

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

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Abstract: This essay describes and comments on some of the key developments in the history of formal semantics and its relation to syntax, focusing on the period from the beginnings of Chomskyan generative grammar in the 1950's up until the mature period of formal semantics in the 1980's, with only a few remarks about earlier background and later developments. One crucial theme is the challenge of developing a compositional semantic theory, and how that challenge has taken on different forms with respect to different syntactic and semantic theories.

Keywords: syntax-semantics interface, history of semantics, compositionality, formal semantics

1. Introduction

The “syntax-semantics interface” is a relatively young topic in the history of linguistics. In early Western linguistics, there was little syntax and essentially no semantics other than some non-formal lexical semantics. Formal syntax came first, with Zellig Harris’s student Noam Chomsky revolutionizing the field of linguistics with his work on syntax. Chomsky shared the field’s general skepticism about the possibility of semantics as a subject of scientific study, but as semantics began to be developed in the context of generative grammar, the issue of the connection between syntax and semantics came to the fore very quickly and soon became a major area of research. “Formal semantics” arose a little later, with the logician Richard Montague as the key figure in its origins, and linguists, logicians, and philosophers cooperated in its early development. From both the syntactic and the semantic side, the emphasis was on the

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structure of sentences more than on the structure of words, and formal semantics has always been in large part “the semantics of syntax.”

2. Before *Syntactic Structures*

In the 19th century linguistics existed within philology in Europe; in the U.S., it was partly within philology (especially Indo-European historical linguistics) and partly within anthropology, with fieldwork among native languages of the Americas a major focus. 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).

As for semantics, there was a mixture of negative attitudes and neglect in American linguistics in the 20th century. The negative attitudes were influenced by logical positivism and by behaviorism in psychology. The neglect of semantics in early American linguistics was also because of the fieldwork tradition, where one generally had to start with phonetics, then phonology, then morphology, then perhaps a little syntax. Field linguists rarely got as far as semantics, other than in word lists and analyses of certain semantic fields such as kinship terms.

In logic and philosophy, there was a great deal of progress in semantics in the late 19th and early 20th centuries (Frege, Russell, Carnap, Tarski, and others), but that was relatively unknown to most linguists.

So before *Syntactic Structures* (Chomsky 1957) there was no syntax-semantics interface to think about in linguistics, and the logicians’ descriptions of the syntax and semantics of their logical languages had no influence on linguistics.

3. In *Syntactic Structures*

Chomsky has always been ambivalent about semantics as a science and about the relation between syntax and semantics. This is evident in *Syntactic Structures* and also in his earlier-written *The Logical Structure of Linguistic Theory (LSLT)* (Chomsky 1975b). In *LSLT*, Chomsky writes in the first chapter:

I will merely emphasize again that the “legitimacy of semantics” (whatever that might mean) has never, to my knowledge, been challenged, nor has there ever been any question of the importance of incorporating a study of reference, meaning, language use, and related topics within a full theory of language that will deal, in particular, with the highly significant relations between formal structure and semantic interpretation. The appeal to meaning must be clearly distinguished from the study of meaning. The

latter enterprise is unquestionably central to the general theory of language, and a major goal of the *SS-LSLT* approach is to advance it by showing how a sufficiently rich theory of linguistic form can provide **structural descriptions that provide the basis for the fruitful investigation of semantic questions**. [emphasis added - BHP] (Chomsky 1975b:21)

From *Syntactic Structures*:

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 1957:93)

Syntactic Structures concludes with the following paragraph, which nicely illustrates Chomsky's ambivalence:

