Appears in Folia Linguistica, 1998

The Semantics of Lexical Underspecification

James Pustejovsky

Computer Science Department
258 Volen Center for Complex Systems
Brandeis University
Waltham, MA 02254 USA
jamesp@cs.brandeis.edu

Abstract

In this paper, I examine the mechanisms responsible for enabling underspecified lexical forms to acquire a determinate and unique interpretation in the composition of the sentence. In particular, I study the behavior of several classes of lexical items exhibiting degrees of systematic or logical polysemy. These words present an interesting challenge to conventional treatments of polysemy and full specification in natural language semantics. Extending the analysis of these classes presented in Pustejovsky (1994,1995), I elaborate the formal mechanisms responisible for capturing the syntactic and semantic behavior of nouns such as *lecture*, *prize*, *book*, and *lunch*, and verbs such as *read*, *rent*, and *break*. I argue that members of these classes must be represented as *complex types*, as they do not allow for simple conjunctive typing; furthermore, these nouns and verbs display a peculiar behavior regarding the quantificational force of the type which is absent from other nominal and verbal classes. I conclude by discussing the consequences of this analysis for a theory of semantic underspecification.

1 Introduction

There has recently been a surge of interest in the problem of how best to represent multiple interpretations of a sentence in a single and compact logical form, as seen, for example, in the works of Reyle (1993), Pinkal (1995), Poesio (1996), and others (cf. van Deemter and Peters, 1996). What distinguishes this work from other strategies for the representation of logical form is the desire to systematically capture the multiple readings inherent in the combinatorics of a given syntactic structure. These theories of underspecification have forced on semantic theory a new approach to how truth is computed in a model.

Coming from another tradition and a generally different set of concerns, there has emerged a movement toward lexical semantic theories in which underspecified representations are crucially part of the compositional process itself, where further specification of meaning comes from context. Examples of this approach, which quite generally can be classified as "generative models of the lexicon" are Pustejovsky (1995), Busa (1996), Copestake and Briscoe (1995), and Dölling (1992). Here the concern is with accounting for classic problems in polyvalency and polysemy, while avoiding a model of lexical semantics that simply enumerates all possible sense extensions.

To begin our discussion, I will distinguish three types of underspecification, described roughly as given below.

A. *Weak Structural Underspecification*: Underspefication of an interpretation that comes about through composition in the sentence.

B. *Weak Lexical Underspecification*: Underspecification due to accidental ambiguity of a lexical sign.

C. *Strong Lexical Underspecification*: Underspecification is present initially in a representation and is resolved through compositionality.

For the most part, the work on providing a logical form that allows for multiple interpretations of a sentence can be grouped into the first category above. This includes any sentence which becomes ambiguous by virtue of composition, e.g., the presence of multiple quantifiers or of a Prepositional Phrase admitting of several attachment possibilities. I will have little to say about this area for the present. Category B includes accidental lexical ambiguity (i.e., homonymy) and is also of little interest to our discussion (but cf. Hirst, 1987, Pustejovsky, 1995). I will focus on the nature of category C above, what I have termed strong lexical underspecification.

Following a general discussion in Pustejovsky (1997), we can classify the set of lexically underspecified items according to four basic phenomena, as listed below:

- Deep Semantic Typing: Single argument polymorphism;

- Syntactic Alternations: Multiple argument polymorphism;
- Terms of Generalization: light verbs and general predicates;
- Complex Typing: objects which are contextually specified.

Deep semantic typing relates to two distinct aspects of underspecification. One is in the expression of a semantic type as distinct syntactic forms, i.e., multiple complement types. The other aspect is how the interpretation of "missing information" is arrived at.

(1) a. Mary began to read the novel.
    b. Mary began reading the novel.
    c. Mary began the novel.

(2) a. Mary enjoyed her cigarette.
    b. John enjoys his coffee in the morning.
    c. Bill enjoyed the movie.

The way that one enjoys a movie is different from the way a coffee is enjoyed. Similarly, for a cigarette. These two phenomena are generally referred to now as "type coercions", where a particular interpretation of what sorts of things are "begun" or how something is "enjoyed" is coerced from the context.

Another kind of deep semantic typing can be observed in the way that adjectival modification operates with evaluative adjectives such as *good* and *dangerous*, as in the noun phrases below.

(3) a. a good book
    b. a good meal
    c. a good knife

(4) a. a dangerous car
    b. a dangerous trail

As discussed extensively in Pustejovsky (1995), the different interpretations of these adjectives when modifying different head nouns is easily explained within a generative model of lexical information. In these constructions, the adjective can be analyzed as an event modifier which subselects for a relational interpretation available in the head noun (cf. Bouillon, 1997, for further extensions of this approach).

All the cases of underspecification examined above deal with what I shall term "single argument polymorphism." The phenomena of *syntactic alternations* (diathesis), once studied as data for movement transformations and now used as diagnostics for verb classifications, can be viewed as a type of polymorphism over several logical parameters, what could be called "multiple argument polymorphisms". Consider, for example, the sentences below.

(5) a. The window opened suddenly.
b. Mary opened the window suddenly.

(6) a. Bill began his lecture late.
b. The class began on time.

(7) a. Mary risked death to save her son.

b. Mary risked her life to save her son.

The verb in each example above behaves polymorphically, appearing in multiple syntactic contexts and exhibiting a regular verbal alternation (cf. Levin, 1993). In order to capture the underlying semantic similarities for these pairs, it is possible to treat these verbs as underspecified, through a systematic underspecification of the verb's type, and how this type is associated with syntactic projections (cf. Pustejovsky, 1995, for discussion of this approach).

Another kind of underspecification is seen in the syntactic and semantic behavior of light verbs, as illustrated in the sentences in (8) and (9)

(8) a. Zac did not have a bath tonight.

b. Sophie has had dinner already.

c. John had an exam (to give/take) last night.

(9) a. Jane gave an interesting talk yesterday.

b. John gave me his cold.

c. John gave an exam last night.

The typical strategy for such cases is to lexically mark these verbs as lacking thematic role assigning properties or specified with an unmarked role (cf. Grimshaw and Mester, 1988, and Rosen, 1989). In fact, most verbs display some degree of flexibility of interpretation relative to the complement(s) selected. For example, functionally dependent verbs such as *open* appear with a range of interpretations exhibiting some of the underspecified nature of light verb predication (cf. (10) .

(10) a. Mary opened the printing program.

b. The rangers have opened the trail for the summer.

c. John opened the door for the guests.

Prepositions, of course, also allow this type of flexible interpretation, as seen in (11).

(11) a. The books are sitting in the box.

b. The coffee is in the cup.

c. The article is in today's paper.

It is tempting to view these diverse phenomena as actually aspects of a common operation. Such a unification is not possible, however, if some verbs are lexically specified as lacking semantic content for certain arguments, such as *have* and *give*, while other verbs seem to merely "modulate" their meaning in different contexts, such as *open* and *close*. In Pustejovsky (1997), I argue that the operation of *co-composition* enables us to analyze all verbs and prepositions as 'light' to a certain extent.

One final type of underspecification that I wish to discuss also involves a contextual specification of meaning, namely the cases of logical polysemy shown in (12) and (13).

(12) a. Mary doesn't believe the book.

b. John bought his books from Mary.

c. Mary bought an interesting book

(13) a. John wrote the exam last night in under 10 minutes.

b. The exam lasted more than three hours this morning.

