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THE STRUCTURE OF MEANING

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1 INTRODUCTION

Semantics is the systematic study of meaning in language. As a discipline, it is directed toward the determination of how humans reason with language, and more specifically, discovering the patterns of inference we employ through linguistic expressions.The study of semantics has diverse traditions, and the current literature is quite heterogeneous and divided on approaches to some of the basic issues facing the field (cf. **SEMANTICS**). While most things in the world have meaning to us, they do not carry meaning in the same way as linguistic expressions do. For example, they do not have the properties of being true or false, or ambiguous or contradictory. (See Davis and Gillon [2004] for discussion and development of this argument.) For this and other reasons, this overview essay addresses the question of how linguistic expressions carry meaning and what they denote in the world.

Where syntax determines the constituent structure of a sentence along with the assignment of grammatical and thematic relations, it is the role of semantics to compute the deeper meaning of the resulting expression. For example, the two sentences in (1) differ in their syntactic structures (through their **VOICE**), but they mean essentially the same thing; that is, their propositional content is identical.

(1) a. The child ate a cookie.
b. A cookie was eaten by the child.

Early on, such observations led philosophers and linguists to distinguish meaning from the pure structural form of a sentence (Saussure [1916] 1983; Russell 1905). Semantic theories in linguistics assume that some sort of logical form is computed from the constituent structure associated with a sentence, and it is this meaning representation that allows us to make categorical and truth-conditional judgments, such as the equivalence in meaning of the two sentences in (1).

Another role played by semantics is in the computation of inferences from our utterances, such as entailments, implicatures, and **PRESUPPOSITIONS**. For example, consider the various notions of *entailment*. From the logical form (LF) of the sentence in (2a), semantics enables us to infer (2b) as a legitimate inference.

(2) a. The girl *laughed and sang*.
b. The girl *laughed*.

This is an example of *structural entailment*, because it is the structure itself that allows the inference (i.e., "if someone does both A and B, then someone does A"). This particular rule is essentially the classical inference rule of *conjunction elimination* from propositional logic; that is,

(3) $$\frac{A \wedge B}{A}$$

While this relies on a largely syntactic notion of entailment, semantics should also explain how (4b) is a legitimate inference from (4a).

(4) a. The drought *killed* the crops.
b. The crops *died*.

Such *lexical entailments* involve an inference that is tied directly to the meaning of a word, namely, the verb *kill*; that is, "when something is killed, it dies." Hence, the role of lexical information in the construction of logical forms and the inferences we can compute from our utterances is an important area of linguistics, and one we return to in Section 3.5 below.

There is an important distinction in semantics among **PROPOSITIONS**, **SENTENCES**, and utterances. We can think of an utterance as a **SPEECH-ACT**, situated in time and space, that is, which happens at a particular time and location. A sentence, on the other hand, is a expression that is inherently linguistic, and can be expressed on multiple occasions by multiple utterances. The notion of a proposition is more complex and contentious, but it is that object that is traditionally taken as being true or false, expressed by the sentence when uttered in a specific context.

1.1 Historical Remarks

The study of meaning has occupied philosophers for centuries, beginning at least with Plato's theory of forms and Aristotle's theory of meaning. Locke, Hume, and Reid all pay particular attention to the meanings of words in composition, but not until the late nineteenth century do we see a systematic approach to the study of logical syntax emerge, with the work of Bertrand Russell and Gottlob Frege. Russell and Frege were not interested in language as a linguistic phenomenon, but rather as a medium through which judgments can be formed and expressed. Frege's focus lay in formulating the rules that create meaningful expressions in a compositional manner, while also introducing an important distinction between an expression's *sense* and its *reference* (cf. **SENSE AND REFERENCE**, **REFERENCE AND EXTENSION**). Russell's work on the way in which linguistic expressions denote introduced the problem of **DEFINITE DESCRIPTIONS** and referential failure, and what later came to be recognized as the problem of presupposition (cf. **PRAGMATICS**).

Ferdinand de Saussure ([1916] 1983), working within an emerging structuralist tradition, developed relational techniques for linguistic analysis, which were elaborated into a framework of componential analysis for language meaning. The idea behind componential analysis is the reduction of a word's meaning into its ultimate contrastive elements. These

contrastive elements are structured in a matrix, allowing for dimensional analysis and generalizations to be made about lexical sets occupying the cells in the matrix.

This technique developed into a general framework for linguistic description called *distinctive* ***FEATURE ANALYSIS***. This is essentially the inspiration for J. Katz and J. Fodor's 1963 theory of lexical semantics within transformational grammar. On this theory, usually referred to as *markerese*, a lexical entry in the language consists of grammatical and semantic markers, and a special feature called a *semantic distinguisher*. In the subsequent discussion by U. Weinreich (1972) and many others, this model was demonstrated to be far too impoverished to characterize the compositional mechanisms inherent in language. In the late 1960s and early 1970s, alternative models of word meaning emerged (Fillmore 1968 [**FRAME SEMANTICS**]; Lakoff [1965] 1970 [**GENERATIVE SEMANTICS**]; Gruber 1976; Jackendoff 1972), which respected the relational structure of sentence meaning while encoding the named semantic functions in lexical entries. In D. R. Dowty (1979), a model theoretic interpretation of the decompositional techniques of G. Lakoff, J. D. McCawley, and J. R. Ross was developed.

In the later twentieth century, **MONTAGUE GRAMMAR** (Montague 1973, 1974) was perhaps the most significant development in the formal analysis of linguistic semantics, as it brought together a systematic, logically grounded theory of compositionality, with a model theoretic interpretation. Subsequent work enriched this approach with insights from D. Davidson (1967), H. P. Grice (1969), Saul Kripke ([1972] 1980), David Lewis (1976), and other philosophers of language (cf. Partee 1976; Davidson and Harman 1972).