More generally, it appears that the notion of "understanding a sentence" must be partially analyzed in grammatical terms. To understand a sentence it is necessary (though not, of course, sufficient) to reconstruct its representation on each level, including the transformational level where the kernel sentences underlying a given sentence can be thought of, in a sense, as the 'elementary content elements' out of which this sentence is constructed. In other words, one result of the formal study of grammatical structure is that a syntactic framework is brought to light which can support semantic analysis. Description of meaning can profitably refer to this underlying syntactic framework, although systematic semantic considerations are apparently not helpful in determining it in the first place. The notion of "structural meaning" as opposed to "lexical meaning", however, appears to be quite suspect, and it is questionable that the grammatical devices available in language are used consistently enough so that meaning can be assigned to them directly. Nevertheless, we do find many important correlations, quite naturally, between syntactic structure and meaning; or, to put it differently, we find that grammatical devices are used quite systematically. These correlations could form part of the subject matter for a more general theory of language concerned with syntax and semantics and their points of connection. (Chomsky 1957:107–108)

Much of Chomsky's early emphasis on the "autonomy of syntax" is directed against earlier attempts to base syntax on semantics or reduce much of syntax to semantics, or to give semantic explanations for various syntactic phenomena and restrictions.

We might loosely paraphrase Chomsky's attitude around the time of *Syntactic Structures* thusly: "We don't really understand anything about semantics, which is a

subject not so far amenable to scientific investigation; but semantics is in principle important, and deep structure reveals semantically relevant structure that is obscured in surface structure.”

The importance of deep structure for revealing semantically relevant structure is illustrated in the famous pair “easy to please” vs. “eager to please”, which Chomsky discusses in various works.

- (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)

But sometimes transformations change meaning: Chomsky (1957:100–101) noted that 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 languages 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. Chomsky himself has a long footnote in Chomsky (1965) noting that it is possible that both sentences are ambiguous, with some as yet unexplained factors making different readings preferred for (2a) and (2b). We return to the topic of quantifier scope in Section 10.

4. 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 (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 [visited Moscow]]] \Rightarrow_{T-NEG} [Mary [has not [visited Moscow]]]

b. [Mary [has [visited Moscow]]] \Rightarrow_{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 (later) 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 counterexamples¹.

Then 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 [visited Moscow]]]] \Rightarrow_{T-NEG} [Mary [has not [visited Moscow]]]

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

On this view, Deep Structure would be the input to semantics, and Surface Structure would then be the input to 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

¹ See Partee (2004, 2005, 2011) for more details on this and some of the other issues mentioned in this paper.

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), 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.").

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." I think of that period as the "Garden of Eden" period: roughly the mid-to-late 1960's, before the linguistic wars broke out in full force, a period when 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, Meulen and Wall (1990:556) 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 linguistics² 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 semantics³).

5. Expulsion from the Garden of Eden: The Linguistic 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.

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

³ For more about debates between philosophers and linguists about the nature of semantics, see Partee (2011).

5.1. Katz-Postal Hypothesis in Trouble

A surprising historical accident is that the behavior of quantifiers with respect to transformational rules familiar from *Syntactic Structures* and *Aspects* was not really noticed until the Katz-Postal hypothesis had for most linguists reached the status of a necessary condition on writing rules. I believe that this historical accident was one of the major causes of the “linguistic wars” between Generative Semantics and Interpretive Semantics, which are described in Section 5.2 below. I give below a few examples of derivations that would have been given in the *Aspects* theory, where the examples given typically involved proper names like *John* and *Mary*, not quantifier phrases, as in the (a) and (b) examples. We see that in the corresponding (c) and (d) examples with quantifier phrases, the transformations radically change the meaning (and it may change in different ways with different quantifiers). I suspect that the Katz-Postal hypothesis would never have been suggested if such quantifier examples had been noticed earlier.

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

b. John voted for John.

c. Every man voted for himself. FROM:

d. Every man voted for every man.

(7) a. Mary wanted to win. FROM:

b. Mary wanted Mary to win.

c. Every candidate wanted to win. FROM:

d. Every candidate wanted every candidate to win.

(8) a. 3 is both even and odd. FROM:

b. 3 is even and 3 is odd.

c. No number is both even and odd. FROM:

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

(9) a. The pacifist who fought was inconsistent. FROM:

b. The pacifist fought. The pacifist was inconsistent.

c. All pacifists who fight are inconsistent. FROM:

d. All pacifists fight. All pacifists are inconsistent.