Depending on the context, *book* is interpreted as something that can be believed (cf. (12a), bought (cf. (12b), or both (cf. (12c)). Similar remarks hold for the sentences in (13) for the noun *exam*. Because of these apparent contradictory selectional environments, this class of nouns has been called *complex types* (cf. Pustejovsky, 1995).

Most of the cases of lexical underspecification discussed above involve either a type of *closed-world* selection over a sortal array of choices (as with the cases of syntactic alternations) or an *open-world* selection over an unbounded range of interpretations (as with light verbs and functionally dependent verbs). Although each of these classes is worthy of further study (cf. Pustejovsky, 1998b), in this paper I would like to focus my attention on the class of complex types in order to show that the source of strong lexical underspecification is to be found in the complexity of the underlying types for these lexical items. In order to do so, I will need to develop the tools necessary for allowing the semantics of such underspecified forms to be contextually determined in the compositional process.

2 Simple and Complex Meanings

Over the past several years, there has been a resurgence of interest in questions relating to the "messiness" of word meaning. Inspired by a few early researchers who admitted of the complexity of sense determination and the fixing of reference (cf. Weinreich, 1972, Nunberg, 1979, Fauconnier, 1985, and Kayser, 1988), much of the work in semantics and computational linguistics is now expressly concerned with the representation and processing of polysemous lexical items and phrases.

I believe the reasons for this resurgence are two-fold. First, there is now an appreciation of the fact that systematic or logical polysemy is formally related to the problem of semantic selection and polyvalency, making the treatment of polysemy much more relevant to theoretical work on issues of syntactic form and polymorphic behavior. Second, formal mechanisms are now available for the analysis of these constructions, which allow them to be viewed as an integral component of the lexicon and the semantics, as opposed to off-line, non-compositional processes of sense extension or metaphorical interpretation.

In the discussion below, I will examine the syntactic and semantic behavior of several nominal types which have polysemous behavior. In particular, I will study one class of nominals which has been particularly difficult to model formally, namely, nouns such as *lecture*, *prize*, *book*, and *lunch*. Members of this class, I argue, must be represented as *complex types* rather than simple or *unified types*, as they do not allow for simple conjunctive typing. This class leads us to a consideration of verb classes which are themselves complex in nature. I provide an analysis of these concepts in terms of Cartesian types and explore their semantics in terms of operations within a relational algebra. Finally, I show how these nouns and verbs display some peculiar properties regarding quantification, which are absent from other nominal and verbal classes. I elaborate on the formal properties of these nouns outlined in Pustejovsky (1995), and explore the consequences of this analysis for discourse anaphora and general issues of reference.

Let us turn now to the behavior of logically polysemous nominals, in order to appreciate why they are intuitively interesting and formally problematic for conventional semantic treatments. The general characterization of some of these nouns has been widely studied (Apresjan, 1973, Ostler and Atkins, 1992, and Pustejovsky, 1991), and I will present only those data relevant to the present discussion. To begin, consider the semantic distinction underlying our conceptions of *food* and *lunch*. How are these nouns distinguished semantically? We obviously understand the concept of food as something paraphrasable by dictionary definitions such as "edible substance or material." What is food for one creature, of course, might be poison for another, giving the concept a slightly relational interpretation, but by no means formally establishing it as a relational noun, such as *brother* or *father*. All that seems to be required to minimally capture the meaning of the noun *food* is some characterization of the relation

between the property of "substance" and that of "edible", relative to a class of certain individuals, e.g., humans. Our conception of *lunch*, however, seems more complex, since it makes reference to a specific period or event in the day as well. Unlike with *food*, it may refer to either the substance or event. For *food*, one might simply conjoin or unify these properties to give a specific intersective property of "edible substance." This assumes that modally subordinating properties such as "edible" have no internal structure, a tenable position only if one is willing to make liberal use of meaning postulates as off-line inferences in the compositional process of interpreting sentence meanings.

Unified Types

Contrary to the rather cavalier approach to representation briefly suggested above, I will assume a mechanism employing significantly more machinery for representing the analytic knowledge associated with words. On this view, the modal subordination of the predicate indicating the use of the substance is given an explicit representation, distinct from the material aspect of *food*. This is accomplished in the following manner. Assume that for a concept such as *food*, we can separate the characteristic property from the functional aspect. Let us call these components the FORMAL and TELIC roles, respectively. Minimally, then, the notion *food* is a concept making reference to distinct and orthogonal facets of knowledge, each expressing a different explanation of this concept. These two facets together with two other roles, CONSTITUTIVE and AGENTIVE, make up what I have referred to as the *qualia structure* for a lexical item (cf. Pustejovsky, 1995). A simple schematic description of a lexical item, α, using this representation is shown below:

(14)
$$\begin{bmatrix} \alpha & \\ \text{ARGSTR} = & \begin{bmatrix} \text{ARG1} = x \\ \cdots \end{bmatrix} \\ \text{QUALIA} = & \begin{bmatrix} \text{CONST} = \textbf{what } x \textbf{ is made of} \\ \text{FORMAL} = \textbf{what } x \textbf{ is} \\ \text{TELIC} = \textbf{function of } x \\ \text{AGENTIVE} = \textbf{how } x \textbf{ came into being} \end{bmatrix} \end{bmatrix}$$

As discussed in Pustejovsky (1995), the qualia constitute the necessary modes of explanation for understanding a word or phrase.[1] For qualia roles FORMAL and CONST, the logical interpretation is fairly direct, since both roles refer to individual variables of related type, and predicate in a conventional fashion. Consider the minimal semantics for a concept such as *snowball*. This makes reference to the formal property of the object being a ball-like entity, as well as its constitution, viz. snow. In Pustejovsky (1993), the qualia were treated as partial functions from the formal individual to a specific mode of description,

[1]These are grounded in the Aristotelian *aitia*, as argued in Moravcsik's study of Aristotle's notion of cause and explanation, cf. Moravcsik (1975).

be it formal, material, an event description, or an event (the FORMAL, CONST, TELIC, and AGENTIVE roles respectively). Modifying this view somewhat, I will identify the qualia as partial functions over types. The FORMAL quale picks out the supertype of the type, as sketched in (15).

(15) $Formal(\lambda x[\alpha(x)]) = \lambda x[Q(x)] \leftrightarrow \alpha \subseteq Q$

Then, a suggestive translation of the constitutive mode, CONST, can be given as (16).

(16) $Const(\lambda x[\alpha(x)]) = \lambda y[Q(y)] \leftrightarrow$
$\forall x[\alpha(x) \rightarrow \exists y[Q(y) \wedge made\_of(x, y)]$

Thus, for our example *snowball*, the conversion from these two qualia to a more conventional logical form is shown below in (17). The logical argument predicated of the FORMAL is a normal λ-abstraction, while the default argument of the material referred to by CONST is introduced with existential closure:

(17) a.
$$\left[\begin{array}{l} \textbf{snowball} \\ \text{ARGSTR} = \left[\begin{array}{l} \text{ARG1} = x \\ \text{D-ARG1} = y \end{array}\right] \\ \text{QUALIA} = \left[\begin{array}{l} \text{FORMAL} = ball(x) \\ \text{CONST} = snow(y) \end{array}\right] \end{array}\right] \Longrightarrow$$

b. $\lambda x[ball(x) \wedge const(x) = \exists y[snow(y)]]$

Now let us consider the interpretation of AGENTIVE, the mode of coming into being of an object. For our previous discussion of FORMAL and CONST, it was adequate to view the individual variable as an object from the conventional domain of entities. Aristotle's goal in introducing the "coming-into-being"-factor of an object was to be able to distinguish the life profiles of different objects; in other words, to consider the spatio-temporal aspects of an object as part of its predicative force. Seen in this light, the definition for FORMAL above is sufficient only if we do not wish to distinguish, for example, natural kinds from artifacts. Let us assume that the definition in (15) generally satisfies the description of natural kinds, where natural kind predicates are relations between an individual and a 'state sort', which is lexically closed; e.g.,*snow* would be represented as $\lambda x \exists e[snow(e, x)]$. For convenience, however, we can also view the FORMAL role as making reference to this event by definition, with an existence state predicate, E.

