PM, Propositional Model, a Computational Psycholinguistic Model of Language Comprehension Based on a Relational Analysis of Written English

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Abstract

A computational psycholinguistic model of written language comprehension called PM (Propositional Model) is described. PM is a highly interactive model. Written English text is processed directly into propositional representations. There is no separate syntactic analysis and no distinctly syntactic representations exist. The processing mechanism is lexically driven and most knowledge of language is assumed to be encoded in the lexicon. Of particular importance to the processing mechanism are the relational lexical items in the input text. These lexical items set up expectations which drive the processing mechanism and determine the possible propositional structures.

PM's system of representation is propositionally and linguistically based. Propositional representations consist of linguistic descriptions of predicates along with linguistic descriptions of their associated arguments. There are two basic types of argument descriptions: (a) object argument descriptions, and (b) propositional argument descriptions. Based on a categorization of English sentence types in terms of the above propositional categories, nine basic propositional forms and four basic predicate modification forms have been identified. Examples of each propositional and predicate modification form are presented and possible extensions are discussed.

The representation of object descriptions is also considered. The relational structure of object descriptions is similar in many ways to that of propositional descriptions. Predicates combine with arguments to form propositional descriptions, and functions combine with terms to form object descriptions. Predicates are the relational elements of propositional descriptions and functions are the relational elements of object descriptions.

PM's system of representation is at a level of abstraction above that of traditional grammar. The relationship between PM and traditional grammar is explored.

The processing of written English text into propositional representations is driven by the expectations of the relational elements in that text. If a relational element expects an argument to occur before it in the text, then that argument is assumed to be available in short-term memory. If the relational element expects an argument to occur after it, then the relational element must be retained in short-term memory until the argument is available to be instantiated into it.

The development of PM has been most heavily influenced by the research of Y. Wilks (Preference Semantics), R. Langacker and G. Lakoff (Cognitive Linguistics), T. Givon (Functional-Typological Grammar), W. Kintsch and J. R. Anderson (Propositional Representation and Processing), G. A. Miller and P. Johnson-Laird (Lexical Semantics), and P. Johnson-Laird (Mental Models).

Chapter 1: The Theoretical Basis of PM

Introduction

PM, Propositional Model, is a computational psycholinguistic model of written language comprehension. It focuses on the modeling of the cognitive processes and memory structures involved in the determination of the propositional content of written English text. To that end, PM is primarily concerned with the development of an adequate system of propositional representation and with a processing mechanism for constructing propositional representations from written English text.

This introductory chapter outlines the key ideas which form the historical and theoretical basis of PM. Many of these key ideas will be discussed in greater detail in subsequent chapters. They are introduced here to provide a framework for that more detailed discussion. They are primarily concerned with two basis issues: (a) representation and (b) process; and, it is in terms of their contribution to the development of PM's system of representation and processing that they are considered important.

The basic assumptions of PM follow those of Preference Semantics (Wilks, 1972, 1975a, 1975b, 1979), including the commitment to the priority of semantics and the nonautonomy of syntax. PM takes a strong position in arguing that there is no distinction between syntactic structure and semantic structure for the representation of linguistic aspects of meaning. This position is consistent with Langacker's claim (1987, p. 12) that "…it makes no more sense to posit separate grammatical and semantic components than it does to divide a dictionary into two components, one listing lexical forms and the other listing lexical meanings. Grammar is simply the structuring and symbolization of semantic content." PM's position is also related to, but stronger than, Jackendoff's Grammatical Constraint:

> "…one should prefer a semantic theory that explains otherwise arbitrary generalizations about the syntax and the lexicon…a theory's deviations from efficient encoding must be vigorously justified, for what appears to be an irregular relationship between syntax and semantics may turn out merely to be a bad theory of on or the other" (Jackendoff, 1983, pp. 13-14).

Further, PM's position differs from approaches like Montague Grammar and Steedman's (1989) Combinatorial Grammar which posit a one-to-one mapping between syntactic and semantic rules. If syntactic and semantic structure are one and the same, there is no need for a one-to-one mapping between syntactic and semantic rules. In terms of the debate over the interaction of syntax and semantics versus the autonomy of syntax, PM's position is interactive in the extreme. In fact, using the term interactive to describe PM is somewhat misleading in that it suggests a distinction between syntactic and semantic influences which is presumed not to exist. As Johnson-Laird (1983, p. 334) notes, "…the

question of autonomy versus interaction can only be raised on the assumption that they [syntactic and semantic processing] are separate enterprises…"

PM does, however, make a distinction between two types of representations: linguistic and nonlinguistic. Both types of representation are perceptually based abstractions and the label nonlinguistic has been chose in preference to conceptual in order to avoid confusion on this issue. In PM, the basic linguistic units of representation are the propositional description and the object description. A propositional description is composed of a linguistic description of a predicate along with linguistic descriptions of its associated arguments. There are actually two types of argument description: (a) propositional argument descriptions, which are just propositional descriptions which function as arguments in higher level propositional descriptions, and (b) object argument descriptions, which are descriptions of objects and entities which participate in propositional descriptions. Linguistic representations are systematically and meaningfully related to nonlinguistic representations, with object descriptions corresponding to nonlinguistic representations of objects and propositional descriptions corresponding to nonlinguistic representations of relations between objects and properties of objects.

As noted above, both linguistic and nonlinguistic representations are perceptually based abstractions. That is, linguistic representations are perceptually based abstractions of linguistic input and nonlinguistic representations are perceptually based abstractions of nonlinguistic input. In PM, there are no completely abstract, nonperceptual representations which mediate between language and the world. In place of a meaning triad (i.e. language, thought, and reality) where meaning mediates between linguistic expressions and the real world, PM posits the existence of a meaning quadrad (language, linguistic representations, representations of the real world, reality: Hockett, 1987) where meaning suffuses linguistic and real world representations and the associations between them.

PM's position is at odds with the assumption that there is something like a conceptual (or propositional) level of representation which mediates between language and the world—an assumption which is widely held by researchers in psychology (Clark & Clark, 1977; Kintsch, 1974; Johnson-Laird, 1983, Miller & Johnson-Laird, 1976), linguistics (Givon, 1984, 1989; Jackendoff, 1983), philosophy (Fodor, 1975), and AI (Schank, 1975). Givon (1989, p. 87) goes so far as to suggest that "since both linguistics and psychology have established the independent reality of both sentences and propositions beyond any reasonable doubt, we will forego belaboring the point here." Here he is using the term proposition to refer to abstract, nonperceptual representations which mediate between language and the world. A basic argument of this position is that two different sentences which are equivalent in meaning should be represented by the same proposition. But Quine (1986, p. 10) argues convincingly that the existence of linguistically independent propositions offers no solution to the problem of determining synonymy of meaning which does not require "…some suitable definition of equivalence of sentences" and this being the case "why not just talk of sentences and let the propositions go?" In essence, Quine is saying that in order to know that two sentences should map to the same

proposition you must first know that they are equivalent in meaning. However, "there is no evident rule for separating the information [contained in sentences] from sylistic and other immaterial features of sentences" (Quine, 1986, p.4). Rather, the lure of propositions and "their promise of more is mainly due to our uncritically assuming for them an individuation which matches no equivalence between sentences that we know how to define" (Quine, 1986, p. 10). In sum, if we can know that two different sentences have the same meaning, then we do not need some deeper representation which merely reflects what we already know about the sentences themselves.

PM assumes that nonlinguistic representations are for the most part efficiently encoded by corresponding linguistic representations and that the structure of linguistic representations maps efficiently to the structure of nonlinguistic representations (keeping in mind the inherent difficulty in mapping from a multidimensional nonlinguistic space to a single or bi-dimensional linguistic space). This is not to deny that there is some degree of arbitrariness in that mapping, but that arbitrariness is largely confined to the lowest level linguistic units (e.g., letters and words) and is more the result of the need for efficient encoding (as in the adoption of alphabets for written language) than the result of any general arbitrariness in the mapping.

Returning to the issue of the integration of syntax and semantics, PM argues against the autonomy of syntax from semantics and argues that morphology and lexical semantics cannot sensibly be separated from them either, agreeing with Langacker (1987, p. 3) in this respect:

> There is no meaningful distinction between grammar and lexicon. Lexicon, morphology, and syntax form a continuum of symbolic structures, which differ along various parameters but can be divided into separate components only arbitrarily.

PM presents a system of representation which blurs the distinction between word structure and sentence structure and argues that meanings are either directly associated with particular structures (be it morphemes, words, phrases or larger structures) or are computed from the meanings of sub-structures, and allowing that metaphoric extension and other noncompositional processes may take part in that computation. Thus, while the meaning of specific words is likely to be conventionally established and the meaning of phrases and sentences is likely to be compositionally and contextually determined, this difference is only a matter of degree and there may well be words whose meaning is determined compositionally or contextually (e.g. the verb **take**, the preposition **of**, and nonce words like **porched** in **he porched the newspaper**, Clark, 1983; Johnson-Laird, 1987) and expressions whose meaning is determined by convention (e.g., the idiom **kicked the bucket**). Further, Lakoff and Johnson (1980) and Lakoff (1987) argue that the metaphoric and metonymic extension of meaning is a basic noncompositional cognitive process. And Johnson-Laird (1983, 1987) argues that mental models are constructed from propositional representations, but are more specific in meaning than the propositional representations from which they are constructed and to the degree that the mental model is more specific, the construction process is noncompositional. Finally,

Langacker (1987) argues for the partial compositionality of the meaning of larger semantic structures from substructures and makes a claim similar to that of Johnson-Laird.

PM makes use of schemas (using Langacker's terminology) for the representation of knowledge of language. In PM there is an abstract schema of the form |**obj pred obj**| (**pred** is short for predicate and **obj** is short for object description) which represents knowledge about the linear encoding, number and type of arguments which are associated with bivalent or transitive predicates. There is also likely to be a more concrete schema of the form |**obj hit obj**|, reflecting specific knowledge about the transitive verb **hit**. And even more concrete schemas like |**obj *hit the nail on the head***| are possible. Thus, PM assumes the existence of schemas at multiple levels of abstraction. Figure 1.1 is a tangled hierarchical diagram of some possible schemas for the verb **hit**. Of interest to note is that a schema which contains specific lexical items might be said to be part of the lexicon (assuming the schema is addressable via the lexical item it contains), whereas a schema which does not contain any specific lexical item might be said to be part of the grammar. But if abstract schemas like |**obj pred obj**| are directly associated with specific lexical items, this distinction loses its force.

