Everyone is eager for everyone to win* ⇒? *Everyone is eager to win*

(10) Better semantics: (Everyone x)(x is eager for x to win): how to derive such a meaning?

(11) Parallel problems:

(a) *Every candidate voted for himself* < ? *Every candidate voted for every candidate* ??

(cf. *John voted for himself*, assumed to be derived from *John voted for John.*)

(b) *Every number is even or odd* < ? *Every number is even or every number is odd* ??

4.2. The linguistic wars.

References: (Newmeyer 1980, Harris 1993)

Two responses to the problematic relation between classic transformational derivations and semantics.

- Generative semantics (Lakoff, Ross, McCawley, Postal): make the deep structures "deeper": find a semantically sound level of underlying structure. Generative semantics underlying structures became more and more abstract, often resembling first-order logic, and those structures plus the syntactic rules to get from there to surface structure often seemed "wild". Famous example: underlying structure for "Floyd broke the glass" had 8 clauses. [3]

[2] See, for instance, the references to Deep Structure in Leonard Bernstein's 1973 Harvard Norton Lectures, (Bernstein 1976).

[3] What seemed wild then might not now: the shocking number of clauses (7 or 8) in Ross's deep structure for "Floyd broke the glass" does not come close to the number of functional projections that now intervene between various pairs of "familiar" syntactic categories in respected generative analyses such as (Cinque 1999).

- The impact of philosophy and logic on semantics in linguistic work of the 50's and 60's was limited; many linguists knew some first-order logic, aspects of which began to be borrowed into linguists' "semantic representations," and there was gradually increasing awareness of the work of some philosophers of language. Generative semanticists in the late 1960's and early 1970's in particular started giving serious attention to issues of "logical form" in relation to grammar, and to propose ever more abstract underlying representations intended to serve simultaneously as unambiguous semantic representations and as input to the transformational mapping from meaning to surface form (see, for instance, Bach 1968, Fillmore 1968, Lakoff 1968, Karttunen 1969, Lakoff 1971, Lakoff 1972). (But these semantic representations were generally not suggested to be in need of further interpretation, and truth-conditions and entailment relations were never explicitly mentioned as an object of study in the indigenously linguistic traditions that existed before formal semantics came into linguistics in the 1970's.)

- Interpretive semantics (Jackendoff, Chomsky): Keep syntax close to classical transformational grammar, figure out which parts of semantic interpretation should be based on deep structure, which on surface structure, which on something else – a more heterogeneous syntax-semantics relationship.

5. Then Montague suggested a different Garden of Eden.

References: (Partee 1996, Partee 1997, Partee 2005)

Richard Montague (1930-1971) was a logician and philosopher whose seminal works on language (Montague 1970a, 1970b, 1973) founded the theory known after his death as Montague grammar, one of the main starting points for the field of formal semantics.

(12) The Principle of Compositionality:
The meaning of any complex expression is a function of the meanings of its parts and of the way they are syntactically combined.

The Fregean principle of compositionality was central to Montague's theory and remains central in formal semantics. The nature of the elements of both the syntactic and the semantic algebras is open to variation; what is constrained by compositionality is the relation of the semantics to the syntax.

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. 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.

The syntax-semantic interface: Syntax is an algebra of 'forms', semantics is an algebra of 'meanings', and there is a homomorphism mapping the syntactic algebra into the semantic algebra. The crucial structure for syntax is the "derivation tree", showing what parts have been combined at each step, by what syntactic rule.

Note: In principle, a syntactic rule might involve a number of syntactic "operations", e.g. concatenation of NP with VP plus agreement, to form a sentence. The "Yes-no question rule" for English might involve Subject – Aux inversion plus *do*-support. (Subj – Aux inversion might be a "Macro" which English syntax uses in several different "Rules". Subject-Aux inversion would not itself be thought of as a "Rule", and it has no semantic interpretation.)

Montague was not a syntactician. He had some interesting syntactic insights, but he had no independent interest in syntax. For him, syntax was a necessary basis for semantic structure: syntax should provide the relevant "part – whole" structure for compositionality to work.

A natural generalization of Montague's approach was suggested by Emmon Bach (Bach 1979, 1981): think of a grammar as a simultaneous recursive definition of "n-tuples" for larger expressions from the n-tuples for their parts, where the n-tuple consists of a phonetic realization, a phonological representation, a morphological representation, a syntactic representation (maybe more than one), and a semantic interpretation. Bach and Wheeler's "Montague phonology" showed what this would mean in phonology and morphophonemics. This is a very "pretty" view of the architecture: the main challenges it faces are in accounting for "mismatches" between the alignment of structures on different levels.

6. Towards a synthesis of Montague and Chomsky

Example of one major obstacle to integrating MG and TG: what to do about deletion rules. In classical TG, as we saw above, (13a) was derived from a structure something like (13b).

(13) 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.

Recall the consequences of the analysis in (13) for a sentence like that in (14a), whose deep structure should be something like (14b), which would clearly give the wrong meaning.