Recently, the role of lexical-syntactic mapping has become more evident, particularly with the growing concern over projection from lexical semantic form, the problem of verbal alternations and polyvalency, and the phenomenon of polysemy. The work of R. Jackendoff (1983, 1997) on conceptual semantics has come to the fore, as the field of lexical semantics has developed into a more systematic and formal area of study (Pustejovsky and Boguraev 1993; Copestake and Briscoe 1995, 15–67).

Finally, one of the most significant developments in the study of meaning has been the "dynamic turn" in how sentences are interpreted in discourse. Inspired by the work of Irene Heim (1982) and H. Kamp (1981), the formal analysis of discourse has become an active and growing area of research, as seen in the works of Jeroen Groenendijk and Martin Stokhof (1991), Kamp and U. eyle (1993), and Nicholas Asher and Alex Lascarides (2003).

In the remainder of this essay, we examine the basic principle of how meanings are constructed. First, we introduce the notion of compositionality in language. Since words are the building blocks of larger meanings, we explore various approaches to lexical semantics. Then, we focus on how units of meaning are put together compositionally to create propositions. Finally, we examine the meaning of expressions above the level of the sentence, within a discourse.

1.2 Compositionality

Because semantics focuses on how linguistic expressions come to have meaning, one of the most crucial concepts in the field is the notion of *compositionality* (cf. **COMPOSITIONALITY**). As speakers of language, we understand a sentence by understanding its parts and how they are put together. The principle of compositionality characterizes how smaller units of meaning are put together to form larger, more meaningful expressions in language. The most famous formulation of this notion comes from Frege, paraphrased as follows:

> The meaning of an expression is a function of the meanings of its parts and the way they are syntactically combined. (Partee 1984)

This view has been extremely influential in semantics research over the past 40 years. If one assumes a compositional approach to the study of meaning, then two things immediately follow: 1) One must specify the specific meaning of the basic elements of the language, and 2) one must formulate the rules of combination for how these elements go together to make more complex expressions. The first aspect includes determining what words and morphemes mean, that is, *lexical semantics*, which we address in the next section. The second aspect entails defining a calculus for how these elements compose to form larger expressions, that is, *argument selection* and *modification*. Needless to say, in both of these areas, there is much divergence of opinion, but semanticists generally agree on the basic assumptions inherent in compositionality.

2 LEXICAL MEANING

Semantic interpretation requires access to knowledge about words. The lexicon of a grammar must provide a systematic and efficient way of encoding the information associated with words in a language. **LEXICAL SEMANTICS** is the study of what words mean and how these meanings are structured. The lexicon is not merely a collection of words with their semantic forms, but rather a set of structured objects that participate in larger operations and compositions, both enabling syntactic environments and acting as signatures to semantic entailments and implicatures in the context of larger discourse.

There are four basic questions in modeling the semantic content and structure of the lexicon: 1) What semantic information goes into a lexical entry? 2) How do lexical entries relate semantically to one another? 3) How is this information exploited compositionally by the grammar? 4) How is this information available to semantic interpretation generally?

The lexicon and lexical semantics have traditionally been viewed as the most passive modules of language, acting in the service of the more dynamic components of the grammar. This view has its origins in the generative tradition (Chomsky [1955] 1975) and has been an integral part of the notion of the lexicon ever since. While the *Aspects*-model of selectional features (Chomsky 1965) restricted the relation of selection to that between lexical items, work by McCawley (1968) and Jackendoff (1972) showed that selectional restrictions must be available to computations at the level of derived semantic representation rather than at deep structure. Subsequent work by Joan Bresnan (1982), Gerald Gazdar et al. (1985), and C. Pollard and I. Sag (1994) extend the range of phenomena that can be handled by the projection and exploitation of lexically derived information in the grammar.

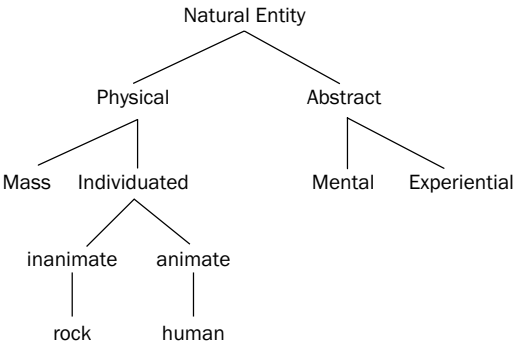

Figure 1.

Recently, with the convergence of several areas in linguistics (lexical semantics, computational lexicons, type theories), several models for the determination of selection have emerged that put even more compostional power in the lexicon, making explicit reference to the paradigmatic systems that allow for grammatical constructions to be partially determined by selection. Examples of this approach are generative lexicon theory (Pustejovsky 1995; Bouillon and Busa 2001), and **CONSTRUCTION GRAMMAR** (Goldberg, 1995; Jackendoff 1997, 2002). These developments have helped to characterize the approaches to lexical design in terms of a hierarchy of semantic expressiveness. There are at least three such classes of lexical description, defined as follows: *sense enumerative lexicons*, where lexical items have a single type and meaning, and *ambiguity* is treated by multiple listings of words; *polymorphic lexicons*, where lexical items are active objects, contributing to the determination of meaning in context, under well-defined constraints; and *unrestricted sense lexicons*, where the meanings of lexical items are determined mostly by context and conventional use. It seems clear that the most promising direction seems to be a careful and formal elucidation of the *polymorphic lexicons*, and this will form the basis of our subsequent discussion.

Lexical items can be systematically grouped according to their syntactic and semantic behavior in the language. For this reason, there have been two major traditions of word clustering, corresponding to this distinction. Broadly speaking, for those concerned mainly with grammatical behavior, the most salient aspect of a lexical item is its *argument structure*; for those focusing on a word's entailment properties, the most important aspect is its *semantic class*. In this section, we examine these two approaches and see how their concerns can be integrated into a common lexical representation.