Example (6) shows that the transformational rule of reflexivization (Lees and Klima 1963), which is apparently meaning-preserving with proper names⁴ is not meaning-preserving with quantifier phrases. Example (7) shows the same thing for the transformation of “Equi-NP Deletion” (Rosenbaum 1967), and (8) shows the same thing for “Conjunction Reduction” (Chomsky 1957), where the transformation preserves truth-value (False) for (a) and (b), but not for (c) and (d). As for example (9), there were semantic problems lurking in the earlier derivations of relative clauses even without quantifiers, but these did not come into focus until the post-*Aspects* period.

5.2. The Linguistic Wars

When the problematic relation between classic transformational derivations and semantics came to light, there were two main classes of responses, characterized as Generative Semantics and Interpretive Semantics (Newmeyer 1980; Harris 1993).

The Generative Semantics response (Lakoff, Ross, McCawley, Postal) was to make the deep structures “deeper”, and try to find a semantically sound level of underlying structure. The underlying structures of the Generative semanticists 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”. In one famous example, the underlying structure for “Floyd broke the glass” had 8 clauses.⁵

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, 1971, 1972; McCawley 1968b, 1970; Karttunen 1969). (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

⁴ Actually, phenomena with “sloppy identity anaphora” show that even with proper names, the reflexive transformation preserves only truth value, not meaning (Keenan 1971); the reflexive pronoun is semantically like a “bound variable”, not like a co-referential copy.

⁵ 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).

object of study in the indigenously linguistic traditions that existed before formal semantics came into linguistics in the 1970's.)

Interpretive semantics (Chomsky 1971; Jackendoff 1972) kept syntax close to classical transformational grammar, and worked on figuring out which parts of semantic interpretation should be based on deep structure, which on surface structure, which on something else, allowing for a more heterogeneous syntax-semantics relationship.

6. Then Montague Suggested a Different Garden of Eden

Richard Montague (1930–1971) was a logician and philosopher whose seminal works on language (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.⁶

The Fregean principle of compositionality was central to Montague's theory and remains central in formal semantics.

(10) 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.

Montague developed a theory in his paper "Universal grammar" (Montague 1970b) in which the syntax is an algebra, the semantics is an algebra, and there must be a homomorphism mapping the syntax onto the 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, his last paper, "The proper treatment of quantification in ordinary English" ("PTQ") (Montague 1973) 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.

So what did the syntax-semantics interface look like in Montague's work, in particular in the fragment of English in PTQ? Syntactic rules built up expressions from

⁶ For more on the antecedents to Montague's work within logic and philosophy, see Cocchiarella (1981), Stokhof (2006) and Partee (2011). For more details about Montague's work, see Partee (1996, 2004, 2005) and Partee with Hendriks (1997).

their parts; and for each syntactic rule there was a semantic rule that specified how the meanings of the parts were to be combined to get the meaning of the whole. 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 (See Dowty, Wall and Peters 1981).

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 (1979, 1984): 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, and a semantic interpretation. Bach and Wheeler’s (1981) “Montague phonology” showed what this would mean in phonology and morphophonemics. This is a very “pretty” view of the architecture: the main challenge it faces is to account for “mismatches” between the alignment of structures on different levels.

7. Towards a Synthesis of Montague and Chomsky

Montague’s work was first introduced to linguists by Partee (1973, 1975b) and Thomason (1974). Partee’s goal was to find a way to combine Montague’s semantics (MG) with Chomskyan transformational grammar (TG).

An example of one major obstacle to integrating MG and TG was what to do about deletion rules. In classical TG, as we saw above, (11a) was derived from a structure something like (11b).

(11) 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 (11) for a sentence like that in (12a), whose deep structure “should” classically have been something like (12b), which would clearly give the wrong meaning.

(12) a. Everyone was eager to win.

b. [_s everyone was eager for [_s everyone Tns win]]

The MG-TG resolution suggested in Partee (1973, 1975b): what we want as “underlying” subject in the embedded sentence was a variable which could get bound⁷; 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.)