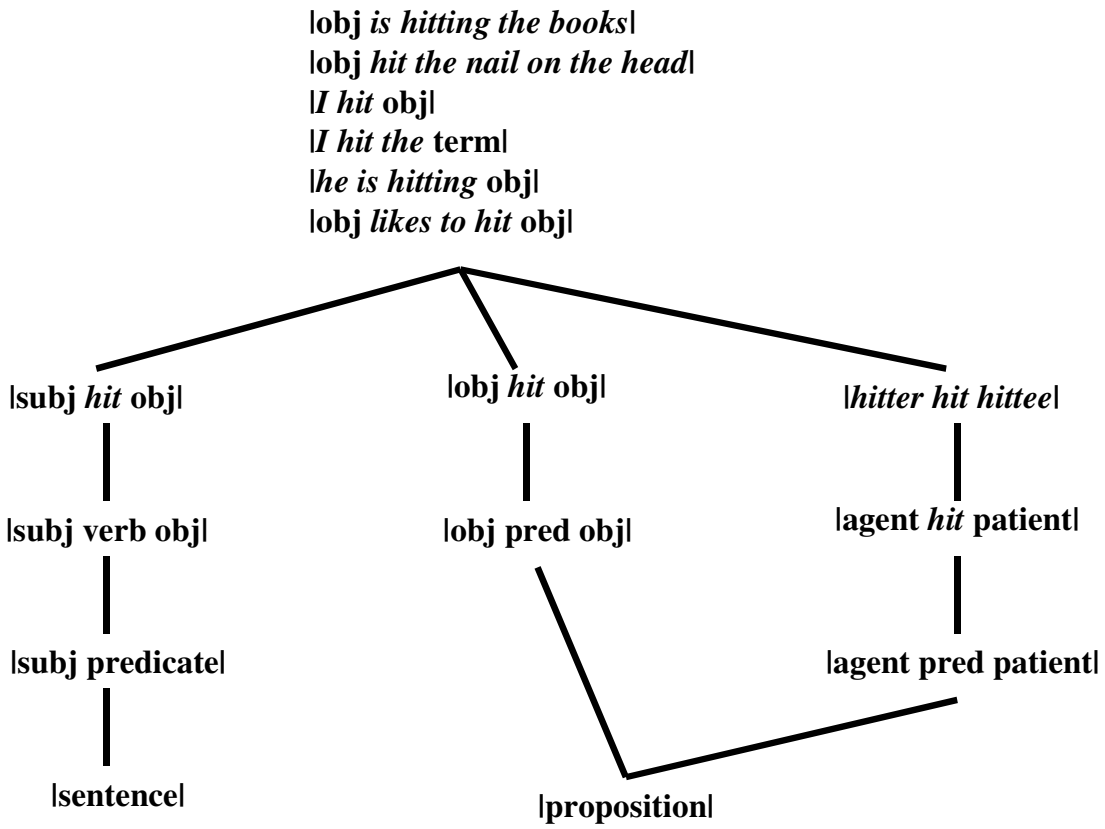

Figure 1.1: Some Possible Schemas for the Verb *Hit*

A consideration of the application of schemas to the processing of language offers several insights. If high level abstract schemas drive the processing mechanism, then the processor can be said to be grammar driven. On the other hand, if low level schemas with specific lexical items drive the processing mechanism, then the processing mechanism is essentially lexically driven. It is an assumption of PM, in agreement with Langacker (1987), that more specific schemas have "priority" over more abstract schemas in normal processing, and that most of the knowledge needed for the processing of familiar expressions has been lexicalized in the form of schemas containing specific lexical items. In unusual situations, abstract schemas may assume greater importance. For example, second language learners who are explicitly taught the grammar of a language may rely on more abstract schemas than native speakers of the language—not only as a result of instruction, but because they may lack the more specific schemas available to native speakers.

It is important to note that schemas set up expectations for the occurrence of various elements, but do not preclude the occurrence of other elements. That is, the application of a schema does not require the exact matching of the elements of the schema with elements of the input text. In this regard, schemas do not behave like the rules of a grammar. For example, the schema **SVO** (e.g. subject-verb-object) set up expectations for the occurrence of a **subject**, **verb** and **object**, but does not preclude the occurrence of an adverb or prepositional phrase in any input text to which the schema corresponds. Thus the schema is entirely consistent with the sentence

He always eats fish on Friday

The occurrence of the adverb **always** and the prepositional phrase **on Friday** in this sentence activate additional schemas which must be integrated with the **SVO** schema during the construction of a representation for this sentence. There is no need for a schema to specify all possible elements which can occur at all possible positions in the schema so long as a mechanism for integrating multiple schemas exists. PM provides such a mechanism. In fact, much of the discussion herein is concerned with this topic. On the other hand, the existence of schemas which are completely specified with regard to their lexical content and are only weakly integrable with other schemas is not precluded (e.g. schemas corresponding to idiomatic and formulaic expressions). In general, abstract schemas will be highly integrable with other schemas, whereas, concrete schemas will be less integrable with other schemas.

In terms of how we acquire schemas, PM agrees with Langacker (1987). An individual is exposed to specific instances of language use and initially acquires rather specific schemas corresponding to those instances. Based on repeated exposure to similar instances with minor differences he or she is able to abstract away from the differences, forming abstract schemas which capture the similarities and abstract away from the differences. Abstraction then provides the mechanism for producing new instances to which the individual has not been exposed. For example, the abstract schema [**obj hit**

obj|, in which the specific linguistic form of the arguments is unspecified, could be used in the production of an infinite number of propositions (theoretically). Thus, schemas allow for the kind of productivity that is apparent in natural language. Under this scenario, abstract schemas are learned and are not innate, and it is not a question of having abstract schemas available and then specifying parameters for specific languages (Berwick & Weinberg, 1984; Chomsky, 1981, 1982b). In an interesting article entitled *Language Acquisition: Schemas Replace Universal Grammar*, Arbib and Hill (1988) put forward a similar position. Further, it does not seem reasonable from a psycholinguistic perspective to suggest that once an abstract schema has been learned, the more specific schemas on which it was based become unavailable for use. Nonetheless, numerous researchers have made proposals which would have just this effect. For example, Hudson's (1984, p. 29) **Linguist's Economy Principle** states that a linguist should

> Never record any property more than once in relation to any entity. That is, once you (the linguist) have decided there is a generalization to be made, you make it in relation to the relevant general category…and then suppress any mention of it in more specific entries which can inherit the information from the general one.

Similarly, in a model of semantic memory, Collins and Quillian's (1969) **Cognitive Economy Principle** assumes that properties of objects are associated directly with the most general category to which they apply and only indirectly with the more specific categories. The psychological validity of this principle in models of semantic memory has already been challenged by Conrad (1972) and Collins and Loftus (1975). As well, the focus on generalization and universality in grammar has led to the creation of very general linguistic categories and to the relegation of idiosyncratic details to the lexicon. However, the more general the categories become, the greater the amount of idiosyncratic detail which must be relegated to the lexicon.

Arguing against such principles, Langacker (1987, p.28) introduces the **Exclusionary Fallacy**, noting that

> The gist of this fallacy is that one analysis, motivation, categorization, cause, function, or explanation for a linguistic phenomenon necessarily precludes another.

PM accepts the validity of Langacker's **Exclusionary Fallacy** and suggests that the above principles commit this fallacy in the name of efficiency and economy of representation. But they ignore the possibility of a trade-off between economy of representation and efficiency of processing. Redundancy in the encoding of information in the internal lexicon at different levels of abstraction is accepted as the norm and may actually improve processing efficiency. This redundancy is functional in that it is not possible to directly encode all values, but the direct encoding of frequently used values reduces considerably the amount of computation required on average.

The existence of schemas at different levels of abstraction is also a generalization of the distinction between **semantic** and **episodic memory** (Tulving, 1972), with semantic memory being composed of schemas which have been abstracted away from specific episodes and entities, and episodic memory containing schemas corresponding to specific events and entities. Further, multiple level schemas are consistent with the distinction between **prototypes**, **exemplars** and **specific instances**. Prototypes correspond to abstract schemas, whereas exemplars and specific instances correspond to specific schemas (the difference between exemplars and specific instances has more to do with reference than level of abstraction). Finally, multiple level schemas can represent the distinction between types and tokens, with types corresponding to abstract schemas and tokens corresponding to specific schemas (the notion of reference is also important to this distinction).

In general, PM argues for the representation and use of specific low level knowledge of language, where possible, and against the extensive use of generalizations and abstractions. PM argues against the cognitive validity of extremely high level abstractions like phrase structure rules of the form **S => NP VP** or **X-bar Theory**. These notions are too abstract to be of much representational value. PM also argues against the use of abstract semantic notions like **agent** and **patient** as basic categories in the system of representation. A person who hunts is a **hunter**, not an agent. The primary semantic categories used in PM are intended to correspond to basic level categories (e.g. Rosch, 1978), rather than the more abstract higher level categories of **Case Grammar** (Fillmore, 1968) or **Conceptual Dependency Theory** (Schank, 1975). In sum, PM makes a strong commitment to the lexicalist hypothesis (Bresnan, 1978; Chomsky, 1970), arguing that much of our more useful knowledge of language is tied to specific lexical items. In this regard, PM's position is more in line with Fillmore's **Construction Grammar** (Fillmore, Kay & O'Connor, 1989) than his earlier Case Grammar. Likewise, Hudson's **Word Grammar** (1984) appears to adopt a similar position; as does Small and Rieger's (1982) **Word Expert Parser**. Finally, PM's position tends toward that of the following claim as reported by Pinker (1989, p.4),

> Elliot and Wexler, in press, have gone so far as to suggest that language acquisition may be nothing but the acquisition of information about the words in the language.

While PM makes a strong commitment to the lexicalist hypothesis, it is true that lexical items themselves vary considerably in their level of abstractness, both in terms of the concreteness of the entities to which they may refer and in terms of their linguistic semantic content. English provides lexical items like **something** and **someone** which are abstract in the sense that they are vague with regard to their semantic content. Such words are typically used in contexts where identification of the referent is either not intended or is obvious given the context. Actually, Johnson-Laird (1987) argues that even content words which tend to have more semantic content than words like those above are more like pronouns than is normally assumed in that they may be used to refer to a wide range of different entities (e.g., consider the variety of entities to which the word **fish** may be used to refer).

Wh-words are used to request information about objects or propositions, but are themselves devoid of such information. The wh-words **who** and **what** are used to request information about objects and the wh-words **what**, **when**, **where**, **why** and **how** are used to request information about propositions. Thus, the wh-words available in English are generally adequate to ask questions about the basic categories of PM's propositional representations. In a sense, the wh-words of English represent a more abstract classificatory scheme then the case roles of Case Grammar. However, it should be remembered that wh-words are used in just those situations where all we know is that there is or might be some object or proposition, without knowing who or what that object or proposition is, or when, where, why or how the proposition occurred. Or if we do know, that knowledge is left unstated, as in the sentence

I know where he is.