2.1 Semantic Classes

One of the most common ways to organize lexical knowledge is by means of type or feature inheritance mechanisms (Evans and Gazdar 1990; Carpenter 1992; Copestake and Briscoe 1992; Pollard and Sag 1994). Furthermore, T. Briscoe, V. de Paiva, and A. Copestake (1993) describe a rich system of types for allowing default mechanisms into lexical type descriptions. Similarly, type structures, such as that shown in Figure 1, can express the inheritance of syntactic and semantic features, as well as the relationship between syntactic classes and alternations, among other relations (cf. Pustejovsky and Boguraev 1993).

2.2 Argument Structure

Once the basic semantic types for the lexical items in the language have been specified, their subcategorization and selectional information must be encoded in some form. The argument structure for a word can be seen as the simplest specification of its semantics, indicating the number and type of parameters associated with the lexical item as a predicate. For example, the verb *die* can be represented as a predicate taking one argument, and *kill* as taking two arguments, while the verb *give* takes three arguments.

(5) a. die(x)
b. kill(x,y)
c. give(x,y,z)

What originally began as the simple listing of the parameters or arguments associated with a predicate has developed into a sophisticated view of the way arguments are mapped onto syntactic expressions. E. Williams's (1981) distinction between *external* (the underlined arguments for "kill" and "give") and *internal* arguments and J. Grimshaw's proposal for a hierarchically structured representation (cf. Grimshaw 1990) provide us with the basic syntax for one aspect of a word's meaning. Similar remarks hold for the argument list structure in HPSG (**HEAD-DRIVEN PHRASE STRUCTURE GRAMMAR**) and LFG (**LEXICAL-FUNCTIONAL GRAMMAR**).

One influential way of encoding selectional behavior has been the theory of *thematic relations* (cf. **THEMATIC ROLES**; Gruber 1976; Jackendoff 1972). Thematic relations are now generally defined as partial semantic functions of the event being denoted by the verb or noun, and behave according to a predefined calculus of role relations (e.g., Carlson 1984; Dowty 1991; Chierchia 1989). For example, semantic roles, such as agent, theme, and goal, can be used to partially determine the meaning of a predicate when they are associated with the grammatical arguments to a verb.

(6) a. put<AGENT,THEME,LOCATION>
b. borrow<RECIPIENT,THEME,SOURCE>

Thematic roles can be ordered relative to each other in terms of an implicational hierarchy. For example, there is considerable use of a universal subject hierarchy such as shown in the following (cf. Fillmore 1968; Comrie 1981).

(7) AGENT > RECIPIENT/BENEFACTIVE > THEME/PATIENT > INSTRUMENT > LOCATION

Many linguists have questioned the general explanatory coverage of thematic roles, however, and have chosen alternative methods for capturing the generalizations they promised. Dowty (1991) suggests that "theta-role" generalizations are best captured by entailments associated with the predicate itself. A theta-role can then be seen as the set of predicate entailments that are properties of a particular argument to the verb. Characteristic entailments might be thought of as prototype roles, or proto-roles; this allows for degrees or shades of

meaning associated with the arguments to a predicate. Others have opted for a more semantically neutral set of labels to assign to the parameters of a relation, whether it is realized as a verb, noun, or adjective. For example, the theory of argument structure as developed by Williams (1981), Grimshaw (1990), and others can be seen as a move toward a more minimalist description of semantic differentiation in the verb's list of parameters.

The interaction of a structured argument list and a rich system of types, such as that presented previously, provides a mechanism for semantic selection through inheritance. Consider, for instance the sentence pairs in (8).

(8) a. The man / the rock fell.
b. The man / *the rock died.

Now consider how the selectional distinction for a feature such as animacy is modeled so as to explain the selectional constraints of predicates. For the purpose of illustration, the arguments of a verb will be identified as being typed from the system shown previously.

(9) a. λx:physical[fall($\underline{x}$)]
b. λx:animate[die($\underline{x}$)]

In the sentences in (8), it is clear how rocks can't die and men can, but it is still not obvious how this judgment is computed, given what we would assume are the types associated with the nouns *rock* and *man*, respectively. What accomplishes this computation is a rule of subtyping, Θ, that allows the type associated with the noun *man* (i.e., human) to also be accepted as the type *animate*, which is what the predicate *die* requires of its argument as stated in (9b) (cf. Gunter 1992; Carpenter 1992):

(10) Θ [*human* $\subseteq$ *animate*]: *human* $\rightarrow$ *animate*

The rule applies since the concept *human* is subtyped under *animate* in the type hierarchy. Parallel considerations rule out the noun *rock* as a legitimate argument to *die* since it is not subtyped under animate. Hence, one of the concerns given for the way that syntactic processes can systematically keep track of which *selectional features* are entailed and which are not is partially addressed by such lattice traversal rules as the one presented here.

2.3 Decomposition

The second approach to the aforementioned lexical specification is to define constraints internally to the predicate itself. Traditionally, this has been known as *lexical decomposition*. Since the 1960s, lexical semanticists have attempted to formally model the semantic relations between such lexical items as the adjective *dead* and the verbs *die* and *kill* (cf. Lakoff [1965] 1970; McCawley 1968) in the sentences that follow.

(11) a. John killed Bill.
b. Bill died.
c. Bill is dead.

Assuming that the underlying form for a verb like *kill* directly encodes the stative predicate in (11c) and the relation of causation, generative semanticists posited representations such as (12).

(12) *CAUSE(x, (BECOME(NOT (ALIVE y))))*

Here, the predicate *CAUSE* is represented as a relation between an individual causer *x* and an expression involving a change of state in the argument *y*. R. Carter ([1976] 1988) proposes a representation quite similar, shown here for the causative verb *darken*:

(13) *x CAUSE((y BE.DARK)CHANGE)*

Although there is an intuition that the cause relation involves a causer and an event, neither Lakoff nor Carter makes this commitment explicitly. In fact, it has taken several decades for Davidson's (1967) observations regarding the role of events in the determination of verb meaning to find their way convincingly into the major linguistic frameworks. Recently, a new synthesis has emerged that attempts to model verb meanings as complex predicative structures with rich event structures (cf. Parsons 1990; Pustejovsky 1991b; Tenny 1992; Krifka 1992). This research has developed the idea that the meaning of a verb can be analyzed into a structured representation of the event that the verb designates, and has furthermore contributed to the realization that verbs may have complex, internal event structures. Recent work has converged on the view that complex events are structured into an inner and an outer event, where the outer event is associated with causation and agency and the inner event is associated with telicity (completion) and change of state (cf. Tenny and Pustejovsky 2000; Levin and Rappaport Hovav 2005).