(18) $Formal(\lambda x[\alpha(x)]) = \lambda x \exists e^S[Q(x)] \wedge E(e^S, x)] \leftrightarrow \alpha \subseteq Q$

The reasons for this move become apparent when we attempt to model the distinction between natural kind predication and artifactual predication. Informally, a "mode of coming into being" is an implicit reference to an individual

event (more complex event descriptions may be considered as well, see below), which brings about the persistence of the individual's formal state. Hence, a first attempt at characterizing the AGENTIVE quale using this intuition, would be the definition given in (19).

(19) $Agentive(\lambda x[\alpha(x)]) = \lambda e[\psi(e)] \leftrightarrow$
$\forall x, e[\alpha(e,x) \rightarrow \exists e' \exists y[\psi(e') \wedge e' \prec e \wedge make(e', y, x)]]$

This states that for every type, α, if there is an AGENTIVE value specified, then there is a distinguished event associated with that type such that it is responsible for the type's coming into being (by default, as modelled with the default conditional, $>$, of Asher and Morreau (1991)). To illustrate what kind of distinction this permits, consider the representations of the natural kind, *snow*, given above, versus an artifact, *wine*, shown schematically in (20a) with a logical translation in (20b), ignoring for now the "functional" aspect of the term.

(20) a.
$$\left[\begin{array}{l} \textbf{wine} \\ \text{ARGSTR} = \left[\begin{array}{l}\text{ARG1} = x \\ \text{D-ARG1} = y\end{array}\right] \\ \text{EVENTSTR} = \left[\text{D-E1} = e\right] \\ \text{QUALIA} = \left[\begin{array}{l}\text{FORMAL} = liquid(x) \\ \text{AGENTIVE} = make(e,y,x)\end{array}\right] \end{array}\right] \Longrightarrow$$

b. $\lambda x[wine(x) : \ formal(x) = \lambda x[liquid](x) \wedge agentive(x) = \lambda e[\psi(e)]]$

The full translation of this last expression makes explicit reference to the persistence of the current formal mode as a result of the AGENTIVE event, as shown below.[2]

(21) $\lambda x \exists e', e, y[wine(e,x) : \ formal(x) = liquid(x) \wedge agentive(x) = [\psi(e') \wedge e' \prec e \wedge make(e', y, x)]$

As is apparent, the sortal distinction between natural kinds and artifacts is a formal one, based on typing and explicit reference to the mode of coming into being. The full impact of this distinction will not be discussed here, but see Pustejovsky (1995) and Busa (1996) for semantic and grammatical applications.

[2]This is assuming that the causal connection between the two events is made explicit, an obvious complication with the above simplification which is rectified by the addition of $\lambda e' \lambda e[cause(e', e)]$ to the expression in the AGENTIVE:

i. $Agentive(\lambda x[\alpha(x)]) = \lambda e[\psi(e)] \leftrightarrow$
$\forall x, e[\alpha(e,x) \rightarrow \exists e' \exists y[\psi(e') \wedge e' \prec e \wedge make(e', y, x) \wedge cause(e, e')]]$

Let us turn our attention finally to the interpretation of the TELIC. Unlike the value of the AGENTIVE, the mode of explanation referring to inherent purpose of an object cannot be an individual event, but must rather be an event description. Consider the TELIC for the artifact *wine* examined above. Intuitively, it should refer to the events of drinking the wine, just in case the appropriate circumstances are satisfied. This is the general strategy adopted in Busa (1996) for the conditional interpretation of TELIC, which we will attempt to unify with the view given above that the TELIC quale is (typically) a partial function from individuals to event descriptions. Assume that ψ is the set of appropriate circumstances for performing an activity ϕ, and that '$>$' is the default conditional as defined in Asher and Morreau (1991). Then, a reasonable approximation of the "analytic generic" interpretation that comes with nouns having TELIC values (e.g., "wine is for drinking", "books are for reading", etc.) might be the following:

(22) $Telic(\lambda x[\alpha(x)]) = \lambda y \lambda e \exists x[\phi(e,y,x)] \leftrightarrow$
$\lambda y \forall x \forall e \forall y[\psi_\alpha(e,y,x) > \exists e'[(\phi(e',y,x) \wedge e < e']]$

In this representation of TELIC, ψ_α denotes the appropriate circumstances of doing something to an x of type α, and $>$ is again the default conditional of Asher and Morreau (1991). Intuitively, the qualia relate modes of description of an object. While the FORMAL is treated as reference to the supertype and CONST returns the material mode of the object, notice that both AGENTIVE and TELIC make reference to events, but in very different ways. While the AGENTIVE identifies a set of individual events associated with the object, the TELIC refers to an event description, namely that which under all appropriate circumstances ψ will by default, be associated with that object as its function.

Applying this interpretation to the artifactual liquid *wine* gives the following expanded interpretation:

(23) $\lambda x \exists e[wine(e,x) : formal(x) = \lambda x[liquid(x)]$
$\wedge\, agentive(x) = \lambda e[\psi(e)]$
$\wedge\ telic(x) = \lambda e \lambda y[drink(e,y,x)]]$

Then, with the full definitions of TELIC and AGENTIVE substituted, this expression becomes:

(24) $\lambda x \exists e', e, y[wine(e,x) : formal(x) = liquid(x)$
$\wedge\ agentive(x) = [\psi(e') \wedge e' \prec e \wedge make(e',y,x)]$
$\wedge\ telic(x) = \lambda y \forall e[\psi_{wine}(e,y,x) > \exists e'[(drink(e',y,x)]]$

This expression now captures our intuitions about a qualia-based interpretation of word meanings; in this case, that wine is a particular liquid made for the purpose of drinking.

Summarizing what I have presented thus far, we have the following picture of word meaning: the qualia structure for an object can be viewed as an elaboration of its typing specification. Each quale role provides a distinct but essential component to uniquely determining the meaning of a word (or phrase). In fact, the qualia can be formally treated as components of the type by means of typed-feature structures, following the general stratety of Carpenter (1992) and Copestake (1992). To see how this might be accomplished, let us return to the examples mentioned briefly above, namely, those of *food* and *lunch*. The meaning of *food* is complex in that, from the perspective of concept classification we are grouping together the properties of physical substance and edibility. These attributes correspond to distinct qualia values contributing to the overall type structure for the concept *food*, e.g., by conjoining or unifying these distinct values from FORMAL and TELIC qualia roles, as illustrated somewhat schematically in (25) below (cf. Pustejovsky, 1995 for discussion).

(25) a. $\sigma = [_{\sigma} \ \ldots \ [Q_F = \mathit{substance} \ ]]$

b. $\tau = [_{\tau} \ \ldots \ [Q_T = \mathit{eat} \ ]]$

These two forms may unify, $\sigma \sqcap \tau$, to form a *unified type*, σ_τ, with the resulting qualia structure given in (26):

(26)
$$\begin{bmatrix} \sigma\_\tau \\ \text{QUALIA} = \begin{bmatrix} \text{FORMAL} = \mathbf{substance} \\ \text{TELIC} = \mathbf{eat} \end{bmatrix} \end{bmatrix}$$

The TELIC relation, of course, carries its argument structure with it, hence a more proper statement of the semantics for a lexical item such as *food* would be that in (27).