(14) a. Everyone was eager to win.
b. [$_S$ everyone was eager for [$_S$ everyone Tns win]]

MG-TG resolution suggested in (Partee 1973, Partee 1975a): what we want as "underlying" subject in the embedded sentence was a variable which could get bound[4]; I followed Montague's line and let it be bound by lambda abstraction to make a VP type. (Others who believed in keeping an S type for the infinitive let the variable be bound by the higher quantifier.)

(15) a. [[to win]] = ^λx [win (x)]
b. alternatively: everyone'(λx[x was eager for [x to win]])

In Chomskyan syntax, a corresponding change was eventually made, replacing the ordinary identical NP by the special null element PRO, interpreted as a bound variable. Other syntactic theories, like GPSG, HPSG, and LFG, and 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 the problems of the old Equi-NP Transformation.

- One of the central questions dividing generative semantics and interpretive semantics had been "Do transformations ever change meaning?". The Katz-Postal hypothesis had posited the answer "No", and Chomsky had accepted that answer, tentatively, in Chomsky (1965). But as the generative semanticists took that "No" answer farther, Chomsky and the interpretive semanticists rejected it, and were left without a clear

[4] Thanks to Paul Postal (p.c.) for reminding me that Jim McCawley was undoubtedly one of the first to notice this point and its importance, at least as early as (McCawley 1968).

picture of the nature of the syntax-semantics interface. Montague gave a different *kind* of answer. For him, the syntactic *Rules* which combine parts into larger wholes might involve phrase-structure-like parts and transformation-like parts together. The corresponding semantic rules combine the meanings of the parts in systematic ways to give the meaning of the whole. There could in principle be a transformation that takes just "one part" and changes it into some other form: within Montague grammar, such a rule could change the meaning as long as it changed it systematically: as long as we could describe the meaning of the output as a function of the meaning of the input. So, for example, in principle (probably not in practice), there could be a "negation transformation" that changes an affirmative sentence into its "negative form", and the meaning of the output would just be the negation of the meaning of the input. (In practice, natural language negation is never that simple!)

7. Chomsky's resistance to formal semantics

My earliest work on formal semantics was concerned with how to integrate it with Chomskyan transformational grammar (Partee 1973, 1975a). I was surprised when it turned out that Chomsky was deeply skeptical of formal semantics and of the idea of compositionality in any form. One of the clearest statements of his skepticism, including a strong attack on compositionality, came in his 1974 Linguistic Institute Golden Anniversary lecture (Chomsky 1975), in which I was the commentator on his paper (Partee 1975b). I have never been able to explain his skepticism on a rational basis; it has seemed to me that it was partly a reaction to a perceived attack on the autonomy of semantics, 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. The child learns syntax and semantics simultaneously, with undoubtedly a great deal of "innate knowledge" guiding the acquisition of both. (My metaphor: if syntax were "explanatorily autonomous", it should be just as easy to learn the syntax of a language by exposure to the radio as by immersion in a real culture or by exposure to television. I don't think there are relevant any "experiments in nature" (I hope not!), but I would be willing to place a bet that it is much harder, if not impossible, to learn the syntax of a language without learning semantics simultaneously: choices of analysis in either one affect choices in the other.

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 is now one of the leading programs in formal semantics as well as syntax.

8. GPSG and the possibility of eliminating transformations

One interesting possibility raised in Montague's work, a new idea for generative linguists, was that for sentences (13-14), there doesn't have to be an embedded full sentence in the syntax at all; an embedded VP is enough, and the "identity" between the subject of *be eager* and the subject of *win* can be part of the semantics of predicates like *eager*. Control can be considered a lexical property of verbs. Lexical semantics can include the information that, for instance, X *promises* Y *to leave* entails that X promises Y that X will leave; or that X *tries to win* entails that X acts with the goal of bringing about a state of affairs in which X wins.

Similarly for the relation between active and passive sentences: as (Dowty 1978) argued, all "governed transformations", that is transformations whose conditions of application depend on the presence of a lexical item of an appropriate sort ("transitive verb",

approximately, in the case of passive), could be and arguably should be replaced by lexical rules. That is, instead of a transformation mapping (12a) into the passive (12b):

(16) a. *Archaeologists have discovered a new fossil skeleton.*

b. *A new fossil skeleton has been discovered by archaeologists*.

there should be a lexical rule as in (17):

(17) (simplified): If V is a transitive verb with syntactic frame NP_1 ___ NP_2 and with meaning α, then V+ed is a (passive) verb with syntactic frame NP_2 *be* ___ (*by* NP_1).

- In general: if we have a "real semantics", syntax doesn't have to try to do everything. The division of labor and the nature of the interface become very interesting questions.

One of the methodological principles implicit in transformational grammar, and explicit in some (not all) versions that included the Katz-Postal hypothesis, and carried to extremes in Generative Semantics, was the principle that **sameness of meaning should be reflected in sameness of deep structure.** But with a real semantics, we don't need sameness at any syntactic level, including "LF", to capture sameness of meaning (cf. Thomason 1976).