Jackendoff (1990) develops an extensive system of what he calls *Conceptual Representations*, which parallel the syntactic representations of sentences of natural language. These employ a set of canonical predicates, including CAUSE, GO, TO, and ON, and canonical elements, including *Thing*, *Path*, and *Event*. These approaches represent verb meaning by decomposing the predicate into more basic predicates. This work owes obvious debt to the innovative work within generative semantics, as illustrated by McCawley's (1968) analysis of the verb *kill*. Recent versions of lexical representations inspired by generative semantics can be seen in the Lexical Relational Structures of K. Hale and S. J. Keyser (1993), where syntactic tree structures are employed to capture the same elements of causation and change of state as in the representations of Carter, Levin and T. Rapoport, Jackendoff, and Dowty. The work of Levin and Rappaport, building on Jackendoff's Lexical Conceptual Structures, has been influential in further articulating the internal structure of verb meanings (see Levin and Rappaport 1995).

J. Pustejovsky (1991b) extends the decompositional approach presented in Dowty (1979) by explicitly reifying the events and subevents in the predicative expressions. Unlike Dowty's treatment of lexical semantics, where the decompositional calculus builds on propositional or predicative units (as discussed earlier), a "syntax of event structure" makes explicit reference to quantified events as part of the word meaning. Pustejovsky further introduces a tree structure to represent the temporal ordering and dominance constraints on an event and its subevents. For example, a predicate such as *build* is associated with a complex event such as that shown in the following (cf. also Moens and Steedman 1988).

(14) [*transition* [*e*1:PROCESS] [*e*2:STATE]]

The process consists of the building activity itself, while the State represents the result of there being the object built. Grimshaw (1990) adopts this theory in her work on argument structure, where complex events such as *break* are given a similar representation. In such structures, the process consists of what *x* does to cause the breaking, and the state is the resultant state of the broken item. The process corresponds to the outer causing event as discussed earlier, and the state corresponds in part to the inner change of state event. Both Pustejovsky and Grimshaw differ from earlier authors in assuming a specific level of representation for event structure, distinct from the representation of other lexical properties. Furthermore, they follow J. Higginbotham (1989) in adopting an explicit reference to the event place in the verbal semantics. Recently, Levin and Rappaport (2001, 2005) have adopted a large component of the event structure model for their analysis of verb meaning composition.

2.4 Noun Meaning

Thus far, we have focused on the lexical semantics of verb entries. All of the major categories, however, are encoded with syntactic and semantic feature structures that determine their constructional behavior and subsequent meaning at logical form. In Generative Lexicon Theory (Pustejovsky, 1995), it is assumed that word meaning is structured on the basis of four generative factors (**QUALIA ROLES**) that capture how humans understand objects and relations in the world and provide the minimal explanation for the linguistic behavior of lexical items (these are inspired in large part by Moravcsik's (1975, 1990) interpretation of Aristotelian *aitia*). These are: the FORMAL role: the basic category that distinguishes the object within a larger domain; CONSTITUTIVE role: the relation between an object and its constituent parts; the TELIC role: its purpose and function; and the AGENTIVE role: factors involved in the object's origin or "coming into being."

Qualia structure is at the core of the generative properties of the lexicon, since it provides a general strategy for creating new types. For example, consider the properties of nouns such as *rock* and *chair*. These nouns can be distinguished on the basis of semantic criteria that classify them in terms of general categories, such as *natural kind* or *artifact object*. Although very useful, this is not sufficient to discriminate semantic types in a way that also accounts for their grammatical behavior. A crucial distinction between *rock* and *chair* concerns the properties that differentiate *natural kinds* from *artifacts*: Functionality plays a crucial role in the process of individuation of artifacts, but not of natural kinds. This is reflected in grammatical behavior, whereby "a good chair" or "enjoy the chair" are well-formed expressions reflecting the specific purpose for which an artifact is designed, but "good rock" or "enjoy a rock" are semantically ill-formed since for *rock* the functionality (i.e., TELIC) is undefined. Exceptions exist when new concepts are referred to, such as when the object is construed relative to a specific activity, for example, as in "The climber enjoyed that rock"; *rock* itself takes on a new meaning, by virtue of having telicity associated with it, and this is accomplished by integration with the semantics of the subject noun phrase (NP). Although *chair* and *rock* are both physical objects, they differ in their mode of coming into being (i.e., AGENTIVE): Chairs are man-made; rocks develop in nature. Similarly, a concept such as *food* or *cookie* has a physical manifestation or denotation, but also a functional grounding pertaining to the relation of "eating." These apparently contradictory aspects of a category are orthogonally represented by the qualia structure for that concept, which provides a coherent structuring for different dimensions of meaning.

2.5 The Problem of Polysemy

Given the compactness of a lexicon relative to the number of objects and relations in the world, and the concepts we have for them, lexical ambiguity is inevitable. Add to this the cultural, historical, and linguistic blending that contributes to the meanings of our lexical items, and *ambiguity* can appear arbitrary as well. Hence, *homonymy* – where one lexical form has many meanings – is to be expected in a language. Examples of homonyms are illustrated in the following sentences:

(15) a. Mary walked along the bank of the river.
b. She works for the largest bank in the city.

(16) a. The judge asked the defendant to approach the bar.
b. The defendant was in the pub at the bar.

Weinreich (1964) calls such lexical distinctions *contrastive ambiguity*, where it is clear that the senses associated with the lexical item are unrelated. For this reason, it is generally assumed that homonyms are represented as separate lexical entries within the organization of the lexicon. This accords with a view of lexical organization that has been termed a *sense enumeration lexicon* (cf. Pustejovsky 1995). Words with multiple senses are simply listed separately in the lexicon, but this does not seem to compromise or complicate the compositional process of how words combine in the interpretation of a sentence.