(27)
$$\begin{bmatrix} \mathbf{food} \\ \text{ARGSTR} = \begin{bmatrix} \text{ARG1} = \texttt{x:physobj} \end{bmatrix} \\ \text{QUALIA} = \begin{bmatrix} \text{FORMAL} = \mathbf{x} \\ \text{TELIC} = \texttt{eat(e}^{P}\texttt{,y,x)} \end{bmatrix} \end{bmatrix}$$

Let us assume that the logical interpretation of the qualia roles is as given above. From a typing perspective, viewing the qualia structure as the conjunction of properties along "orthogonal" dimensions enables us to model the semantics of a large class of nominals in natural language. For example, following our previous discussion above, we might view an artifact as something having an AGENTIVE quale value, viz., something having been made:

(28)
$$\begin{bmatrix} \mathbf{artifact} \\ \text{ARGSTR} = \begin{bmatrix} \text{ARG1} = x \end{bmatrix} \\ \text{QUALIA} = \begin{bmatrix} \text{FORMAL} = \mathbf{x} \\ \text{TELIC} = \texttt{make(e,y,x)} \end{bmatrix} \end{bmatrix} \Longrightarrow$$

Putting the above concept together with a specific FORMAL value, e.g., a physical object, gives rise to the concept of a *physical artifact*, which can also be modeled as the conjunction of predicates (or unification of types):

(29)
$$\begin{bmatrix} \textbf{artifact} \\ \text{ARGSTR} = \begin{bmatrix} \text{ARG1} = x \end{bmatrix} \\ \text{QUALIA} = \begin{bmatrix} \text{FORMAL} = \texttt{physical(x)} \\ \text{TELIC} = \texttt{make(e,y,x)} \end{bmatrix} \end{bmatrix} \Longrightarrow$$

This method, in fact, permits us a general strategy for creating increasingly specific concepts with conjunctive properties. Such types, what I will call *unified types* (cf. Pustejovsky, 1995), can be seen as structured by orthogonal dimensions or perspectives, rather than as multiply inherited concepts. We, of course, do not want to allow the free structuring or combinatorics of conjunctive properties, however, since this would generate more nonsense than well-formed concepts. The question of what constitutes a well-formed concept is at the core of lexical semantic research, and it is necessary for any theory to address this issue directly in how representations are structures and generated.

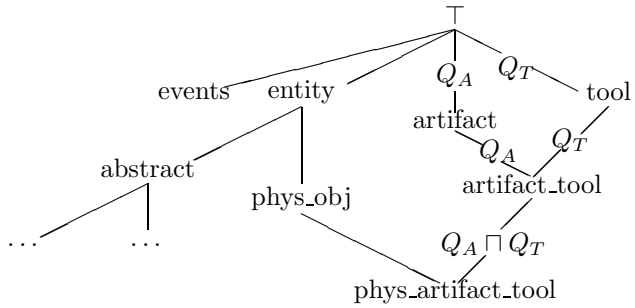
Relating to this point, I will argue that there is no multiple inheritance per se in natural language semantics. I will argue that what appear to be instances of concepts which inherit from multiple superordinates, are in fact either:

(a) *Typed orthogonal inheritance* structures; or

(b) *Complex types*, to be introduced below.

The qualia provide us with typed orthogonal information of the appropriate sort for the former class above. Let us assume that a concept is well-formed only if it inherits from a single parent within a given quale. Under this assumption, then, the only way to form more complex lexical or phrasal expressions would be by unifying predicates from distinct and orthogonal qualia. This is in fact what we proposed for the noun *food* above. The space of concepts generated by such a constraint is shown below in (30), where type unification generates new concepts. The unlabeled edges denote the FORMAL quale, Q_A denotes the AGENTIVE role, and Q_T denotes the TELIC.

(30)



By positing distinct (orthogonal) modes of explanation for a concept, functional descriptions, for example, can be expressed without commitment to a specific material form. This view would appear to entail that all complex notions are derived by combining predicates (or types) from orthogonal qualia (or modes of explanation). For example, nothing can be both abstract and physical, or abstract and eventlike. The mode of "coming into being", i.e., AGENTIVE role, however, can annotate the description of a particular physical object to create a more complex concept along orthogonal descriptions.

Complex Types

As useful as this technique is for modeling concepts, it seems woefully inadequate to account for the many apparent counterexamples encountered in natural language. Notice in the sentences below, how the underlined nouns denote what would arguably be contradictory types, according to the concept construction algorithm given above.

(31) a. Mary doesn't believe the book.
Type(*book*) = `info`

b. John sold his books to Mary.
Type(*book*) = `physobj`

(32) a. Eno the cat is sitting on yesterday's newspaper.
Type(*newspaper*) = `physobj`

b. Yesterday's newspaper really got me upset.
Type(*newspaper*) = `info`

(33) a. Mary is in Harvard Square looking for the Bach sonatas.
Type(*sonata*) = `physobj`

b. We won't get to the concert until after the Bach sonata.
Type(*sonata*) = `event`

(34) a. I have my lunch in the backpack.
Type(*lunch*) = `food`

b. Your lunch was longer today than it was yesterday.
Type(*lunch*) = `event`

(35) a. The phone rang during my appointment.
Type(*appointment*) = `event`

b. My next appointment is John.
Type(*appointment*) = `human`

What is interesting about the above pairs is that the two senses are related to one another in a specific and non-arbitrary way. The apparently contradictory nature of the two senses for each pair actually reveals a deeper structure relating these senses, what I will call a *dot object*. For each sense pair, there is a relation which "connects" the senses in a well-defined way. I will characterize this structure as a Cartesian type product of n types, with a particularly restricted interpretation, to be explained below. The product $\tau_1 \times \tau_2$, of types τ_1 and τ_2, each denoting sets, is the ordered pair $<t_1, t_2>$, where $t_1 \in \tau_1$, $t_2 \in \tau_2$. Obviously, the pairing alone does not adequately determine the semantics of the dot object; rather, there must exist a relation R which relates the elements of τ_1 and τ_2; i.e., $R(t_1, t_2)$. This relation must be seen as part of the definition of the semantics for the dot object $\tau_1 \cdot \tau_2$ to be well-formed. It should be pointed out that the dot-operator, unlike the Cartesian product, is not a commutative product. This is reflected in part by the constraints imposed on the interpretation of the relation R.

The set of relations, $\{R_i\}$, can be seen as specialized type product operators, where the specific relation is built into the constructor itself:

(36) $\{R_i\} = \cdot_{R_1}, \cdot_{R_2}, \ldots, \cdot_{R_n}$

For nouns such as *book*, *disk*, and *record*, the relation R is a species of "containment," and shares grammatical behavior with other container-like concepts. For example, we speak of information *in* a book, articles *in* the newspaper, as well as songs *on* a disc. This containment relation is encoded directly into the semantics of a concept such as *book* —i.e., $hold(x, y)$— as the FORMAL quale value. For other dot object nominals such as *prize*, *sonata*, and *lunch*, different relations will structure the types in the Cartesian product, as we see below. Let us say that, for any dot object, α, defined as a Cartesian product, $\tau_1 \cdot \tau_2$, the following must hold:

(37) $\lambda x.y \exists R[\alpha(x : \tau_1 . y : \tau_2) : R(x, y) \ldots]$

The lexical structure for *book* as a dot object can then be represented as in (38).