(13) 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, positing the special null element PRO, interpreted as a bound variable, instead of the earlier “identical NP”. Other syntactic theories, like Generalized Phrase Structure Grammar (GPSG), Head-Driven Phrase Structure Grammar (HPSG), and Lexical-Functional Grammar (LFG), and modern versions of Categorical Grammar (CG)⁸, 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 picture of the nature of the syntax-semantics interface. Montague gave

⁷ 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 (1968a).

⁸ For GPSG, HPSG, LFG, and modern CG, see Gazdar, Klein, Pullum and Sag (1985), Pollard and Sag (1994), Kaplan and Bresnan (1982), and Bach, Oehrle and Wheeler (1987), respectively.

a different *kind* of answer. For him, the syntactic *Rules* which combine parts into larger wholes might compose phrase-structure-like operations and transformation-like operations 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 expression as input 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!)

8. 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, 1975b). 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 1975a), in which I was the commentator on his paper (Partee 1975a). I have never been able to fully explain his skepticism; 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 any relevant “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 Stechow, in 1994, and is now one of the leading programs in formal semantics as well as syntax.

9. GPSG and the Possibility of Eliminating Transformations

One interesting possibility raised in Montague's work, a new idea for generative linguists at the time, was that for sentences (11)–(12), 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 semantic property of verbs (Chierchia 1983). 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 (14a) into the passive (14b):

- (14) 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 (15):

- (15) (simplified): If *V* is a transitive verb with syntactic frame $NP_1 \text{ ___ } NP_2$ and with meaning α , then *V+ed* is a (passive) verb with syntactic frame $NP_2 \text{ be ___ } (\text{ by } NP_1)$, with a meaning which is the "inverse" of α .

In general, once we have a semantics that can do some real work, then syntax doesn't have to try to solve problems that may be semantic in nature. The division of labor and the nature of the interface become very interesting questions.

One of the methodological principles implicit in transformational grammar, 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 implicitly semantic, this led to the renewed interest in the possibility of English as a context-free language first raised by Harman (1963), Gazdar (1982) and subsequent work in GPSG. That 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.

10. Quantifier Scope Ambiguity: A Perennial Problem for the Syntax-Semantics Interface

In both transformational and non-transformational syntactic theories, the problem of quantifier scope ambiguity has remained 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 (16) must have two different syntactic structures, even though there may be no independent syntactic evidence of ambiguity.

(16) Every student read one book.

One can hardly count the number of different solutions that have been proposed to the problem of 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 providing an algorithm for converting among the three different approaches.

Here we give just a thumbnail sketch of six different approaches to quantifier scope ambiguity from the 60’s to the 80’s, before the introduction of choice functions and various non-quantificational analyses of indefinites. There are many more approaches by now.

(i) Generative semantics (McCawley 1970; Lakoff 1971; and others): Underlying structures were proposed that were 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 (See debate in Lakoff 1970; Partee 1970).

(ii) Interpretive semantics (Chomsky 1971; Jackendoff 1972) proposed a separate mechanism for quantifier scope; see Cooper and Parsons (1976) for a reformulation as an indexing mechanism (Cooper and Parsons proved intertranslatibility among approaches i, ii, and iii).

(iii) Montague's Rule-by-rule approach, with a rule of Quantifying In. Different derivational order of quantifying in different quantifiers is automatically interpreted as giving different scopes. Montague generates one "syntactic structure" via distinct derivations; compositionality is homomorphism between syntactic and semantic **derivations**.

(iv) Cooper storage: Cooper (1975) proposed a modified version of compositionality: the semantics should compositionally derive a *set* of interpretations for each syntactic structure. Working up the syntactic tree, when you reach a quantifier phrase, you can 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.) Cooper storage was also used in GPSG.

(v) Quantifier Raising: May's (1977) Quantifier Raising rule is a syntactic rule, roughly the inverse of the Generative Semantics rule of Quantifier Lowering. Quantifier Raising (QR) produces a derived syntactic structure dubbed LF (for "logical form"); that's the syntactic level that gets compositionally interpreted.