This model becomes difficult to maintain, however, when we consider the phenomenon known as *polysemy*. Polysemy is the relationship that exists between different senses of a word that are related in some logical manner, rather than arbitrarily, as in the previous examples. It is illustrated in the following sentences (cf. Apresjan 1973; Pustejovsky 1991a, 1998).

(17) a. Mary carried the book home.
b. Mary doesn't agree with the book.

(18) a. Mary has her lunch in her backpack.
b. Lunch was longer today than it was yesterday.

(19) a. The flight lasted three hours.
b. The flight landed on time in Los Angeles.

Notice that in each of these pairs, the same nominal form is assuming different semantic interpretations relative to its selective context. For example, in (17a), the noun *book* refers to a physical object, while in (17b), it refers to the informational content. In (18a), *lunch* refers to the physical manifestation of the food, while in (18b), it refers to the eating event. Finally, in (19a), *flight* refers to the flying event, while in (19b), it refers to the plane. This phenomenon of regular (or logical) polysemy is one of the most challenging in semantics

and has stimulated much research recently (Bouillon 1997; Bouillon and Busa 2001; Cooper 2006). The determination of what such lexical items denote will of course have consequences for one's theory of compositionality, as we will see in a later section.

3 BUILDING SENTENCE MEANINGS

3.1 Function Application

The principle of compositionality follows the view that syntax is an initial guide to the interpretation process. Hence, there would appear to be a strong relationship between the meaning of a phrase and where it appears in a sentence, as is apparent from grammatical function in the following sentences.

(20) a. The woman loves the child.
b. The child loves the woman.

However, this is not always a reliable association, as seen in languages that have freer word order restrictions, such as German.

(21) a. Die Frau liebt das Kind.
The woman loves the child.
b. Das Kind liebt die Frau.
The child loves the woman.

In German, both word orders are ambiguous, since information about the grammatical case and gender of the two NPs is neutralized.

Although there is often a correlation between the grammatical relation associated with a phrase and the meaning assigned to it, this is not always a reliable association. Subjects are not always "doers" and objects are not always "undergoers" in a sentence. For example, notice how in both (22a) and (22b), the NP *the watch* is playing the same role; that is, it is "undergoing a change," even though it is the subject in one sentence and the object in the other.

(22) a. The boy broke *the watch*.
b. *The watch* broke.

To handle such *verbal alternations* compositionally requires either positing separate lexical entries for each syntactic construction associated with a given verb, or expressing a deeper relation between different verb forms.

For most semantic theories, the basic mechanism of compositionality is assumed to be *function application* of some sort. A rule of *application*, APPLY, acts as the glue to assign (or discharge) the argument role or position to the appropriate candidate phrase in the syntax. Thus, for a simple transitive sentence such as (23a), two applications derive the propositional interpretation of the sentence in (23d).

(23) a. John loves Mary.
b. love(Arg1,Arg2)
c. APPLY love(Arg1,Arg2) to Mary = love(Arg1,Mary)
d. APPLY love(Arg1,Mary) to John = love(John,Mary)

One model used to define the calculus of compositional combinations is the λ-calculus (Barendregt 1984). Using the language of *types*, we can express the rule of APPLY as a property associated with predicates (or functions), and application as a relationship between expressions of specific types in the language.

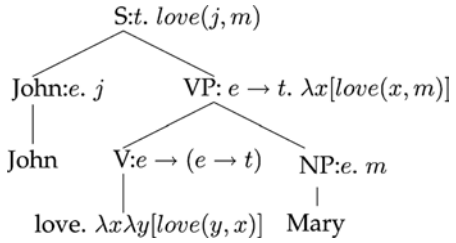

Figure 2.

(24) Function Application:
If α is of type *a*, and β is of type $a \rightarrow b$, then β(α) is of type *b*.

Viewed as typed expressions, the separate linguistic units in (23a) combine as function application, as illustrated in Figure 2.

As one can see, the λ-calculus is an expressive mechanism for modeling the relation between verbs and their arguments interpreted as function application.

One important extension to the type language used here provides a compositional analysis of the semantics of propositional attitude verbs, such as *believe* and *think* (Montague 1973). The sentential complements of such verbs, as is well known, create *opaque contexts* for substitutions under identity. For example, if Lois is unaware of Superman's true identity, then the belief statement in (25b) is false, even though (25a) is true.

(25) a. Lois believes Superman rescued the people.
b. Lois believes Clark Kent rescued the people.

On this view, verbs such as *believe* introduce an **INTENSIONAL** context for the propositional argument, instead of an extensional one. In such a context, substitution under identity is not permitted without possibly affecting the truth value (**TRUTH CONDITIONAL SEMANTICS**). This is an important contribution to the theory of meaning, in that a property of opacity is associated with specific types within a compositional framework.

One potential challenge to a theory of function application is the problem of ambiguity in language. *Syntactic ambiguities* arise because of the ways in which phrases are bracketed in a sentence, while *lexical ambiguity* arises when a word has multiple interpretations in a given context. For example, in the following sentence, the verb *treat* can mean one of two things:

(26) The doctor *treated* the patient well.

Either 1) the patient is undergoing medical care, or 2) the doctor was kind to the patient. More often than not, however, the context of a sentence will eliminate such ambiguities, as shown in (27).

(27) a. The doctor *treated* the patient with antibiotics. (Sense 1)
b. The doctor *treated* the patient with care. (Sense 2)

In this case, the interpretation is constructed from the appropriate meaning of the verb and how it combines with its arguments.

3.2 Quantifiers and Scope

Another type of ambiguity, one that is not associated with the constituent structure of the sentence or lexical senses in any obvious way, involves *quantified noun phrases* (e.g., *every cookie*, *some cake*, and *most pies*). It is interesting that when a sentence has more than one of these phrases, one often sees more than one interpretation possible because of the ways the quantified NPs relate to each other. This is not the case in the following sentence, however, where there is only one interpretation as to what happened with the cookie.