PM makes a distinction between linguistically relational and non-relational units and for relational units considers the valency (i.e., the number of arguments the relation is associated with) to be important (relations which take a single argument are more usually called properties). While this extended notion of valency (descriptions of **Valency Grammar** typically only deal with verbs—e.g., Somers 1987) is not so broad as that of Langacker (1987), where all linguistic units have a valency, PM does agree with Langacker in arguing that valency is a semantic notion. In PM, structure is largely represented in the schemas associated with individual relational units. For example, a specific relational unit which takes a single argument may prefer that argument to occur either before it or after it in the input text. The relational units in a piece of text largely determine the structure of that text, and since relational units are semantically based, it follows that structure is largely a reflection of meaning. PM's strong commitment to representing relational structure is most readily seen in its treatment of prepositions. In PM, prepositions take part in two basic propositional schemas |**obj prep obj**| and |**prop prep obj**| (verb particles are treated differently). That is, prepositions (**prep**) establish relations either between two object descriptions (**obj**) or between a propositional description (**prop**) and an object description. A prepositional phrase is an incomplete relational structure in PM. This does not mean that prepositional phrases don't or can't occur in isolation, only that when they do so occur, it is assumed that one of the arguments to the preposition has not been explicitly expressed. The specific treatment of prepositions, which follows from the strong commitment to representing relational structure, differentiates PM from most other linguistic systems of representation.

The focus of this thesis is on the determination of the propositional (or relational) content of written English text. The sentence

The book is on the table

and the expression

have effectively the same relational content. However, they differ in their surface realization. An important reason for this difference is that in addition to encoding relational information, surface text encodes other facets of meaning. In this case, the difference in surface realization reflects the profiling of different elements of the relation expressed by the linguistic expressions. Thus, the above sentence profiles the relationship **is on** which exists between **the book** and **the table**, whereas the noun phrase profiles **the book** which happens to be **on the table**. In general, PM follows Givon (1984) in arguing that surface variation is largely the result of a compromise between the differing requirements for the encoding of both semantic and discourse pragmatic aspects of meaning. For example, according to Givon, the discourse topic is typically encoded as the subject in English, as is the semantic agent of an action. However, when the discourse topic and agent do not coincide in a given sentence, surface variation (e.g., passivation or topicalization) results. While this manuscript does address the meaningful consequences of various aspects of surface variation, as in the difference between the word **red** in **the book is red** and **the red book**, no attempt is made to provide a complete account of surface variation. To large extent, the discussion of the representation and processing of relational entities will assume an unmarked or canonical ordering of lexical items. A more complete treatment will have to show how various schemas function in the representation and processing of marked or noncanonical forms of input.

The fact that surface text encodes multiple aspects of meaning can lead to representational problems for systems of representation which commit the **Exclusionary Fallacy**. For example, the argument over whether the basic structure of the sentence is that of a verb and its complement(s) or a subject and its predicate rests on the **Exclusionary Fallacy** in assuming that the basic structure of the sentence must be one or the other. In fact, the basic structure of the sentence may reflect both the combining of a verb with its complements and the asymmetry in the representational status of subjects and objects. Both PM and **Government and Binding Theory (GB Theory)** allow for this possibility, however, PM is primarily concerned with determination of relational structure, and the asymmetry of subject and objects is not a central concern as it is in GB Theory.

Different languages encode different aspects of meaning. A meaning component which may be crucial to proper expression in one language may be completely missing in another language. This reality does not detract from the meaningfulness of such encodings. It only reflects the crosslinguistic diversity in the encoding of various aspects of meaning. PM agrees with Langacker (1987) in suggesting that the linguistic representation of meaning is to large extent language dependent and non-universal. This position follows from the rejection of anything like a universal nonlinguistic conceptual level of representation. But all is not chaos. After all, languages do reflect reality, they just don't do so via some universal conceptual realm which clarifies all confusions and divides the world up into neat well-defined categories (Lakoff, 1987). Linguistic representations for a given language should represent those aspects of meaning which are

explicitly encoded in that language, and should avoid representing aspects of meaning for which the language makes no provision. According to Fawcett (1988, p. 206),

> the SEMANTICS of a given language…contains THOSE MEANINGS THAT ARE BUILT INTO THE ORGANIZATION OF THE LANGUAGE…

This position is in conflict with the search for language universals to the extent that that search leads to the assumption that purported universals which are not manifested in particular languages nonetheless exist in those languages. Case Grammar is a case in point. English just does not express case roles like agent, patient and instrument as the participants of predications. Rather, in English the participants of predications are specified as semantic complexes called subjects, objects, and complements. That these grammatical categories are semantically based is suggested by Halliday (1988, p. 35)

> In my opinion the category of Subject is no less 'meaningful' (semantically motivated) than other functional categories in grammar.

English also provides for the more specific description of the participants in various relationships via the use of semantic markers like the morpheme **-er** as in **hunter**, **batter**, **runner**, **receiver**, etc., and the less common morphemes **-ee** and **-or** as in **lessee** and **lessor**. The problem with Case Grammar is that it represents a level of organization of meaning which is not manifest in English. The techniques which are available in English for expressing various aspects of meaning are entirely adequate and need not be supplemented by purported universals which are not manifest. Not only are such universals not needed, but since they are not marked in the language, their identification in a given text (to the extent they can be identified) requires the very understanding of that text which they are supposed to facilitate. For example, in the sentence **the man traveled** (Miller & Johnson-Laird, 1976) we just do not know whether **the man** is the **agent** or the **patient**, but we do know that **the man** is the person doing the traveling (i.e. the **traveler**).

It has been suggested that knowledge of language consists largely in the availability of schemas at multiple levels of abstraction, with more concrete schemas carrying most of the burden for language processing. But how might these schemas be organized, and how might they be accessed in language processing? PM assumes that these schemas are organized in the form of an associative network over which a spreading activation process operates (e.g., Anderson, 1984, Collins & Loftus, 1975). As a piece of text is processed, schemas containing representations of lexical items which correspond to lexical items in the input text will be activated and will in turn activate associated schemas to some degree. Given this spreading activation mechanism, it follows that those schemas which most closely correspond to the input text will be most strongly activated. For the most part, these schemas will be concrete and lexically laden. Very abstract schemas which contain no lexical items can only be indirectly activated since they have no direct correspondence to the input text. Further, a schema may be activated despite the fact that it does not correspond exactly to the input text. This fact makes it

possible for the system to deal with degraded or erroneous input, although in general the closer the correspondence between the input text and a schema, the higher the activation of that schema. In addition to the activation mechanism, there must be some selection mechanism for choosing among the activated schemas. In the simplest case this mechanism may simply select the most highly activated schema, and this selection process may be automatic. But selection of a particular schema should not preclude subsequent change in the context of new information and it may also be the case that more than one schema may be selected under certain circumstances (e.g., in the case of puns and double entendres). Thus, the selection process is both tentative (i.e., subject to revision) and preference based (Wilks, 1975a).

In PM there is effectively no grammar and no top-down control mechanism. How then does PM construct representations of input text? Operating on the text from left to right, schemas corresponding to lexical items are activated. For those lexical items which are relational, these schemas establish expectations which both determine the possible structures and drive the processing mechanism. A short-term memory is available for storing arguments which have yet to be integrated into a relational structure, partially instantiated relational structures, and completed structures. If a relational entity is encountered which expects to find an argument to its left in the input text then that argument is assumed to be available in short-term memory. If the relational entity expects to find an argument to its right in the input text, then the relational entity is stored in short-term memory as a partially completed structure and waits for the occurrence of the appropriate argument. When that argument is encountered it is instantiated into the relational structure in short-term memory. In the case where the text contains a profiled or otherwise salient non-relational entity, that entity may be made separately available in short-term memory. Otherwise, non-profiled and non-salient arguments are incorporated into relational structures and are not separately available in short-term memory. This keeps the number of separate linguistic units which must be maintained in short-term memory to a minimum. A key component of the processing mechanism is the activation and selection of schemas associated with the relational units in the input text. These schemas set up expectations which drive the processing mechanism and they also function as the key determiners of the structure of the input text.

Many of the topics which have been introduced in this chapter will be explored in more depth in subsequent chapters. Chapters 2 to 5 present PM's system of representation at progressively more detailed levels of analysis. Chapter 2 presents an overview of PM's system of representation. Chapters 3 and 4 provide a more detailed examination of the relational structure of written English. Chapter 5 explicates the relationship between PM's system of representation and the more detailed and often orthogonal representational concerns of traditional grammar. Chapter 6 is concerned with the processing of English text into propositional representations.

In terms of historical development, the development of PM was influenced early on by the research of Y. Wilks and his **Preference Semantics**. C. Fillmore's **Case Grammar** was also an early influence. A reading of Winograd's *Language as a Cognitive Process* and T. Givon's *Syntax, a Functional-Typological Introduction* moved development of the

model in a more cognitive direction. Subsequently, the major research programs of W. Kintsch, J. R. Anderson, G. A. Miller, P. Johnson-Laird, H. Clark, E. Clark, M. Just, P. Carpenter, and R. Jackendoff were influential. More recently, the work of G. Lakoff, W. Chafe and especially R. Langacker has reinforced my confidence in the validity of the model and provided many new insights. Of course many other researchers not mentioned above have influenced the model in significant and positive ways, and perhaps I should also mention the significant if countervailing influence of researchers like N. Chomsky, J. A. Fodor, L. Frazier and R. Schank (for differing reasons).

Chapter 2: Overview of PM's System of Mental Representation

Introduction

This chapter begins with an overview of PM's system of mental representation followed by a consideration of the perceptual basis of mental representation. The chapter continues with a consideration of the psychological validity of propositional representation followed by a description of the particular form of propositional representations used in PM. PM assumes that the basic structure of the sentence is propositional, with the main verb corresponding to the predicate and the subject and objects corresponding to the arguments of the predicate. The arguments of the predicate are typically object descriptions, but they may also be embedded propositional descriptions. The representation of the propositional structure of a sentence is called a **propositional description** in PM. Propositional descriptions are linguistically based and contain actual and ambiguous linguistic tokens. They are disambiguated via their relationships to other linguistic representations and to two types of nonlinguistic representation: (a) representations of prototypes and exemplars which ground the sense of propositional and object descriptions, and (b) representations of specific instances which are the referents of propositional and object descriptions. The importance of nonlinguistic representations for grounding the meaning of linguistic representations will be addressed to some extent, however, the focus of this chapter is on the representation of propositional descriptions. As such, the grounding of propositional descriptions in nonlinguistic representations will not be considered in detail. Despite this omission, PM assumes that linguistic representations are systematically and meaningfully related to nonlinguistic representations such that the structure of linguistic representations is a reflection of the structure of the world. In this regard, PM agrees with Russell (1969),

> I believe that by means of a study of language much can be learned about the structure of the world.