(38)
$$\left[\begin{array}{ll} \textbf{book} & \\ \text{ARGSTR} = & \left[\begin{array}{l} \text{ARG1} = \texttt{y:information} \\ \text{ARG2} = \texttt{x:phys\_obj} \end{array}\right] \\ \text{QUALIA} = & \left[\begin{array}{l} \text{FORM} = \texttt{hold(x,y)} \\ \text{TELIC} = \texttt{read(e,w,x.y)} \\ \text{AGENT} = \texttt{write(e',v,x.y)} \end{array}\right] \end{array}\right]$$

This translates roughly to the following logical form:

(39) $\lambda x.y \exists e' \exists v[book(x{:}\ \texttt{physobj}.y{:}\ \texttt{info}) : hold(x,y) \wedge \lambda w \lambda e[read(e,w,x.y)] \wedge [write(e',v,x.y)]]$

Nouns such as *sonata*, *lunch*, and *appointment*, on the other hand, are structured by entirely different relations, as explored below. What is important to note, however, is that the dot object construction (i.e., the type product) allows otherwise contradictory types to be combined into a single type. From a conceptual development point of view, this suggests that complex types are in fact learned later than simple or unified types (cf. Pustejovsky, 1995, for some discussion).

In order to make this clearer, I will distinguish two classes of complex type nominals, *endocentric* and *exocentric* dot objects. This distinction will reflect the manner in which the elements of the product are structured in the qualia, as defined below:

(40) **Dot Object Nominal Types:**

a. *Endocentric*: the entire dot object is made reference to in the qualia of the lexical structure;

$$\left[\text{QUALIA} = \left[\ Q_i = R(...,x.y,...)\ \right]\right]$$

b. *Exocentric*: the dot elements are split either within a single quale or between two qualia;

$$\left[\text{QUALIA} = \left[\begin{array}{l} Q_i = R(...,x,...) \\ Q_j = R(...,y,...) \end{array}\right]\right] \text{ or}$$

$$\left[\text{QUALIA} = \left[\ Q_i = R(x,...,y,...)\ \right]\right]$$

This distinction has important consequences for quantification and reference. As we will see in the next section, endocentric dot objects such as *book* and *record* refer to both elements in the type product, whereas an exocentric dot object may refer to only one or both.

The notion of a complex type proves useful for explaining the polysemy associated with process-result nominalizations, such as *construction* and *examination* (cf. Grimshaw, 1990). Consider the senses of the noun *construction* in the three sentences below.

(41) a. The house's construction was finished in two months.
b. The construction was arduous and tedious.
c. The construction is standing on the next street.

In Pustejovsky (1995), it is suggested that a dot object actually allows us to capture all three senses of *construction* manifested in the sentences in (41) above. Informally, we can imagine this class of nominalizations as a type product (i.e., a dot object) of the two subevents constituting the transition event denoted by the verb.

(42) $\lambda e.e'\exists x\exists y[construction(e{:}\,\texttt{process}.e'{:}\,\texttt{state}) :<_{\propto} (e,e') \wedge Agentive(e,x,y)] \wedge Formal(e',y)]]$

In some sense, the only thing different about this dot object is the typing on the dot elements and the specific relation which structures them. Thus, whereas a book is a dot object composed of `information` and `physobj` and is structured by the relation of containment, *construction* is a dot object composed of `process` and `state`, related by the temporal relation in the event structure of precedence, namely, $<_{\propto}$. It is interesting to speculate briefly on the semantic contribution of the *-ion* nominalizing morpheme more generally. For any verb with a complex event structure, application of the *-ion* nominalizer produces a dot object nominal, with a polysemy reflecting the types of the subevents from the verb's event structure. Hence, from the left-headed transition verb *examine*, the nominalization *examination* denotes a dot object with process and state dot elements, as illustrated below:

(43)
$$\left[\begin{array}{ll} \textbf{examination} & \\ \textsc{eventstr} = & \left[\begin{array}{l} \textsc{e}_1 = \textbf{process} \\ \textsc{e}_2 = \textbf{state} \\ \textsc{Restr} = <_{\propto} \end{array}\right] \\ \textsc{argstr} = & \left[\begin{array}{ll} \textsc{arg1} = \boxed{1} & \left[\begin{array}{l} \textbf{animate\_ind} \\ \textsc{formal} = \textbf{physobj} \end{array}\right] \\ \textsc{arg2} = \boxed{2} & \left[\begin{array}{l} \textbf{physobj} \\ \textsc{formal} = \textbf{entity} \end{array}\right] \end{array}\right] \\ \textsc{qualia} = & \left[\begin{array}{l} \textbf{event\cdot event\_lcp} \\ \textsc{formal} = \textbf{examine\_result}(\mathbf{e}_2, \boxed{2}) \\ \textsc{agentive} = \textbf{examine\_act}(\mathbf{e}_1, \boxed{1}, \boxed{2}) \end{array}\right] \end{array}\right]$$

The nominalization of a complex event by *-ion* in English results in a reification of all aspectual views of the event, lexicalized into one word; that is, *examination* serves the same function as the imperfect, perfect, and simple tenses, as witnessed by its polysemy.

Another example of an exocentric dot object is seen in the semantics of the noun *exam*. What is interesting about *exam* is that it can refer to the questions which compose the event of the examination, or the event of the examining itself, as illustrated in the sentences below.

(44) a. The exam lasted for several hours.
b. Bill was confused by the exam.

Questions, like any information objects, may also have physical manifestation, but need not (e.g., an oral exam). The ambiguity arises from the combination of the inherent polysemy possible in the type of information object of `question`, and the `event` of the examination. In this case, the relation which structures the two dot elements in the type product refers directly to the "asking" event, as illustrated below.

(45)
$$\left[\begin{array}{l} \textbf{exam} \\ \text{ARGSTR} = \left[\text{ARG1} = \textbf{x:question}\right] \\ \text{EVENTSTR} = \left[\text{E}_1 = \textbf{e}_1\textbf{:process}\right] \\ \text{QUALIA} = \left[\begin{array}{l} \textbf{question·process\_lcp} \\ \text{FORMAL} = \textbf{ask}(\textbf{e}_1\textbf{,z,x}) \\ \text{AGENT} = \textbf{make}(\textbf{e}_2\textbf{,y,x}) \end{array}\right] \end{array}\right]$$

That is, an exam is both a type of "propositional content" as well as the activity of "the questioning of this propositional content," and the object is structured by the very act of questioning itself.

Thus far, we have encountered dot objects comprised of the following pairs of types:

(46) a. `physobj·info`: e.g., *book*, *record*;

b. `event·event`: e.g., *construction*, *examination*;

c. `event·question`: e.g., *exam*;

d. `event·food`: e.g., *lunch*, *dinner*;

e. `event·human`: e.g., *appointment*.

For each of the above type products, there is a unique relation, R_i, which structures the types. Cases that we have not examined here include nouns such as *prize*, *sonata*, and the more complicated concepts of *city* and *organization*. From our initial study, however, it appears that the theory of dot objects simplifies the model of complex meanings and the behavior of polysemous nominals. In this section, I have of course only scratched the surface of what the formal properties of these logical constructions are. Further considerations of the nature of dot objects are explored in Asher and Pustejovsky (forthcoming).