(28) Some student ate a cookie.

Now consider the sentences in (29), where there is a combination of a *some*-NP and an *every*-NP.

(29) a. Every student saw a movie.
b. Every cookie was eaten by a student.

The sentence in (29a) can mean one of two things: 1) that there was one movie, for example, *Star Wars*, that every student saw; or 2) that everyone saw a movie, but it didn't have to be the same one. Similarly, for (29b), there could be one student who ate all the cookies, or each cookie that was eaten by a different student. This kind of quantifier scope ambiguity has to be resolved in order to determine what kind of inferences one can make from a sentence. Syntax and semantics must interact to resolve this kind of ambiguity, and it is the theory of sentence meaning that defines this interaction (cf. **QUANTIFICATION**).

One of the roles of semantic theory is to correctly derive the entailment relations associated with a sentence's logical form, since this has an obvious impact on the valid reasoning patterns in the language. How these interpretations are computed has been an area of intense research, and one of the most influential approaches has been the theory of generalized quantifiers (cf. Barwise and Cooper 1981). On this approach, the denotation of an NP is treated as a *set of sets of individuals*, and a sentence structure such as [NP VP] is true if and only if the denotation of the VP is a member of the family of sets denoted by the NP. That is, the sentence in (30) is true if and only if *singing* (the denotation of the VP) is a member of the set of properties denoted by *every woman*.

(30) Every woman sang.

On this view, quantifiers such as *most*, *every*, *some*, and so on are actually second-order relations between predicates, and it is partly this property that allows for the compositional interpretation of quantifier scope variation seen previously. The intended interpretation of (30) is (31b), where the subject NP *every woman* is interpreted as a function, taking the VP as its argument.

(31) a. $\forall\lambda P\, x[woman(x) \rightarrow P(x)](sang)$
b. $\forall x[woman(x) \rightarrow sang(x)]$

When combined with another quantified expression, as in (32a), the relational interpretation of the generalized quantifiers is crucial for being able to determine both scope interpretations shown in (32).

(32) a. Every woman sang a song.
b. $\forall x \exists y[woman(x) \rightarrow [song(y)\ \&\ sang(x, y)]]$
c. $\exists y \forall x[[song(y)\ \&\ woman(x)] \rightarrow sang(x, y)]]$

An alternative treatment for handling such cases is to posit a rule of quantifier raising, where the scope ambiguity is reduced to a difference in syntactic structures associated with each interpretation (May 1985).

3.3 Semantic Modification

In constructing the meaning of expressions, a semantic theory must also account for how the attribution of properties to an entity is computed, what is known as the problem of modification. The simplest type of modification one can imagine is *intersective attribution*. Notice that in the phrases in (33), the object denoted correctly has both properties expressed in the NP:

(33) a. black coffee $\lambda x[black(x)\ \&\ coffee(x)]$
b. Italian singer $\lambda x[Italian(x)\ \&\ singer(x)]$
c. metal cup $\lambda x[metal(x)\ \&\ cup(x)]$

There are two general solutions to computing the meaning of such expressions: a) Let adjectives be functions over common noun denotations, or b) let adjectives be normal predicates, and have a semantic rule associated with the syntax of modification.

Computing the proper inferences for relative clauses will involve a similar strategy, since they are a sort of intersective modification. That is, for the relative clause in (34), the desired logical form will include an intersection of the head noun and the relation predicated in the subordinated clause.

(34) a. writer who John knows
b. $\lambda x[writer(x)\ \&\ know(j, x)]$

Unfortunately, however, most instances of adjectival modification do not work so straightforwardly, as illustrated in (35). Adjectives such as *good*, *dangerous*, and *fast* modify polysemously in the following sentences.

(35) a. John is a *a good teacher.*
b. *A good meal* is what we need now.
c. Mary took *a good umbrella* with her into the rain.

In each of these sentences, *good* is a manner modifier whose interpretation is dependent on the noun it modifies; in (35a), it means "to teach well"; in (35b), it means a "tasty meal"; and in (35c), it means "something keeping you dry." Similar remarks hold for the adjective *dangerous*.

(36) a. This is *a dangerous road* at night.
b. She used *a dangerous knife* for the turkey.

That is, the road is dangerous in (36a) when "one drives on it," and the knife is dangerous in (36b) when "one cuts with it." Finally, the adjective *fast* in the following sentences acts as though it is an adverb, modifying an activity implicit in the noun, that is, *programming* in (37a) and *driving* in (37b).

(37) a. Mary is *the fastest programmer* we have on staff.
b. The turnpike is *a faster road* than Main Street.

To account for such cases, it is necessary to enrich the mode of composition beyond simple property intersection, to accommodate the context dependency of the interpretation. Analyses taking this approach include Borschev and Partee (2001), Bouillon (1997), and Pustejovsky (1995).

3.4 Arguments versus Adjuncts

In our discussion thus far of how predicates select arguments to create compositionally complex expressions, we have assumed that the matrix predicate (the main verb of the sentence) acts as the only function over other phrases. In fact, what an argument of the verb is and what an adjunct is are questions just as much of meaning as of syntax. In this section, we examine the semantic issues involved.

In this overview, we have adopted the position that language reflects the workings of our deeper conceptual systems in some direct and nonidiosyncratic manner. Lexical choice as well as specific grammatical phenomena can be constrained by underlying conceptual bias. Well-known examples of this transparency include count/mass noun distinctions in the lexicon, and case marking and valence distinctions in the syntax. For example, concepts entailing unindividuated *stuff* or material will systematically be semantically typed as mass nouns in the grammar, whereas naturally individuating (countable) substances will assume the status of count nouns, with their respective grammatical consequences, as illustrated in (38). (Some mass terms are not shared by all languages, such as the concept of "paper" or "furniture.")

(38) a. {not much/all/lots of} *gold/water/dirt/sand*
b. {every/two/several} *chairs/girls/beaches*

Similarly, as presented in previous sections, the classification of verbs appears to reflect their underlying relational structure in fairly obvious ways.