PM's System of Mental Representation

In Cognitive Psychology there is a long-standing debate over the validity of **dual code** vs. **propositional code** theories of representation (Kosslyn, 1980; Paivio, 1971, 1986; Pylyshyn, 1973, 1984). In dual-code theory there are two distinct types of representations, verbal and imaginal, which are generally assumed to be modality dependent and essentially different in nature. In propositional code theory there is a single modality independent level of representation (a language of thought). PM's position is a mixture of these two theories. Like dual-code theory, it assumes that there are two types of representation, linguistic and nonlinguistic. However, unlike dual-code theory, it assumes that the difference in these two types of representation results from the

different nature of the input, not from any inherent difference in the nature of representation. Like propositional code theory, it accepts the validity of propositional representations. However, unlike propositional code theory, it does not assume that there is some completely abstract, non-perceptual, modality independent language of thought where propositional representations reside. Rather, it is assumed that linguistic representations have a propositional structure, and that that structure is a reflection of the systematic relationship between linguistic and nonlinguistic representations. Like dual-code theory, it is assumed that there is no level of representation which is completely independent of perception. Linguistic representations are abstractions of linguistic input and nonlinguistic representations are abstractions of nonlinguistic input. However, unlike dual-code theory, it is assumed that there are representations at multiple levels of abstractions such that very abstract linguistic and nonlinguistic representations approach (but never attain) the level of abstraction of the representations put forward in propositional code theory. Except as noted above, PM is in general agreement with the following two quotes:

> The guiding theoretical assumption is that internal (mental) representations have their developmental origin in perceptual, motor, and affective experience and that they retain those experientially derived characteristics so that representational structures and processes are modality specific rather than amodal. The assumption implies the continuity between perception and memory as well as between behavioral skills and cognitive skills…The empiricist claim also implies that mental representations cannot be completely abstract…(Paivio 1986, p. 55-6).

> …I will assume that all knowledge either takes the form of perceptual images or of verbal predications…Saying that all knowledge is either perceptual or verbal implies that there is no room for 'concepts' or 'ideas' apart from those which can be captured by either images or verbal predications or combinations of these. (Dik 1987a, p. 160).

The basic relationship between linguistic and nonlinguistic representations is one of grounding. Nonlinguistic representations ground the sense and reference of related linguistic representations. Nonlinguistic representations of prototypes and exemplars (i.e., previous instances) ground the sense of corresponding linguistic representations, and nonlinguistic representations of current instances ground the reference of corresponding linguistic representations. Linguistic representations may be directly related to other linguistic representations, and may gain much of their meaning from such associations, but linguistic representations are ultimately ground in nonlinguistic representations (see Figure 2.1).

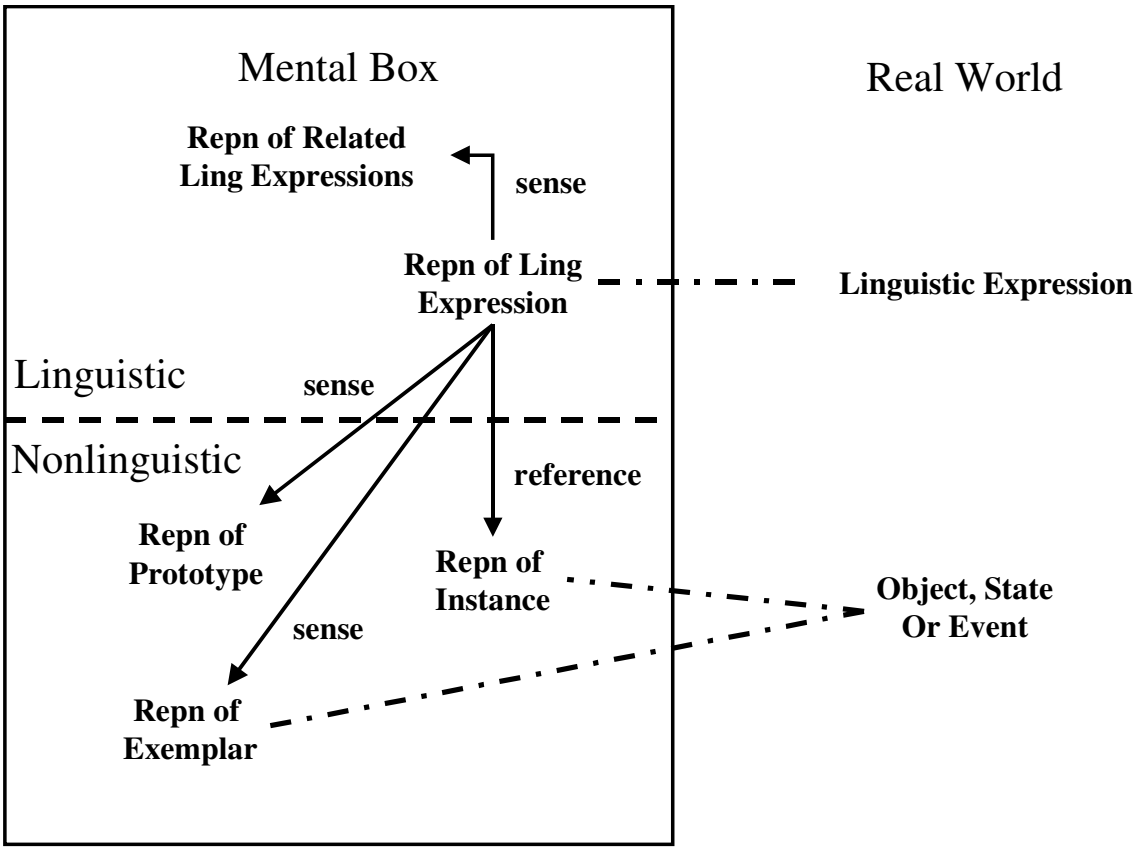

Figure 2.1: PM's System of Mental Representation

The Perceptual Basis of Mental Representation

As was stated above, PM adopts a variant of Paivio's (1986) dual-code hypothesis. However, dual-coding results from the nature of input to the system, and not from any basic partitioning of the system of representation itself. Both linguistic and nonlinguistic representations are perceptually based abstractions. Thus, in the case of written linguistic input, the resulting representations may abstract away from the particular font or case of the actual input. And in the case of nonlinguistic input, the resulting representations may abstract away from pervasive details like color and texture as well as specific details about individual objects and activities. The process of abstraction results from the activation of existing mental representations by the input. These representations are learned from experience such that exposure to a range of similar experiences results in the creation of mental representations which capture the similarities between those experiences and abstract away from the differences. PM makes no commitment to the existence of a single correct level of representation. However, since the creation of mental representations is based on experience, if those experiences reflect levels of representation, then such levels will be encoded in memory. Thus, for readers of English, there is likely to be a level of representation for letters and words, but there is no suggestion that mental representations at other levels cannot or do not occur. There are of course perceptual considerations which interact with experience in determining which mental representations are constructed. For example, the internal contiguity of a stimulus and its external separateness from other stimuli are likely to be influential. On this basis, letters and words are again posited as likely candidates for separate representation in memory.

Based on experience, humans also construct representations of nonlinguistic entities and activities. Perceptual influence is demonstrated here by empirical evidence in support of the existence of basic level categories (Lakoff, 1987; Rosch, 1975). Although basic level categories are learned early on, humans are also capable of constructing representations for more abstract categories as well as more specific but less perceptually salient categories. The creation of linguistic categories relies on the same basic cognitive abilities as those required for the creation of nonlinguistic categories (Taylor, 1989) and the resulting categories exhibit characteristics of prototypicality, family resemblance, radial structure and the like (Lakoff, 1987). During the course of a lifetime, humans create a large stock of linguistic and nonlinguistic representations at multiple levels of abstraction and complexity which are available for interpreting incoming stimuli.

In PM, there are no completely abstract representations, since there is no way for such representations to get into the system and since I do not believe that innate mental representations exist (and even if they did exist, how would they become associated with actual inputs?). The introductory chapter has already discussed some objections to the assumption that abstract conceptual representations are needed for dealing with problems of synonymy and equivalence of sentences. The main point of that discussion is that such representations offer no real solution to the problem.

The situation with regard to word sense disambiguation is similar. Assuming the existence of abstract word senses appears to provide a means for dealing with the important problem of lexical disambiguation—we need only decide which sense of a word is being used in a given context. However, there is no sound basis for deciding what the word senses for a given word should be. Abstract word senses make most sense in just those cases where there are significant perceptual differences between the entities, activities or states to which the word is used to refer. Assuming the existence of nonlinguistic mental representations corresponding to such entities, activities and states, we need only associate ambiguous words with the corresponding nonlinguistic representations to capture the different senses of such words, and there is no need to posit the existence of abstract word senses. For example, consider the ambiguous word **bank**. Assuming the existence of nonlinguistic mental representations corresponding to banks as **financial institutions**, **boundaries of rivers** and **turning activities** of moving entities, there seems no reason to posit the existence of abstract word senses corresponding to these senses of the word.

There is no suggestion in all of this that nonlinguistic representations provide an escape from the mental box (see Figure 2.1). Nonlinguistic representations are themselves symbolic. Wilks' (1988) "**autonomy of symbolism**" is certainly correct. The use of the term **reference** to refer to the relationship between linguistic representations and one type of nonlinguistic representation (e.g., representations of specific instances) is not meant to suggest an escape from the mental box. However, it is assumed that nonlinguistic representations are representational analogues of the real world, and that it is reasonable to talk about linguistic representations referring to such nonlinguistic representations. It is also assumed that such nonlinguistic representations may be richly structured and directly meaningful, and that the meaning of linguistic representations is ultimately ground in these nonlinguistic representations.

Given the grounding of linguistic representations in nonlinguistic representations, it is assumed that nonlinguistic representations will form an important part of any reasonable model of language comprehension. However, the attempt to incorporate nonlinguistic representations into models of language comprehension is made exceedingly difficult by the nonexistence of such entities in the current metaphor for the mind—the computer. We just don't know how to represent and manipulate nonlinguistic representations in computational terms. Those few researchers who have attempted to deal with nonlinguistic representations in computational terms have met with much skepticism. And not without justification, since their attempts seem crude and limited. One such attempt is Johnson-Laird's description of **Mental Models** (1983). But his effort leaves me wondering if I know (he knows) what a Mental Model is when all is said and done. Even his simplest examples which rely on spatial orientation of simple objects leave one in doubt as to the validity of these models. At least Johnson-Laird does attempt to provide a computational account of some types of nonlinguistic representation. Langacker (1987) makes no such attempt in describing his nonlinguistic **Semantic Poles**, nor is such an account at all obvious. Can one really imagine "something being over something" or is language far vaguer than nonlinguistic representations of real world situations are capable of being?