(vi) Type-shifting: On Hendriks's (1988) approach, there is no 'movement'; alternative readings are derived via type-shifting of verbs and other functors so as to change relative 'function-argument command' relations.

11. "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 will not discuss this part of linguistic history in any detail (see Newmeyer 1980; Harris 1993), but I will state as my own opinion that some of the semantics that was developed under the label of "Logical Form" or "LF" in the Chomskyan school (first within the Revised Extended Standard Theory, then in Government and Binding, then in Principles and Parameters) amounted to an adaptation or rediscovery of various ideas from Generative Semantics but "upside down": LF was not viewed by Chomskyans as a "deep structure", but as a separate syntactic level derived from Surface 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. Chomsky now seems to find much of the compositional part of formal semantics quite reasonable, but prefers to view it as a kind of syntax. In recent years Chomsky’s deepest skepticism about formal semantics appears to be more centered on issues of reference and on the possibility of grounding lexical meaning in truth-conditions. Those issues, especially the problem of lexical semantics, also remain foundational questions within formal semantics itself.

12. Later 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. The attractive feature is that there is a rather close match between the structure represented by a Montagovian “derivation tree” and the structure of a Heim and Kratzer LF tree.

13. 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 of how we process language word by word. Non-transformational grammars compatible with compositional semantics include GPSG, HPSG, and their descendants, several modern versions of Categorical Grammar, Joshi's Tree-Adjoining Grammar, and Bresnan and Kaplan's Lexical Functional Grammar. Such theories have been particularly popular within the computational linguistics community, where great progress is being made, including much progress in computational formal semantics.

More recently the mathematical linguist Ed Stabler has shown how one can formalize current ("Minimalist") Chomskyan syntax in such a way that it can be made computationally tractable as well (Stabler 2011); that combined with compositional semantics of the sort described by Heim and Kratzer makes that theory more comparable to other more Montagueian theories than I had earlier thought possible.

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.

14. Tectogrammatical Structure

One promising way of bringing different particular theories closer together are approaches that invoke a "tectogrammatical" structure. The distinction between *tectogrammatical* and *phenogrammatical* structure comes from Haskell Curry (1961).

Tectogrammatical structure is analogous to Montague's derivation trees; it reflects how a sentence is built up, abstracting away from language-particular realization. David Dowty (1982) advocated linguistic recognition of the tectogrammatical/phenogrammatical distinction, using a modified version of Montague's analysis trees, eliminating the language-particular expressions at the nodes.

Montague's distinction between syntactic *rules* (such as transitive verb-plus-object combination) and syntactic *operations* (such as concatenation and assignment of accusative case) corresponds to the tecto-/pheno- distinction. Dowty suggested that the *rules*, and hence the tectogrammatical structures, may well be universal. What varies are the morpho-syntactic *operations* that are used in the rules.

Reinhard Muskens (2010) offers a version which gives a core tectogrammatical structure for each sentence, and then with explicit mapping rules maps that common structure homomorphically both onto a morphosyntactic structure (and a terminal string) and a semantic interpretation. This structure in effect shows the common algebraic structure of semantics and syntax for a language, and is compatible with many different theories of what meanings are and of morpho-syntactic structure. As in Montague: syntax is an algebra, semantics is an algebra, and there should be a homomorphism between them. This is the same idea in cleaner and clearer form.

15. Concluding Remarks

Formal semantics is still a relatively young field. It has 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.

In recent decades, which I mostly do not discuss here, work at the syntax-semantics interface has been greatly enriched by the fact that it has become much more common for linguists who want to work on either syntax or semantics to feel some obligation to pay attention to both. Syntax remains formally autonomous on many current approaches, but the goal of compositionality is now a widely shared goal, and it is understood that both syntactic and semantic evidence can be important for finding the best syntactic or semantic analysis of any phenomenon, and essential for figuring out the best division of labor between syntax and semantics and the nature of the interface between them.

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