3 Complex Relations

In the previous section, we saw that certain classes of nominals, i.e., endocentric dot objects, have qualia values which are relations selecting for the dot objects directly. The examples we encountered above were the *read* and *write* relations as selected by the TELIC and AGENTIVE qualia, respectively, for a concept such as *book*. This is illustrated schematically below:

(47) a. $\lambda y.z\lambda x\lambda e[read(e, x, y.z)]$

b. $\lambda y.z\lambda x\lambda e[write(e, x, y.z)]$

What does it mean, however, for a verb to select a dot object as an argument and is there any way to distinguish such a relation from those that do not or cannot select a dot object? To answer this question, let us compare the selectional distribution of a lexical item typed as a dot object, with a word carrying the type of one of the dot elements; namely, *book* versus *story*.

(48) a. $\mathbf{Type}(book) = \texttt{physobj.info}$

b. $\mathbf{Type}(story) = \texttt{info}$

Given this distinction, there should be contexts in which one type is selected for and the other is prohibited. This is, in fact, what we observe. Notice that while the verb *read* permits direct selection of both types, the verb *tell* does not allow *book* as the head of its complement.

(49) a. Mary read a book.

b. Mary read a story.

(50) a. Mary told a story.

b. *Mary told a book.

While both books and stories are informational in nature, a story, unlike a book, need not be realized as a physical object. To illustrate this distinction, consider what the logical interpretations for the sentences in (49a) and (50a) are. For a type such as *book*, we will say that the dot elements of the type product are both extensional. Hence, for a dot object α, the following holds:

(51) EXISTENTIAL DISTRIBUTION:

$\Box\forall\alpha\forall x.y[\alpha(x.y) \rightarrow \exists\alpha_1\exists\alpha_2[\alpha_1(x) \wedge \alpha_2(y)]]$

This property holds for a complex type such as *book* because the FORMAL quale is an *extensional relation* between two individuals, viz. *hold*. The consequences of this are that both dot elements are existentially closed when existential force is given to the dot object. Hence (52c) follows as the interpretation of (52a).

(52) a. Mary read a book. $\Longrightarrow$

b. $\exists y.z \exists e[read(e, m, y.z) \wedge book(y.z)] \Longrightarrow$

c. $\exists y.z \exists e[read(e, m, y.z) \wedge book(y.z) \wedge physobj(y) \wedge info(z)]$

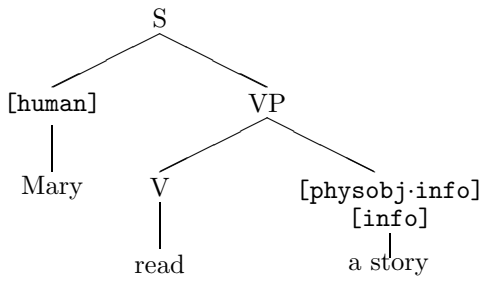
Because the noun *story* is a simple type, however, no such interpretation is possible, and all that is existentially asserted of (53a) is the story itself.

(53) a. Mary told a story. $\Longrightarrow$

b. $\exists x \exists e[tell(e, m, x) \wedge story(x)]$

Nevertheless, the verb *read* is able to coerce its complement in (49b) into both components of the complex type, `physobj.info`. The behavior of the verb *read* relative to the selection of a non-dot object complement illustrates the coercive nature of the predicate, as shown below (cf. Pustejovsky, 1995).

(54)



What is interesting about this example is that the type of the noun *story*, by virtue of the coercion, has been embedded within a complex type, which brings with it, a very different quantificational force than that seen when selected by the verb *tell* in (50a).

(55) a. Mary read a story. $\Longrightarrow$

b. $\exists y.z \exists w \exists e \exists P[read(e, m, y.z) \wedge P(y.z) \wedge story(w) \wedge w = z] \Longrightarrow$

c. $\exists y.z \exists w \exists y \exists e \exists P[read(e, m, y.z) \wedge P(y.z) \wedge physobj(y)$
$\wedge\ story(w) \wedge w = z]$

Thus, the NP *a story* appears to inherit additional existentially quantified properties by virtue of the semantic context within which it appears. Notice that the interpretation of the NP has not been type shifted in the sense of Partee and Rooth (1993), but rather embedded in a metonymic reconstruction, while preserving the underlying semantics of the NP, i.e., it is coerced.

It should be pointed out that verbs like *tell* do not appear to be able to coerce their complements in the same way that *believe* and *enjoy* are able to. Such considerations and other grammatical distinctions between coercing and non-coercing predicates lead us to distinguish between two types of selection, *active* and *passive*.

(56) a. *Active Selection*: Enables coercion, and allows accommodation to the required type.

b. *Passive Selection*: No coercion possibilities; requires direct selection of type by the complement.

I will have little more to say about this distinction here; this topic is taken up in the context of the theory of selection in Pustejovsky (1996).

Thus far we have explored the selectional distinctions between *read* and *tell*, and this has brought us a bit closer to understanding what it means for a predicate to select a dot object complement. It was observed that endocentric dot objects have the property of existential distribution, repeated below:

(57) Existential Distribution:

$$\Box\forall\alpha\forall x.y[\alpha(x.y) \rightarrow \exists\alpha_1\exists\alpha_2[\alpha_1(x) \wedge \alpha_2(y)]]$$

Now recall from our previous discussion how the verb *read* is able to impose an interpretation on a complement that it would otherwise not carry, as in (50), where `physobj` was imposed on an informational concept. Notice that a similar phenomenon occurs when the complement carries no intrinsic interpretation as an informational concept, as in (58).

(58) Mary read the subway wall.

We understand (58) as referring to an event involving the same meaning of *read*, but one which introduces the "argument" of the readable material. In the framework proposed here, this is simply part of the dot object type itself.

Furthermore, observe that the subcategorization behavior for *read* permits the following structures.

(59) a. Mary read the book.

b. Mary read the book of articles.

c. Mary read the articles in the book.

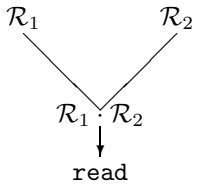
d. Mary read the articles.

The form in (59b) is, of course, not entirely due to the verb but also to the semantics of the head noun. Nevertheless, these considerations together with the

coercive behavior of *read* strongly suggest that it is a complex relation, formed from relations which each take an element of the dot object as an argument.

A complex relation is one which decomposes into simpler component parts, each of which is itself a relation. For a relation such as *read*, which we modeled as selecting for a dot object in complement position, let us say that there are as many component relations as there are elements in the dot object selected for, in this case, two. This is illustrated schematically in (60) below.

(60)



If a *book* is a complex type, then the characteristic functions over this type must be decomposable and identifiable. Intuitively, we can separate the visual perception of the physical aspect of the dot object `physobj·info` from the understanding or comprehending of its informational aspect. Let us call these two relations $\mathcal{R}_1$ and $\mathcal{R}_2$, respectively. They are furthermore structured by a temporal precedence relation, $<_\propto$, since one must first see in order to comprehend the text. On this view, the verb *read* denotes a Cartesian type over relations, $\mathcal{R}_1 \times \mathcal{R}_2$, with a similar restriction to that mentioned in the previous section, namely that there must exist a relation structuring these relational elements. Hence, something like the following must hold for a complex relation which selects for a dot object:

(61) Relation Decomposition:

a. $\lambda x.y\lambda z\lambda e[\mathcal{R}_1.\mathcal{R}_2(e, z, x.y)] \Longrightarrow$

b. $\lambda x\lambda y\lambda z\lambda e_1\lambda e_2[\mathcal{R}_1(e_1, z, x) \wedge \mathcal{R}_2(e_2, z, y) \wedge <_\propto (e_1, e_2)]$

In order to model the semantics of this complex relation more precisely, one might view such structures in terms of relational algebraic operations. Let us begin with our observation above that *read* might be viewed as a Cartesian product (where $\dot\cup$ denotes disjoint union):

(62) $\times : \mathcal{R}(\tau_1) \times \mathcal{R}(\tau_2) \rightarrow \mathcal{R}(\tau_1 \dot\cup \tau_2)$

But this is not quite right, for what is unique about a predicate such as *read* is that each relation in the product shares an *attribute* value. That is, the subject of R is the same as the subject of S. Therefore, let us call *read* the *join* of the two relations, R and S; more specifically, let us refer to it as a Θ-join operation over these relations (cf. Maier, 1983).