(39) a. Mary *arrived*.
b. John *greeted* Mary.
c. Mary *gave* a book to John.

That is, the argument structure of each verb encodes the semantics of the underlying concept, which in turn is reflected in the projection to the specific syntactic constructions, that is, as intransitive, transitive, and ditransitive constructions, respectively. For unary, binary, and ternary predicates, there is a visible or transparent projection to syntax from the underlying conceptual structure, as well as a predictable compositional derivation as function application.

So, the question arises as to what we do with nonselected arguments and adjuncts within the sentence. It is well known, for example, that arguments not selected by the predicate appear in certain contexts (cf. Jackendoff 1992; Levin and Rappaport Hovav 2005).

(40) a. The man laughed *himself* sick.
b. The girl danced *her way* to fame.
c. Mary nailed the window *shut*.

Each of the italicized phrases is an argument of something, but is it selected by the matrix predicate? Jackendoff has proposed a solution that relies on the notion of construction, as introduced by A. E. Goldberg (1995) (cf. **CONSTRUCTION GRAMMARS**).

Another problem in compositionality emerges from the interpretation of adjuncts. The question posed by the examples in (41) is this: Which NPs are arguments semantically and which are merely adjuncts?

(41) a. Mary ate the soup.
b. Mary ate the soup with a spoon.
c. Mary ate the soup with a spoon in the kitchen.
d. Mary ate the soup with a spoon in the kitchen at 3:00 P.M.

For Davidson (1967), there is no semantic distinction between arguments and adjuncts in the logical form. Under his proposal, a two-place predicate such as *eat* contains an additional argument, the event variable, *e*, which allows each event participant a specific role in the interpretation (cf. Parsons 1990; **EVENT STRUCTURE AND GRAMMAR**).

(42) $\lambda y \lambda x \lambda e$[eat($e$, x, y)]

Then, any additional adjunct information (such as locations, instruments, etc.) is added by conjunction to the meaning of the main predicate, in a fashion similar to the interpretation of intersective modification over a noun. In this manner, Davidson is able to capture the appropriate entailments between propositions involving action and event expressions through conventional mechanisms of logical entailment. For example, to capture the entailments between (41b–d) and (41a) in the following, each more specifically described event entails the one above it by virtue of *conjunction elimination* (already encountered) on the expression.

(43) a. $\exists e$[eat(e, m, the-soup)]
b. $\exists e$[eat(e, m, the-soup) & *with*(e, a spoon)]
c. $\exists e$[eat(e, m, the-soup) & *with*(e, a spoon) & *in*(e, the kitchen)]
d. $\exists e$[eat(e, m, the-soup) & *with*(e, a spoon) & *in*(e, the kitchen) & *at*(e, 3:00 P.M.)]

This approach has the advantage that no special inference mechanisms are needed to derive the entailment relations between the core propositional content in (43a) and forms modified through adjunction. This solution, however, does not extend to cases of verbs with argument alternations that result in different meanings. For example, how do we determine what the core arguments are for a verb like *sweep*?

(44) a. John *swept*.
b. John *swept* the floor.
c. John *swept* the dirt.
d. John *swept* the dirt off the sidewalk.
e. John *swept* the floor clean.
f. John *swept* the dirt into a pile.

The semantics of such a verb should determine what its arguments are, and how the different possible syntactic realizations relate to each other semantically. These cases pose an interest-

ing challenge for the theory of compositionality (cf. Jackendoff 2002).

3.5 Presupposition

In computing the meaning of a sentence, we have focused on that semantic content that is asserted by the proposition. This is in contrast to what is *presupposed*. A presupposition is that propositional meaning that must be true for the sentence containing it to have a proper semantic value (Stalnaker 1970; Karttunen 1974; Potts 2005). (Stalnaker makes the distinction between what a speaker says and what a speaker presupposes.)

Such knowledge can be associated with a word, a grammatical feature, or a syntactic construction (so-called *presupposition triggers*). For example, in (45) and (46), the complement proposition to each verb is assumed to be true, regardless of the polarity assigned to the matrix predicate.

(45) a. Mary realized that she was lost.
b. Mary didn't realize that she was lost.

(46) a. John knows that Mary is sick.
b. John doesn't know that Mary is sick.

There are similar presuppositions associated with aspectual predicates, such as *stop* and *finish*, as seen in (47).

(47) a. Fred stopped smoking.
b. John finished painting his house.

In these constructions, the complement proposition is assumed to have been true before the assertion of the sentence.

Such *conventional presuppositions* are also triggered by interrogative contexts, such as seen in (48).

(48) a. Why did you go the store?
b. When did you see Mary?

As with all presuppositions, however, they are defeasible, as the answer to (48b) in (49) illustrates.

(49) But I didn't see Mary.

Conversational presuppositions, on the other hand, are implicated propositions by virtue of a context and discourse situation. The response in (50b) conversationally implicates that I am not hungry (Recanati 2002); **CONVERSATIONAL IMPLICATURE**).

(50) a. Are you hungry?
b. I've had a very large breakfast.

The meaning of such implicatures is not part of the asserted content of the proposition, but computed within a conversational context in a discourse. We will return to this topic in a later section.

3.6 Noncompositionality

While semantic theory seems to conform to the principles of compositionality in most cases, there are many constructions that do not fit into the conventional function application paradigm. A phrase is noncompositional if its meaning cannot be predicted from the meaning of its parts. We have already encountered modification constructions that do not conform to simple intersective interpretations, for example, *good teacher*. There are two other constructions that pose a problem for the principle of compostionality in semantics:

(51) a. Idioms: *hear it through the grapevine*, *kick the bucket*;
b. Coercions: *begin the book*, *enjoy a coffee*.

The meaning of an idiom such as *leave well enough alone* is in no transparent way composed of the meanings of its parts. Although there are many interesting syntactic properties and constraints on the use of idiomatic expressions in languages, from a semantic point of view its meaning is clearly associated with the entire phrase. Hence, the logical form for (52),

(52) Every person kicked the bucket.

will make reference to quantification over "persons," but not over "buckets" (cf. [53]).