Clearly, PM has something of a problem. On the one hand, the importance and relevance of nonlinguistic representations to the process of language comprehension is taken as given. On the other hand, it is not known how to actually go about incorporating nonlinguistic representations into the system of representation. Working within the computer metaphor, about the best that can be done is to suggest positing the existence of unstructured constants corresponding to nonlinguistic representations of prototypes, exemplars, and specific instances which can then be used to ground linguistic representations. Numerous computationally based models of language processing which have been put forward have adopted approaches along this line (e.g., Anderson, 1983; Clark & Clark, 1977; Clark & Haviland, 1977; Fauconnier, 1985; Just & Carpenter, 1987; Kamp, 1988, Kintsch & van Dijk, 1978; Rapaport et al., 1989; Shadbolt, 1984). Typically such models posit the existence of constants or quantified variables corresponding to the referents of linguistic expressions and rely on the use of unambiguous metalinguistic symbols to represent concepts, word senses or predicates. PM suggests that these metalinguistic symbols are themselves no more than constants, despite their different surface form in such models. In essence, these models make use of two types of constant, constants which ground the sense of linguistic expressions, and constants which ground the reference of linguistic expressions.

Unfortunately, PM will not offer a new approach to the integration of nonlinguistic representations into a system of mental representation. That effort falls outside the current scope which is focused on the construction of propositional descriptions from written English sentences. Nonetheless, the importance of nonlinguistic representations to a more complete treatment of language comprehension is assumed. Such treatments will have to seriously contend with the imaginal and analog nature of nonlinguistic representations. I optimistically look forward to the appearance and development of such models. However, Block (1990) is less optimistic in this regard. He suggests that imaginal or analog processes may be grounded in neurophysiology and may, therefore, be impervious to explanation within cognitive science (since there are no representations to speak of). In a fairly neutral context he states

> At one extreme, we can imagine that the brain is a single analog processor – in which case cognitive science is a flat-out dead end. At the other extreme, we can imagine that imagistic primitives are involved in a few peripheral realms of cognitive activity, and that connections among different types of imagistic processes are handled by a central descriptional system. In this case, cognitive science is unscathed. (p. 599)

Block's main thesis is that much of cognition may involve such primitive analog processes.

> …my point is that such processors would probably carry much more of the load of explaining how the mind works than is envisioned by current proponents of the computer metaphor (p. 598).

PM accepts Block's suggestion that imaginal and analog processes form an important part of cognition (and more specifically language processing), but does not assume that such processes are outside the realm of explanation of cognitive science (although providing such explanations may involve rejection or substantial modification of the prevailing computer metaphor of the mind).

The Psychological Validity of Propositional Representations

Propositional representations are a mainstay of many psychologically based models of language comprehension (Anderson, 1976, 1983; Clark & Clark, 1977; Just & Carpenter, 1987; Kintsch, 1974, 1998; Kintsch & van Dijk, 1978; Miller & Johnson-Laird, 1976). Unfortunately, the psychological validity of such representations is not firmly established. Rather, researchers have generally adopted propositional representations as largely unsupported elements of their theories. In a review of these models, specifically looking for such support, I was surprised at how little was provided. Van Dijk and Kintsch (1983) have perhaps made the strongest attempt at motivating such representations. However, even that attempt is not convincing and in the end they are left suggesting that,

> In part because of a lack of serious alternatives, the proposition has been taken as a fundamental unit in cognitive semantics" (van Dijk & Kintsch, 1983, p. 124).

And later,

> In a sense we will take propositions for granted as theoretical units of a cognitive model… (van Dijk & Kintsch, 1983, p. 125).

They further note that

> Our claim that propositions are suitable units for a cognitive model is made in spite of repeated warnings from philosophers and logicians to the contrary" (van Dijk & Kintsch, 1983, p. 125).

Despite the disclaimers of van Dijk and Kintsch, propositional representations do appear to have some theoretical support. One is on fairly sound footing in allowing for the existence of objects and relations (between or among objects) in one's ontology of mental entities. Most philosophers include such entities in their own ontologies (with the possible exception of Quine's objectless ontology). To the extent that propositional representations are composed of representations of objects and relations between objects (or properties of objects), they inspire little controversy, either theoretically or psychologically. It is in the consideration of specific systems of propositional representation that theory and psychology diverge. For example, the hypothesis that the language of thought is none other than the First Order Predicate Calculus (FOPC) has inspired much controversy in psychological circles (e.g., Johnson-Laird, 1983; Braine,

1978). Jackendoff (1983) includes an important criticism of FOPC as a basis for mental representation. And higher order logics have even more serious problems as psychological models of mental representation. For example, the theoretical notion of possible worlds has little psychological support. Likewise, the treatment of the denotation of a singular term as the set of all objects to which the term applies is a psychologically implausible treatment.

Many researchers have been willing to overlook the psychological shortcomings of systems of representation like the FOPC in order to take advantage of the formalization and proof procedures they provide. I have even seen claims to the effect that a system of representation which provides no proof procedure is valueless (Kamp, 1988). This researcher disagrees with such statements and is willing to give up on the formalization and proof procedures (temporarily) in order to pursue the development of a more psychologically plausible propositional system of representation. The hope is that the end result will be a system of representation which is both psychologically plausible and theoretically well formalized.

Although there is only limited theoretical support for the use of propositional representations in cognitive modeling, such representations are at least consistent with a large body of empirical evidence. For example, Kintsch and Keenan (1973) have demonstrated a correlation between the complexity of sentences as measured by the number of propositions in those sentences and processing difficulty. And Anderson (1976, 1983) has conducted many studies of memory, the results of which are consistent with a propositional organization of information in memory. Thus, despite the lack of a sound theoretical basis for the use of propositional representations in cognitive modeling, such representations are at least consistent with much of the available experimental evidence.

Studies of sentence comprehension point to the existence of something like a propositional level of representation, but they do not preclude the existence of other types or levels of representation. Two other forms of representation which have been studied extensively are the linear encoding of sentences in memory (Anderson, 1983, is a proponent of such representations) and the existence of syntactic representations like those posited in **Transformational Grammar** (Chomsky, 1965, 1957). While linear and syntactic representations are not precluded, the studies cited above argue against the relevance of such representations for language comprehension. Further, according to Tanenhaus (1988, p.11)

> By the middle of the 1970's there remained no unequivocal evidence that transformational grammar provided a model of either the rules or representations that listeners and speakers use during comprehension (Johnson-Laird 1974).

Nevertheless, several psychologically informed models of language representation and process have been proposed which include a Transformational Grammar based syntactic level of representation (e.g., Bresnan, 1982; Ford, 1986; Frazier & Fodor, 1978). The

validity of syntactic representations and the question of their autonomy from semantic influence was a hotly debated topic in psycholinguistics in the late 1980's and early 1990's (e.g., Coltheart, 1987; Garfield, 1987). On the other hand, the validity of some propositional, functional or logical level of representation is accepted by most researchers—with the possible exception of researchers positing distributed connectionist (subsymbolic) models of language comprehension (Rumelhart & McClelland, 1986; Smolensky, 1990; but see Fodor & Pylyshyn, 1988, and Pinker & Prince, 1988, for arguments against the subsymbolic position).

Specification of the Propositional Representations Used Herein

A major topic of this work is the propositional representation of linguistic expressions. In PM, such representations are called propositional descriptions to emphasize their linguistic and descriptive basis. Propositional descriptions contain actual and ambiguous linguistic tokens. They are disambiguated via association with related linguistic representations and with nonlinguistic representations of corresponding prototypes, exemplars and specific instances.

PM's use of the term proposition differs from that of most other psychologically based systems of representation. The relationship between PM's use of this term and others (e.g., Clark & Clark, 1977; Just & Carpenter, 1987; Kamp, 1988; Kintsch, 1974; Miller & Johnson-Laird, 1976) is shown by the following example. A typical propositional representation of the sentence

The man hit the ball

is given by

HIT(m,b) & MAN(m) & BALL(b).

In this representation, the capitalized words **HIT**, **MAN** and **BALL** are unambiguous metalinguistic representations of abstract concepts which, for convenience, reflect the spelling of the linguistic tokens which evoked them, and the constants **m** and **b** (one could choose to use existentially quantified variables instead) are referential pointers to the corresponding objects in the world (or some model of the world) to which the concepts apply. The corresponding representation in PM has the form

hit(the man, the ball),
hit(Obj-X,Obj-Y) & the(Term) & man & ball …
m & b & H(m,b)…

The first element of this triple is a propositional description containing actual and ambiguous linguistic tokens. The second element (inadequately) represents the sense of the propositional description, and the third element (inadequately) represents the reference of the propositional description. In the representation of the sense of the

propositional description, **hit(Obj-X,Obj-Y)** is a representation of a prototypical linguistic form of the verb **hit**, **the(Term)** is a representation of the prototypical linguistic form of the determiner **the**, **man** and **ball** are representations of the prototypical linguistic forms of the nouns **man** and **ball**, and the continuation suggests the possible inclusion of other prototypical linguistic forms as well as nonlinguistic representations of prototypes and exemplars. In the representation of the referent of the propositional description, the constants **m** and **b** are the referents of the expressions **the man** and **the ball**, respectively, and the structure **H(m,b)** is the referent of the entire propositional description.

A propositional description is a representation of a piece of text in terms of the predicate/argument structure of that text (see Figure 2.2). In a propositional description, the predicate specifies the type of state of affairs, action or event, and the arguments specify the type of participants in the state of affairs, action or event. All the elements of propositional descriptions are themselves descriptions (i.e., propositional descriptions do not contain any referential elements). A predicate in a propositional description is described by a linguistic entity which specifies a property of some argument or a relation between either two or three arguments. The arguments to the predicates are themselves described by linguistic expressions. Together with the description of the predicate, they constitute a propositional description. Predicates are linguistically relational. That is, predicates are linguistic units which must stand in relation to some other linguistic unit or units and are incomplete linguistic units in and of themselves. On the other hand, predicates are referentially non-relational. That is, predicates have no referential aspect in and of themselves. It is the propositional description as a whole and not the predicate which refers to a state of affairs or event. For example, in the sentence

The man hit the ball

it is the entire propositional description

hit(the man, the ball)

which refers to an event and not just the predicate **hit**. The argument descriptions which participate in propositional descriptions are linguistically nonrelational. That is, argument descriptions are linguistically complete units which may stand on their own and need not be in some relationship with other linguistic units.

Propositional descriptions include two types of arguments: embedded propositional descriptions and object descriptions (see Figure 2.2). The existence of propositional argument descriptions and propositional modifiers gives propositional descriptions a recursive potential.