(63) $[X\Theta Y] : \mathcal{R}(\tau_1) \times \mathcal{R}(\tau_2) \rightarrow \mathcal{R}(\tau_1 \dot{\cup} \tau_2)$

Let Θ be a comparison operator on the common domain of X and Y, $W(X) = W(Y)$. We will say that a tuple from $R \times S$ satisfies the conditions defined by the filter $X\Theta Y$, if components with respect to the parameters X and Y stand in relation Θ. Hence, the Θ-join is defined according to this condition, for two relations R and S:

(64) $R[X\Theta Y]S \ := \ s_{X\Theta Y}(R \times S)$

A specific example of this that will be relevant to our discussion is a particular constraint on the relational product called an *equijoin*.

(65) $R[X = Y]S \ := \ s_{X=Y}(R \times S)$

Now, we can return to the sentence in (49a), and provide for the complete interpretation. Making use of both Existential Distribution and Relation Decomposition, we arrive at the following derivation:

(66) a. Mary <u>read</u> a book. $\Longrightarrow$

b. $\exists y.z \exists e[read(e, m, y.z) \wedge book(y.z)] \Longrightarrow$

c. $\exists y.z \exists e[read(e, m, y.z) \wedge book(y.z) \wedge physobj(y) \wedge info(z)] \Longrightarrow$

d. $\exists y \exists z \exists e_1 \exists e_2[read_1(e_1, m, y) \wedge physobj(y) \wedge read_2(e_2, m, z)$
$\wedge info(z) \wedge <_{\propto} (e_1, e_2)]$

The machinery creating complex relational types can also be used to explain some peculiar properties of certain "cooperative activity" predicates such as *rent* and *lease*, as well as "weakly symmetric" predicates, such as *meet*, *touch*, and *debate*. Consider briefly the behavior of *rent*. This verb is interesting because it allows for two subcategorizations, each corresponding to a distinct interpretation of the verb. Observe in (67) how the directionality of the relation is affected or dictated by the prepositional phrase selected for (cf. Bierwisch, 1983, Jackendoff, 1983).

(67) a. Mary <u>rented</u> the room to John.

b. Mary <u>rented</u> the room from John.

The interpretation given in one sentence entails the interpretation provided for in the other. The fact that the "renting event" entails two subparts or subevents suggests that the relation is itself complex in nature, where the relation actually refers to both perspectives on the transaction, i.e., the "giving" and the "taking" events. That is, we can abstract the components of the relation of *renting* to be two subrelations, $R_1(x, y, z)$ and $R_2(z, y, x)$, where the relations share the object in the transaction.

This predicate can be modeled as a Θ-join complex relation, $R[X\Theta Y]S$, with the comparison operator constraining Y_R, the second parameter of R, to be identical to Y_S, the second parameter of S.

(68) $R[Y_R = Y_S]S \ := \ s_{Y_R=Y_S}(R \times S)$

It is interesting to note that, in (69), the VP is semantically underspecified with respect to which subevent is being referred to. The semantics of the subject in each case acts to strongly bias the interpretation to one perspective or the other.

(69) a. The landlord rented the apartment.

b. The tenant rented the apartment.

If the verb with its complement are, in fact, underspecified, then the prepositional phrases in (67a) and (67b) are acting as filters on the interpretation of the complex relation. For example, in sentence (67a), the `to NP` phrase acts as a selector function over the relation, returning that relational element from the complex which satisfies its type (cf. Pustejovsky, 1996 for more details). Viewed somewhat schematically below, the semantics of the PP is satisfied by the semantics of the "giving" relational element of the complex, deriving the sense in context of *rent* in sentence (67a).

(70) a. $\Sigma_1 =$ `to-PP`

b. $\mathcal{R}_1 \cdot \mathcal{R}_2 =$ `rent the house`

c. $\Sigma_1[\mathcal{R}_1 \cdot \mathcal{R}_2] : \ \mathcal{R}_1$

d. $\Rightarrow \ R_1(x, y, z)$

To conclude this section, let us briefly discuss why exocentric dot object nominals such as *meal* behave differently, with respect to quantification, from endocentric nouns such as *book*. Notice that the mention of *my meal* in (71a), while asserting the existence of the food, does not guarantee the existential closure of the event of eating the food. This remains intensional or irrealis in nature.

(71) a. I have my meal in the backpack.

b. Your meal was longer today than it was yesterday.

When asserting the occurrence of the event of eating in (71b), however, there is also existential closure of the food. What formal properties of the semantics of *meal* might account for this distinction? In fact, this closure behavior is a property generally of any dot object with an event as a dot element. Namely, if

the event element is existentially closed, all other dot elements in the complex type are also closed.

In Section 1.0, I demonstrated how a concept such as *meal* could not be viewed as a conjunctive (or unified) type, and must be analyzed as a dot object, i.e., `event·food`. Looking more carefully at the semantics of this concept, we discover that the above mentioned asymmetric closure behavior is due to the event being positioned within the TELIC role, which forces a modal subordination on the relation of eating.

(72)
$$\left[\begin{array}{l} \textbf{meal} \\ \text{ARGSTR} = \left[\text{ARG1} = \texttt{x:food}\right] \\ \text{EVENSTR} = \left[\text{E1} = \texttt{e:process}\right] \\ \text{QUALIA} = \left[\begin{array}{l}\texttt{event·food} \\ \text{FORMAL} = \texttt{x} \\ \text{TELIC} = \texttt{eat(e,x,y)}\end{array}\right] \end{array}\right]$$

For our present purposes, this translates to the following logical interpretation:

(73) $\lambda x.e[meal : food(x) \wedge \lambda y \Diamond [eat(e, y, x)] \ldots]$

Closure on an exocentric dot object does not distribute to all dot elements, however, as illustrated in (74) with *Existential Blocking*.

(74) EXISTENTIAL BLOCKING:

$\Box \forall \alpha \forall x.y[\alpha(x.y) \wedge Telic(..., y, ...) \rightarrow \exists \alpha_1[\alpha_1(x)]]$

Rather, only when the intensional element in the dot object, i.e., the event, is asserted as in (71b), will both elements be existentially closed. The sentence in (71a) does not entail closure on the event in the dot object, while that in (71b) entails both closure on the food and on the event.

4 Conclusion

In this paper, by focusing on one aspect of the semantics of underspecification, the problem of complex types, I have only scratched the surface of this difficult issue. I have attempted to clarify what the general properties of complex types in natural language are, and to characterize some of the formal aspects of these structures. In the process, I hope to have demonstrated that conventional typing models for lexical description are inadequate for explaining the logical and syntactic behavior of these objects. The machinery introduced to account for cases of complex type nominal polysemy was extended to handle some cases of verbal semantics, and specifically for those verbs themselves selecting for dot objects.