(53) $\exists x[person(x) \& kick.the.bucket(x)]$

We confront another kind of noncompositionality in semantics when predicates seem to appear with arguments of the "wrong type." For example, in (54a), a countable individual entity is being "coerced" into the food associated with that animal, namely, bits of chicken, while in (54b), the mass terms *water* and *beer* are being packaged into unit measures (Pelletier, 1975). In (55), the aspectual verbs normally select for an event, but here are coercing entities into event denotations. Similarly, in (56), both object NPs are being coerced into propositional interpretations. (Cf. Pustejovsky 1995 and Jackendoff 2002 for discussions of coercion phenomena and their treatment.)

(54) a. There's chicken in the salad.
b. We'll have a water and two beers.

(55) a. Roser finished her thesis.
b. Mary began the novel.

(56) a. Mary believes John's story.
b. Mary believes John.

These examples illustrate that semantics must accommodate specific type-shifting and coercing operations in the language in order to remain compositional. In order to explain just such cases, Pustejovsky (2007) presents a general theory of composition that distinguishes between four distinct modes of argument selection: a) function application, b) accommodation, c) coercion by introduction, and d) coercion by exploitation.

4 DISCOURSE STRUCTURE

Thus far we have been concentrating on the meaning of single sentences. But no sentence is really ever uttered outside of a context. Language is used as a means of communication and is as much a way of acting as a means of representing (Austin 1975; Searle 1969). In this section, we briefly survey the major areas of research in discourse semantics. We begin by examining the semantic models that have emerged to account for "dynamic phenomena" in discourse, such as intersentential

anaphora. We then look at how discourse relations can be used to model larger units of meaning.

From our previous discussion, we have assumed the sentence as the unit for semantic interpretation, including the level for the interpretation of quantifier scope and anaphoric binding, as in (57).

(57) a. Every actress said she was happy.
b. Every actress came in and said hello.

Notice that the anaphoric link between the quantifier and the pronoun in (57a) is acceptable, while such a binding is not possible within a larger discourse setting, as in (58) and (59).

(58) a. Every actress came in.
b. *She said she was happy.

(59) a. Every actress came in.
b. *She said hello.

So, in a larger unit of semantic analysis, a bound variable interpretation of the pronoun does not seem permitted.

Now notice that indefinites do in fact allow binding across the level of the sentence.

(60) a. An actress came in.
b. She said hello.

The desired interpretation, however, is one that the semantic model we have sketched out is unable to provide.

(61) a. $\exists x[actress(x) \,\&\, come.in(x)]$
b. $[\&\, say.hello(x)]$

What this example points out is that the view of meaning we have been working with so far is too static to account for phenomena that are inherently dynamic in nature (Chierchia 1995; Groenendijk and Stokhof 1991; Karttunen 1976). In this example, the indefinite NP "an actress" is being used as a discourse referent, and is available for subsequent reference as the story unfolds in the discourse.

Following Kamp and Reyle's (1993) view, an indefinite NP introduces a "novel discourse referent," while a pronoun or definite description says something about an existing discourse referent. Using the two notions of *novelty* and *familiarity*, we can explain why *she* in (60b) is able to bind to the indefinite; namely, *she* looks for an accessible discourse referent, the indefinite. The reason that (58) and (59) are not good discourses is due to the universally quantified NP "every actress," which is inaccessible as an antecedent to the pronoun.

One influential formalization of this approach is Dynamic Predicate Logic (Groenendijk and Stokhof, 1991), which combines conventional interpretations of indefinites as existentials with the insight from incremental interpretations, mentioned previously. On this view, the interpretation of a sentence is a function of an ordered pair of assignments, rather than a static single assignment. The "output condition" for a sentence with an indefinite NP, such as (60a), specifies that a subsequent sentence with a pronoun can share that variable assignment: "The meaning of a sentence lies in the way it changes the representation of the information of the interpreter" (ibid.). That is, when a quantified expression is used in discourse, something new is added to the listener's interpretation state so that the listener can use the quantifier to help understand future utterances. In this way, the meaning of a sentence is interpreted dynamically.

The dynamics of discourse, of course, involve more than the binding of anaphors to antecedents across adjacent sentences. Every utterance is made in the context of a common ground of shared knowledge (presuppositions), with a communicative intent, and in a particular time and place (cf. **DISCOURSE ANALYSIS**, **COMMUNICATIVE INTENTION**). Just as sentences have internal structure, with both syntactic and semantic dependencies, discourse can also be viewed as a sequence of structured segments, with named dependencies between them. For example, the sentences in (62) form a discourse structured by a relation of *narration*, implying temporal sequence (Dowty, 1986).

(62) a. John entered the room.
b. He sat down.

In (63), on the other hand, the two sentences are related by the dependency of *explanation*, where (63b) temporally precedes and explains (63a).

(63) a. Max fell.
b. John pushed him.

Theories of discourse relations, such as rhetorical structure theory (Mann and Thompson 1986), segmented discourse representation theory (SDRT) (Asher and Lascarides 3), and that of Hobbs (1985) attempt to model the rhetorical functions of the utterances in the discourse (hence, they are more expressive of discourse structure and speaker intent than discourse representation theory [DRT], which does not model such parameters). For the simple discourses above, SDRT, for example extends the approach from dynamic semantics with rhetorical relations and their semantic values, while providing a more complex process of discourse updates. Rhetorical relations, as used in SDRT, carry specific types of **ILLOCUTIONARY** force (cf. Austin 1975; Searle 1969, 9), namely, explanation, elaboration, giving backgrounds, and describing results.

5 CONCLUSION

In this essay, I have attempted to outline the basic components for a theory of linguistic meaning. Many areas of semantics were not touched on in this overview, such as issues relating to the philosophy of language and mind and the psychological consequences of various semantic positions. Many of the accompanying entries herein, however, address these issues directly.

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