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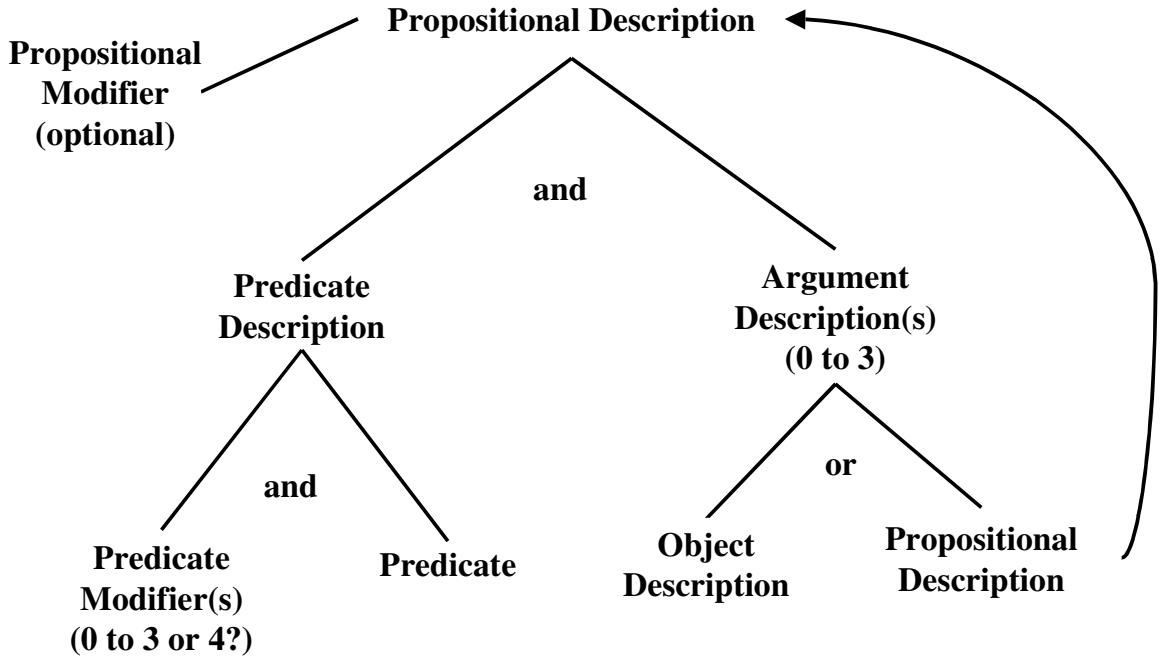


Figure 2.2: The Representation of Propositional Descriptions

Object argument descriptions are the descriptions of objects which participate in propositional descriptions. An object argument is a triple consisting of an object description, associated linguistic and nonlinguistic representations which explicate the sense of the object argument, and a representation of the referent of the object description.

An object description is a representation of a piece of text in terms of the function/argument structure of that text (see Figures 2.3 and 2.4). Functions come in three basic types: (a) functions which indicate that the object description is a referring expression (i.e. specifiers or determiners), and (b) functions which explicate some property of an argument or establish a relationship between two arguments, but which are not concerned with reference, and (c) functions which modify functions. Generally speaking, functions which function as specifiers combine with terms to form object descriptions, functions which explicate some property of an argument, combine with terms to form complex terms, and functions which modify functions combine with them to form complex functions. The distinction between an object description and a term has to do with the notion of reference. For example, the function **old** can combine with the term **man** to form a complex term which can be represented as

<old<man>>

where **<>**'s are used to indicate the category **term**. This complex term can combine with the determiner **the** to form a full object description which can be represented as

(the<old<man>>)

where ( )'s indicates that the resulting structure has the status of an object description.

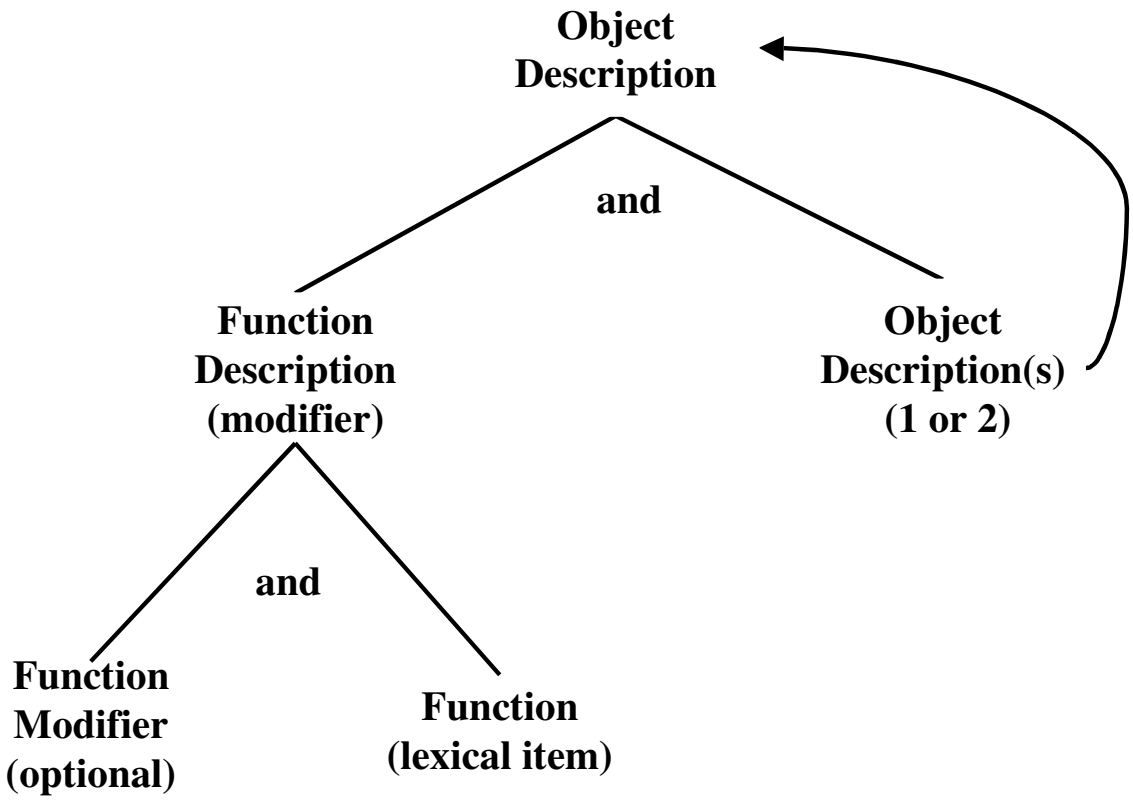


Figure 2.3: The Representation of Object Descriptions

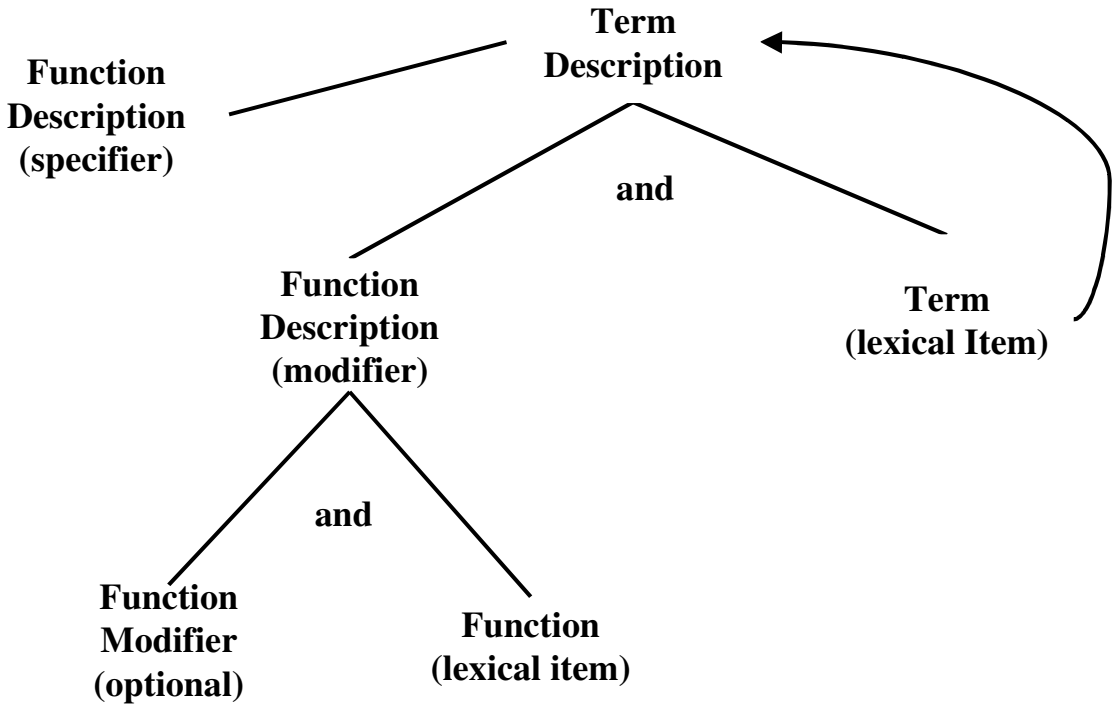


Figure 2.4: The Representation of Term Descriptions

The adoption of the representational categories described above is based in part on the assumption that English has a predicate/argument structure at the level of the sentence, such that the main verb corresponds to the predicate and the subject and objects correspond to the arguments of the predicate. In the predicate calculus, arguments are merely pointers (either fixed or variable) to objects in the domain being considered. The arguments in the predicate calculus have a purely referential function (i.e., they have no descriptive content). In most propositional systems of representation based on the predicate calculus, all descriptive information is expressed by predicates—despite the fact that the use of descriptive predicates in the predicate calculus is no more than a notational convenience. However, in English, both the verb (predicate) and the subject and objects have considerable descriptive content. If one desires to map a propositional analysis of English onto predicate calculus representations, few choices are available. The descriptive content of subjects and objects can be translated into predicates (the typical approach), the descriptive content of the subject and objects can be ignored (more common than might be imagined), or we can allow arguments as well as predicates to have descriptive content. This third approach is reflected in the introduction of the **iota** operator into the predicate calculus (e.g., Allwood, Andersson & Dahl, 1977). The iota operator allows formulas containing predicates to refer to individual constants and is used in the representation of definite descriptions. For example, according to Allwood et al. (1977, p. 152)

> Using this operator, we can write e.g. 'the x such that it has a property F' as iota-x(F(x)).

PM's treatment of object arguments is like that of the iota operator in that it allows object arguments to have descriptive content. However, instead of introducing a special operator which maps propositional arguments into object arguments, PM introduces two new types of linguistic entities to represent the internal linguistic structure of object arguments. I have chose to call these two types of entities **functions** and **terms**. As stated above, functions are the relational elements and terms are the non-relational base entities of object descriptions.

There is a clear correspondence between predicates and functions and between objects and terms. The distinction between predicates and functions is closely tied to the distinction between propositional and object descriptions. Essentially, a propositional description is used to refer to an action, event or state of affairs and in so doing indirectly refers to the participants in that action, event or state of affairs. On the other hand, an object description is used to refer to an object or entity and in so doing may indirectly refer to a property of that object or to a relation between that object and another object. The focus of the propositional description is on the relation and the relation may be said to be the **head** of the propositional description, whereas the focus of the object description is on the object and the term which provides the most descriptive content functions as the head of the object description, with relational elements functioning as **modifiers** of the head.