Bibliography

Apresjan, J. D. 1973a. "Synonymy and Synonyms," in F. Kiefer (ed.), 173-199.

Asher, N. and M. Morreau. 1991. "Common Sense Entailment: A Modal Theory of Nonmonotonic Reasoning," in *Proceedings to the 12th International Joint Conference on Artificial Intelligence*, Sydney, Australia.

Asher, N. and J. Pustejovsky. Forthcoming. "The Metaphysics of Words," ms. Brandeis University and University of Texas.

Bierwisch, M. 1983. "Semantische und konzeptuelle Repräsentationen lexikalischer Einheiten", in R. Ruzicka and W. Motsch (eds.), *Untersuchungen zur Semantik*, Berlin, Akademische-Verlag.

Bouillon, P. 1997. "Polymorphie et smantique lexical: le case des adjectifs", Ph.D., Paris VII. Paris.

Busa, F. 1996. *Compositionality and the Semantics of Nominals*, Ph.D. Dissertation, Brandeis University.

Carpenter, B. 1992. "Typed Feature Structures," *Computational Linguistics*, 18:2.

Copestake, A. 1992. *The Representation of Lexical Semantic Information*, CSRP 280, University of Sussex.

Copestake, A. (1993) "Defaults in the LKB", in T. Briscoe and A. Copestake (Eds.) *Default Inheritance in the Lexicon*, Cambridge University Press.

Copestake, A. and E. Briscoe. (1992) "Lexical Operations in a Unification-Based Framework," in J. Pustejovsky and S. Bergler (Eds.) *Lexical Semantics and Knowledge Representation*, Springer Verlag, New York.

Dölling, J. (1992) "Flexible Interpretationen durch Sortenverschiebung", in Ilse Zimmermann, Anatoli Strigen (eds.) *Fügungspotenzen*, Berlin, Akademie Verlag.

Dowty, D. R. (1985) "On Some Recent Analyses of Control", *Linguistics and Philosophy* 8, pp. 1-41.

Egg, M. and Lebeth, K. (1995) "Semantic underspecification and modifier attachment ambiguities," in J. Kilbury and R. Wiese (eds.) *Integrative Ansätze in der Computerlinguistik*, Düsseldorf, Seminar für Allgemeine Sprachwissenschaft.

Fauconnier, Gilles. 1985. *Mental Spaces*, MIT Press, Cambridge.

Grimshaw, Jane. 1990. *Argument Structure*, MIT Press, Cambridge, MA.

Grimshaw, J. and A. Mester. 1988 "Light Verbs and θ-Marking," *Linguistic Inquiry* 10:205-232.

Hirst, G. 1987. *Semantic Interpretation and the Resolution of Ambiguity*, Cambridge University Press, Cambridge.

Jackendoff, R. (1985) "Multiple Subcategorization and the Theta-Criterion: The Case of *Climb*", *Natural Language and Linguistic Theory* 3, 271-295.

Kayser, Daniel (1988) "What Kind of Thing is a Concept?" *Computational Intelligence* 4:158-165.

Maier, David (1983) *The Theory of Relational Databases*, Computer Science Press.

Moravcsik, J. M. 1975. "Aitia as Generative Factor in Aristotle's Philosophy", *Dialogue*, 14:622-36.

Nunberg, G. (1979) "The Non-uniqueness of Semantic Solutions: Polysemy", in *Linguistics and Philosophy* 3:143-184.

Ostler, N. and B. T. Atkins. 1992. "Predictable Meaning Shift: Some Linguistic Properties of Lexical Implication Rules," in J. Pustejovsky and S. Bergler (eds.), *Lexical Semantics and Knowledge Reperesentation*, Springer Verlag, Berlin.

Partee, B. and M. Rooth. (1983) "Generalized Conjunction and Type Ambiguity", in *Meaning, Use, and Interpretation of Language*, Bäuerle, Schwarze, and von Stechow (eds). Walter de Gruyter.

Pinkal, M. (1995), "Radical Underspecification," in *Proceedings of the Tenth Amsterdam Colloquium*.

Poesio, M. (1994) "Ambiguity, underspecification, and discourse interpretation," in H. Bunt, R. Muskens, and G. Rentier (eds.) *International Workshop on Computational Semantics*, University of Tilburg.

Pustejovsky, J. (1991) "The Generative Lexicon", in *Computational Linguistics*, 17.4.

Pustejovsky, J. (1994) "Semantic Typing and Degrees of Polymorphism", in Martin-Vide *Current Issues in Mathematical Linguistics*, Elsevier, Holland.

Pustejovsky, J. (1995a) "Linguistic Constraints on Type Coercion", in P. Saint-Dizier and E. Viegas (eds.), *Computational Lexical Semantics*, Cambridge University Press.

Pustejovsky, J. (1995b) *The Generative Lexicon*, MIT Press, Cambridge, MA.

Pustejovsky, J. (1996) "Lexical Shadowing and Argument Closure," ms. Brandeis University.

Pustejovsky, James. 1997. "Multiplicity of Meaning," ms., 1997 Gustaf Stern Memorial Lectures, Gothenburg, Sweden.

Pustejovsky, J. (1998) "Generativity and Explanation in Semantics: A Reply to Fodor and Lepore," *Linguistic Inquiry*, 29.2.

Pustejovsky, J. and B. Boguraev. (1993) "Lexical Knowledge Representation and Natural Language Processing", in *Artificial Intelligence*, 63:193-223.

Reyle, U. (1993) "Dealing with ambiguities by underspecification: construction, representation, and deduction," *Journal of Semantics* 10, 123-179.

Rosen, S. 1989. *Argument Structure and Complex Predicates*, Ph.D. Dissertation, Brandeis University.

Sanfilippo, A. (1990) *Grammatical Relations, Thematic Roles, and Verb Semantics*, Ph.D. Thesis, Centre for Cognitive Science, University of Edinburgh.

Sowa, J. "Logical Structures in the Lexicon", in J. Pustejovsky and S. Bergler (Eds.) *Lexical Semantics and Knowledge Representation*, Springer Verlag, New York, 1992. Strachey, C. "Fundamental Concepts in Programming Languages,"

Lecture Notes for International Summer School in Computer Programming, Copenhagen, 1967.

Talmy, Len, "Semantics and Syntax of Motion," in J.P. Kimball (Ed.), *Syntax and Semantics 4*, Academic Press, New York, 1975.

Talmy, Len, "Lexicalization Patterns", in *Language Typology and Syntactic Description*, Shopen, Timothy (Ed.), Cambridge, 1985.

van Deemter, K. and S. Peters, eds. (1996) *Ambiguity and Underspecification*, CSLI, Chicago University Press.

Vendler, Zeno, *Linguistics and Philosophy*, Cornell University Press, Ithaca, 1967.

Weinreich, U. "Travels through Semantic Space," *Word* 14, pp. 346-366, 1959.

Weinreich, U. "On the Semantic Structure of Language," in J. Greenberg (ed.) *Universal of Language*, MIT Press, Cambridge, MA., 1963.

Weinreich, U. "*Webster's Third*: A Critique of its Semantics," *International Journal of American Linguistics* 30, pp. 405-409, 1964.

Weinreich, U. *Explorations in Semantic Theory*, Mouton, The Hague, 1972.

Wilks, Yorick, "A Preferential Pattern Seeking Semantics for Natural Language Inference," *Artificial Intelligence*, 6, 53-74, 1975.

Wright, Georg H. von, *Norm and Action: A Logical Inquiry*, Routledge and Kegan Paul, London, 1963.