So when it was noticed that many arguments for "syntactic relatedness" that motivated transformations were in part implicitly semantic, this led to the new possibility of English as a context-free language (Gazdar 1982 and subsequent work in GPSG), and is probably the principal reason for the positive (although partial) correlation between preference for a non-transformational syntax (GPSG, HPSG, versions of categorial grammar, etc.) with work in formal semantics. This preference is far from absolute, however, and especially since the 90's, with Heim and Kratzer among the leaders, many contemporary linguists combine contemporary Chomskyan syntax with formal semantics.

I should mention that even in GPSG and other non-transformational syntactic theories, the problem of quantifier scope remains a difficult one: it is in fact a difficult problem for *every* theory of the syntax-semantics interface. The basic problem is that if one accepts the principle of compositionality, then an ambiguous sentence like (2b) or (18) must have two different syntactic structures, even though there may be no independent syntactic evidence of ambiguity.

(18) Every student read one book.

One could give a whole lecture – probably a whole semester's course – on the different solutions that have been proposed to the problem posed by quantifier scope ambiguity. A nice early comparative paper is (Cooper and Parsons 1976), comparing the way generative semantics, interpretive semantics, and Montague grammar handled quantifier scope ambiguities and binding, and proposing an indexing mechanism that could do the same things without movement of the quantifying NP.

9. "Logical Form" or "LF" in later generative grammar

Generative semantics lost favor for a complex of reasons; but not because of any great success of "interpretive semantics". I am not going to try to discuss this part of linguistic history in any detail, but I will state as my own opinion that much of the semantics that was eventually developed under the label of "Logical Form" in the Chomskyan school (first within the Revised Extended Standard Theory, then in Government and Binding, then in Principles and Parameters) amount to the rediscovery of various ideas from Generative Semantics but "upside down", since LF was not viewed by Chomskyans as a "deep

structure". So where Generative Semantics had "Quantifier Lowering", May (1977) invented "Quantifier Raising".

Chomsky himself has remained quite skeptical of whether "real semantics" belongs in linguistics; he seems to have some respect for it, but he also seems inclined to draw a line at some level such as LF: something which may have a close relation to semantics, but it's still syntactic in form. I'm not an expert on what Chomsky believes about semantics, though.

10. New synthesis: Heim, Kratzer doing formal semantics on (improved) LF

Both Generative Semantics and Logical Form in Chomskyan theories included structures that were hard to make clear semantic sense of. Heim in her dissertation (Heim 1982), and Heim and Kratzer together in their textbook (Heim and Kratzer 1998), made some simple but fundamental changes that made it possible to give a compositional formal semantic interpretation of sentences represented at a suitable level of "Logical Form". The architecture of the syntax-semantics interface on the model of the Heim and Kratzer textbook is that there are syntactic rules that derive a Logical Form for each sentence, and then the compositional semantic interpretation rules operate directly on that structure. To a classical Montague grammarian, the unattractive feature of that approach is that it gives up on being able to compositionally interpret the independently motivated syntactic structure of sentences.

11. Alternative conceptions of syntax and semantics and their interface

There are many theories of syntax, and many theories of semantics, and the interface questions look different for all of them. Jackendoff (2002) suggests a view on which semantic structures and syntactic structures are independently generated, and the interface conditions may be quite complex.

Among the theories which do use or could use a compositional formal semantics, most are non-transformational. Transformational grammars, in spite of the many good things about them and their central role in the development of modern linguistic theory, were never computationally very tractable, nor formally elegant, nor easy to work with for models how we process language word by word. Non-transformational grammars compatible with compositional semantics include GPSG, HSG, and their descendants, several modern versions of Categorial Grammar, Joshi's Tree-Adjoining Grammar, and Bresnan and Kaplan's Lexical Functional Grammar. Such theories particularly popular within the computational linguistics community, where great progress is being made, including much progress in computational formal semantics.

The contemporary architectures that are probably closest to the vision of what Montague's ideas might make possible are various kinds of "Surface Compositionality" (Jacobson 1999, Barker and Jacobson 2007), employing syntactic theories that generate surface structures directly, and interpreting them compositionally. Bittner (2006), who is known for her work on Greenlandic Eskimo, has done a great deal of work on formal semantics and typology, and is another advocate of surface compositionality; her typological work has led her to propose a number of innovations in the basic ontology of the model theory underpinning natural language semantics, as well as a very "dynamic" architecture for the semantics.

Formal semantics is still a relatively young field. It has only a small, but growing, presence in fieldwork and in language typology, and a small but growing presence in psycholinguistics and theories of on-line language processing. But it has already had enough impact to convince linguists that it is important to study syntax and semantics together, and to keep talking to one another as we try to figure out the division of labor between syntax and semantics and the nature of the interface between them.

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