The difference between predicates and functions has important implications for the system of representation. That difference is not relational, but it is certainly meaningful. For example, it seems reasonable to suggest that the expression

The red book

is about "something" which happens to be a red book, whereas the sentence

The book is red

is about something being red which also happens to be a book. Numerous attempts to capture this distinction have been made. Langacker (1987) makes use of the term **profile** in arguing that noun phrases and sentences like those above serve not only to describe properties of objects, but also to differentially profile elements in those descriptions. The traditional distinction between **heads** and **modifiers** is based on similar considerations. Heads are frequently described as what the larger expression of which they form a part is essentially about. And modifiers are constituents which provide additional information about the head. Based on this distinction, it has been claimed that verbs are the heads of sentences, with subjects, objects and other complements functioning as modifiers, whereas nouns are the heads of noun phrases, with adjectives and prepositional phrases functioning as modifiers. **Dependency Grammar** (e.g., Matthews, 1981) makes use of an adaptation of this distinction in suggesting that modifiers depend on their heads. Thus, verb complements depend on the main verb in sentences in which they participate, and adjectival and prepositional phrase modifiers depend on the head noun in noun phrases in

which they participate. From a relational perspective, this notion of dependency is unmotivated. Relations are incomplete units of meaning which depend on their arguments to complete the idea they are used to express. Objects, on the other hand, are not dependent on the relations in which they participate for their meaning. For example, it is difficult to think about an act of hitting without thinking about something being hit and something doing the hitting. On the other hand, it is not difficult to think about a ball in isolation from any relations it might participate in. The notion of dependency adopted in PM is related to that of Langacker (1987, p. 306ff) rather than dependency grammar.

The distinction between predicates and functions is also tied up with the notion of presupposition. Functions are presupposed. They are used in the identification of referents and it is assumed that the relational information provided is known. In **the red book** it is presupposed that the book is red, and this information is (or may be) used in the process of identifying the referent of the expression. Predicates are asserted. In **the book is red** it is asserted that the book is red.

From a processing perspective, the distinction between predicate and function is important because the same relation behaves differently in each context. For example, the argument to a predicate adjective occurs to its left in English, whereas, the argument to an attributive adjective occurs to its right. Further, transitive verbs used predicatively expect two arguments (e.g. **the team is kicking the ball**) whereas, transitive verbs used functionally expect only a single argument (e.g. **the kicking team**), with the nonsalient argument being left unexpressed. The difference between the predictival and functional used of a relation is not marked by the word form itself, but must be determined from the context in which the word occurs.

Linguistic Semantics

PM assumes the meaning of most (if not all) linguistic expressions is ultimately determined via relationships with nonlinguistic representations (and processes operating over such representations). However, as noted above, PM is not concerned with the development of a nonlinguistic semantics, nor is such a semantics readily available elsewhere. While linguistic representations are ultimately grounded in nonlinguistic representations, it is assumed that the structure of linguistic representations is systematically and meaningfully related to the structure of corresponding nonlinguistic representations. Hence, a purely linguistic semantics can go a long way toward explicating the meaning of linguistic expressions. On the other hand, PM does not include such notions as **concept** or **word sense** in its ontology—notions which are crucial to most studies of linguistic semantics. PM's ontology does include such notions as prototype, exemplar and instance, and suggests that the meaning of linguistic expressions is ground in these notions.

A major objective of the research described herein is the eventual development of computer based natural language understanding systems. In the absence of an adequate nonlinguistic semantics, it may be necessary to rely on existing theories of linguistic

semantics in the development of NLU systems—at least for the foreseeable future. In that effort, such notions as word sense and concept may be exploited as useful fictions, without making ontological commitments to their existence, and in full recognition of their shortcomings.

Chapter 3: The Representation of Propositional Descriptions

Introduction

This chapter considers the representation of propositional descriptions corresponding to written English sentences. Given the assumption that English text has an underlying propositional structure composed of predicate descriptions and descriptions of associated propositional and object arguments, what are the range of such structures which actually occur in English? Initially, nine basic propositional forms (i.e. abstract propositional schemas) will be considered. Subsequently, some additional propositional forms will be suggested. The next chapter presents a consideration of the relational structure of object descriptions. The relational structure of object descriptions is similar in many ways to that of propositional descriptions. Predicates combine with arguments to form propositional descriptions, and functions combine with arguments to form object descriptions. Predicates are the relational elements of propositional descriptions and functions are the relational elements of object descriptions.

As part of the exploration of the categories relevant to a propositional analysis of English, PM's system of categorization will be compared to the traditional grammatical classification of words, phrases and clauses. In general, PM's propositional categories are more abstract than are traditional grammatical categories. The relationships between the propositional categories and grammatical categories are summarized below:

Propositional Description => Clause, Sentence, Conjoined Clauses and Sentences

Predicate Description => Verb, Adjective, Adverb, Preposition, Auxiliary Verb,
Modal Auxiliary, Negative, Verb Particle,
Conjunctions of the above

Predicate Specifier => Auxiliary Verb, Modal Auxiliary, Negative?
Conjunctions of the above
Predicate Modifier => Adverb, Verb Particle, Negative?,
Prepositional Phrase,
Conjunctions of the above
Propositional Modifier => Adverb, Prepositional Phrase,
Conjunctions of the above

Object Description => Noun Phrase, Noun Phrase + Prepositional Phrase,
Conjunctions of the above

This comparison makes sense given the assumption that grammatical categories constitute a system of classification that is semantically motivated and not purely syntactic (Chafe, 1970; Jespersen, 1965; Lakoff, 1987; Lyons, 1977; Taylor, 1989).

The Representation of Propositional Descriptions

Predicates are the linguistically relational entities which largely determine the structure of propositional descriptions. The prototypical predicate is the verb, however, there are numerous other types of predicates as shown above. In PM, predicates are specified in terms of both the number and type of the arguments they take. For example, there is a category of predicate which takes two arguments, the first of which is an object description and the second of which is a propositional description. This category is exemplified by verbs which express a propositional attitude (e.g., **believe**, **think**, **know**, as in, **I believe he likes me**).

In total, nine basic propositional forms can be identified:

He went	**pred(obj)**	**[went(he)]**
He kissed me	**pred(obj,obj)**	**[kissed(he,me)]**
He gave me it	**pred(obj,obj,obj)**	**[gave(he,me,it)]**
He quickly went	**pred(prop$_{head}$)**	**[quickly([went(he)])]**
He believes you like me	**pred(obj,prop)**	**[believes(he,[like(you,me)])]**
He kissed me by it	**pred(prop$_{head}$,obj)**	**[by(kissed(he,me)],it)]**
He told me you like him	**pred(obj,obj,prop)**	**[told(he,me,[like(you,him)])]**
I like you and you like me	**pred(prop$_{head}$,prop$_{head}$)**	**[and([like(I,you)],[like(you,me)])]**
He ate, I sang and she sat	**pred(prop$_{head}$,prop$_{head}$,prop$_{head}$)**	**[and([ate(he)],[sang(I)],[sat(she)])]**

In addition, there are four forms of predicate modification:

I am sad	**pred{pred$_{head}$}(obj)**	**[am{sad}(I)]**
He went over it	**pred{pred$_{head}$}(obj,+obj)**	**[over{went}(he,it)]**
He hit and kicked it	**pred{pred$_{head}$,pred$_{head}$}**	**[and{hit,kicked}(he,it)]**
He hit, kicked and bit it	**pred{pred$_{head}$,pred$_{head}$,pred$_{head}$}**	**[and{hit,kicked,bit}(he,it)]**

In terms of notation, **pred** is a predicate description, **obj** is an object description, and **prop** is a propositional description. **( )**'s are used to circumscribe the arguments of the predicate. In these abstract schemas, the surface order of the predicate relative to the arguments is left unspecified, however, the order of the arguments is significant. The two forms **pred(obj,prop)** and **pred(prop$_{head}$,obj)** differ in this latter respect. All of the basic propositional forms result in propositional descriptions when the predicate and arguments are instantiated. **[ ]**'s are used to circumscribe a complete propositional description. **( )**'s are used to circumscribe a complete object description, however, the **( )**'s around object descriptions will be dropped when the object description functions as an

argument in one of the basic forms. Thus, the propositional description **[went(he)]** would be represented as **[went((he))]** if the inner ( )'s had not been dropped. For embedded propositional descriptions the **[ ]**'s will not be dropped since the ( )'s surrounding the arguments of a predicate suggest that the arguments are object descriptions and not propositional descriptions. For predicate modification, **{ }**'s are used to circumscribe the predicate being modified.

The basic propositional forms are annotated to reflect the **head** of the resulting form whenever the main predicate of the form is not the head. There are four instances of propositional modification and four instances of predicate modification where this is the case.

The decision to represent the order of arguments, but not the relative position of the predicate can be questioned. More abstract schemas which abstract away from the surface order of arguments could be posited. Thus, the two forms **pred(obj,prop)** and **pred($\mathbf{prop_{head}}$,obj)** could be collapsed into a single form (ignoring the different heads of the forms)—although it is difficult to describe such a form in linear text. Alternatively, more concrete schemas which specify the position of the predicate relative to the arguments could be posited resulting in forms like **|obj pred prop|** and **|prop pred obj|** where the **|** **|**'s suggest an uninstantiated propositional description. If we provide functional labels for the arguments of the predicate we get a schema of the form **|subj pred obj|.** Such schemas look very much like the **SVO** schema of traditional grammar.

In addition to questions about the specification of the position of predicates and arguments, basing the system of representation on the three categories: predicate, propositional description, and object description can be challenged. Positing the existence of additional categories to capture differences between types of predicates and types of descriptions could prove fruitful for processing various linguistic forms.

Given PM's commitment to the existence of representations at multiple levels of abstraction (see Chapters 1 and 2), all of these possibilities exist and may in fact be realized. Nonetheless, there is some motivation for the particular level of representation posited for discussion in this chapter. In particular, more concrete schemas would force consideration of details which detract from the major concern of this chapter—examination of the basic propositional structure of English.

Additional forms at more concrete levels of abstraction will be posited when needed to facilitate discussion. For example, it should be noted that the sentences above were specifically selected because they directly reflect the underlying propositional forms. Thus, the sentence **he told me you like him** contains two complete object descriptions **he** and **you** and a complete propositional description **you like him** in addition to the predicate **told**. On the assumption that the predicate **told** determines a relation between these three arguments, the propositional form **pred(obj,obj,prop)** is supported. Of course, English has many other surface forms which do not so directly reflect underlying propositional forms. Infinitive phrases are a case in point. In the sentence

I want to go

The infinitive phrase **to go** functions as a propositional argument to the predicate **want** which invokes the abstract schema **pred(obj,prop)** in the construction of the representation

[want(I_i,[to_go(e_i)])]

(where e_i represents an empty argument that is co-referential with the argument I_i). The existence of such reduced propositional forms is important in terms of the processing mechanism which must recover the elided information (or establish the co-reference) and in terms of more specific schemas which may be available to facilitate that processing. Discussion of the nine basic propositional forms abstracts away from such considerations.

Similar limitations follow from the fact that the nine basic propositional forms make no commitment to the relative position of the predicate. For example, the schema **pred(prop)** is compatible with all of the following:

Quickly, he went
He, quickly, went
He went, quickly

leading to the representation

[quickly([went(he)]).

While the predicate **quickly** (an adverb) can legitimately occur in several positions, the position of the object description **he** (the subject) is more rigidly determined. It is because the position of the predicate is indeterminate relative to its arguments that a single propositional form which does not specify the location of the predicate is adequate for the treatment of adverbs. However, this same flexibility fails to capture the fixed position of the subject relative to the main predicate. A possible solution is to suggest the existence of propositional forms which specify the preferred location of subjects and objects, while retaining a position indeterminate form in the case of adverbs.

The remainder of this chapter will be focused on a consideration of those aspects of representation which can be captured by the basic propositional forms, ignoring for the most part representational considerations which the basic propositional forms fail to capture. Again, it should be reiterated that the failure of the basic propositional forms to account for various aspects of surface variation is taken to provide support for the existence of representations at multiple levels of abstraction and is not assumed to invalidate the basic forms.

Pred(Obj).

Predicates which take a single object description as an argument typically represent properties or states of that object, or actions which do not involve other participants. The grammatical categories **predicate adjective** and **intransitive verb** correspond to this category of predicate. Thus, for the sentence

He went

The predicate **went** (an intransitive verb) takes the single object description **he** and forms the propositional description

[went(he)]

The second type of predicate which takes a single object description for an argument is the **predicate adjective** (**attributive adjectives** are treated as functions in PM). It is a fact of English that predicate adjectives do not normally occur in sentences without the help of an auxiliary verb to mark tense. The auxiliary verb acts as a predicate modifier using the form **pred{pred}**. Thus, given the sentence

He is sad

the predicate **is** takes the predicate **sad** as its argument forming the complex predicate **is{sad$_{head}$}** which in turn takes the pronoun **he** as an argument and forms the following propositional description:

[is{sad$_{head}$}(he)]

Like predicate adjectives, there are verb forms which rely on the occurrence of auxiliary verbs for the specification of tense (e.g. verb participles). The propositional representation of such verb forms mirrors that of the predicate adjective. The present participle **going** in the sentence

He is going

uses the **pred(obj)** schema to form the following propositional description:

[is{going$_{head}$}(he)]

Since the innermost predicate is always the head of such complex predicates, they will not be explicitly marked as such henceforth.

Pred(Obj,Obj).

Predicates which take two object descriptions for arguments typically specify a relationship between these arguments which is either active or stative. Predicates which establish an active relationship tend to be categorized as "transitive verbs". For example, the sentence

He hit the ball

contains the predicate **hit** (a transitive verb) which establishes an active relationship between the object descriptions **he** and **the ball** resulting in the following structure:

[hit(he,the ball)]

(Note that the internal structure of object descriptions is ignored in the current discussion.)

English typically makes use of lexical items which have grammatically been classified as **prepositions** to establish stative (or locative) relationships between two object descriptions. Like predicate adjectives and verb participles, an auxiliary verb is usually required in such constructions. In the sentence

The pen is in the box

in is a predicate which establishes a locative relationship between the two object descriptions **the pen** and **the box** resulting in the structure:

[is{in}(the pen, the box)]

The sentence

He is hitting the ball

is represented similarly as

[is{hitting}(he, the ball)]

There is a predicative use of the verb **to be** which is transitive in nature. In the sentence

He is a man

The predicate **is** establishes a relation between the object descriptions **he** and **a man** resulting in

[is(he, a man)]

Many researchers find the superficial occurrence of two object descriptions in such English sentences unacceptable (beginning perhaps with Bertrand Russell's early writings) in that while the sentence contains two object descriptions, there is clearly only one entity which the sentence is about. A frequent treatment is to suggest that despite the apparent transitive structure of such sentences, what we really have is a complex predicate **is a man** explicating a property of the single argument **he**. However, this approach runs into problems since the object argument can be arbitrarily complex as in

He is the man with a broken arm that I told you about yesterday.

PM offers an alternative treatment which preserves the basic transitive structure of the sentence. In PM it is suggested that it is part of the meaning of this use of the predicate **be** that the relationship that is established between the two object descriptions is one of equivalence of reference. Thus, in constructing the nonlinguistic representation corresponding to the sentence only one entity will be posited despite the occurrence of two object descriptions. It is in the relationship between the object descriptions and the object to which they refer that this aspect of meaning is captured. (A treatment involving **predicatization** of the argument **a man** will also be discussed later.)

Pred(Obj,Obj,Obj)

This category of predicate is typically used to represent relations involving more than two participants. This class of predicate is exemplified by **ditransitive verbs** which take an indirect object. For example, the sentence

He gave me the ball

contains the predicate **gave** (a ditransitive verb) which establishes a relationship between the three object descriptions **he**, **me** and **the ball**. In PM, this is represented as

[gave(he,me,the ball)]

By way of contrast, the sentence

He gave the ball to me

Contains two relational entities—**gave** and **to**—and its representation in PM is structurally different:

[to([gave(he,the ball)]$_{\text{head}}$,me)]

Thus, the two dative forms lead to different representations in PM. It has frequently been suggested that the two forms of the dative construction do not differ in meaning and that a single representation of the meaning suffices. However, Langacker (1987) and Pinker (1989) demonstrate that there are differences in meaning between these two

constructions. Single level systems of representation which abstract away from the different surface forms will fail to be able to represent these differences. There may nevertheless, be a level of representation which does abstract away from the differences, perhaps facilitating the operation of certain inferential processes. One commits the **Exclusionary Fallacy** (Langacker, 1987 p. 28) in suggesting that there is only one level of representation for such constructions.

In terms of the linguistic structure of English, no predicate (except perhaps conjunctions) takes more than three argument descriptions. This is not to say that a propositional description cannot refer to an action, event or state of affairs which involves more than three participants (e.g., the sales transaction), only that the linguistic structure of English limits predicates to directly tying together at most three participants. Of course, English does provide means for tying more than three participants together, but doing so involves the use of more than one relational element. For example, the sentence

He sold me the car for $5000

contains four participants **he**, **me**, **the car** and **$5000** which are tied together by two relational elements **sold** and **for**. Up to now the discussion has focused on the representation of sentences containing a single relational element. However, in general, linguistic expressions will contain multiple relational elements and PM is largely concerned with the representation of such relationally complex expressions. For the sentence above, the predicate **sold** (a ditransitive verb) combines with three object descriptions **he**, **me** and **the car** to form the propositional description

[sold(he,me,the car)]

This propositional description then functions as the first argument of the predicate **for** (a preposition). The predicate **for** take two arguments, the first is a propositional description and the second is an object description. Thus, **for** establishes a relation between the propositional description **[sold(he,me,the car)]** and the object description **$5000** resulting in

[for([sold(he,me,the car)] $_{\textbf{head}}$**,$5000)]**

This complex propositional description does indeed refer to all four participants in the sales transaction, although doing so requires a more complex relational structure than would be required if English allowed **sold** to be directly associated with four arguments.

When a sentence is used to describe a situation involving more than three participants, a subset of the participants is selected for direct association with the main predicate and other participants may only be indirectly associated with that predicate using additional relational elements. The set of participants which are directly associated with the main predicate obtain a saliency from that association which does not hold for the peripherally associated participants. Fillmore (1977a) refers to this asymmetry in the saliency of

participants as a **perspective on the scene** and Langacker (1987) makes use of the related notion **profiling**, in describing such asymmetry.

The assumption that no predicate can take more than three arguments in English has interesting psychological implications. Logically, a predicate can establish a relationship between any number of arguments. Is there some processing or representational limitation which precludes the existence of predicates which take four or more arguments? If so, then we would expect other languages to have a similar limitation. If not, then this would appear to be a contingent fact about English. The claim that English only allows for a maximum of three arguments per predicate is supported by the fact that English only marks three functional categories: **subject**, **object**, and **indirect object** (where both the **object** and **indirect object** receive objective case marking). On the other hand, the conjunction of a series (greater than 3) of arguments provides the most obvious counterexample. However, there may be alternative explanations for the conjunction of more than three arguments which do not require rejection of this assumption. One such alternative will be considered in the discussion of conjunctions later in this chapter.

An example of a relational entity which is frequently assumed to take three arguments in logical treatments is the predicate **between**. However, a closer examination of English texts in which it occurs shows that it actually only takes two object descriptions, with the second object description frequently including a conjunction. Consider the sentence

The block is between the ball and the pyramid.

While there are clearly three objects descriptions in this sentence, it is not the case that the predicate **between** directly establishes a relationship between these three object descriptions. Rather, **between** establishes a relationship between the object description **the block** and a conjunction of object descriptions. This is represented by

[is{between}(the block,and(the ball,the pyramid))]

The bivalent nature of **between** is made even more explicit in

The pillow is between the sheets

where the object description **the sheets** refers to multiple participants via use of the plural form of **sheet**. Thus, it does not appear that **between**—and prepositions more generally—are capable of taking three arguments.

Besides the ditransitive verbs, conjunctions can be used to combine three object descriptions as in

He, she and it left

which can be represented as

[left(and(he,she,it))].

As will be seen throughout this and the next chapter, conjunctions are the most prolific relational elements in English in terms of the number and types of arguments they can conjoin.

Pred(Prop$_{head}$), Pred{Pred$_{head}$} and Pred{Pred$_{head}$}(+Obj)

These propositional categories cut across more parts of speech than any others. They include auxiliary verbs, modal auxiliaries, adverbs, negatives, verb particles, the infinitive marker **to**, and wh-words. Words in this category either modify predicates or entire propositional descriptions, or both. Predicates which modify predicates may be further subdivided into those that provide the specifications needed to support reference and those that modify the main predicate without supporting reference. These two sub-categories are represented by

pred-spec{pred$_{head}$}
pred-mod{pred$_{head}$}

PM's predicate modification is similar to Miller and Johnson-Laird's (1976) representation of predicate modification (of adverbs). In their notation

He walks slowly

would be represented as

(slowly(walks))(he)

whereas in PM's notation, this is represented as

[slowly{walks}(he)].

It should be noted that the distinction between predicate specification and predicate modification is not marked in the above representation, nor will it be marked in the representations discussed in this chapter. The reasons for not marking this distinction are discussed below.

Auxiliary and Modal Verbs. These verbs modify predicates by providing information about tense, aspect, and modality that serve to "specify" the predicate and help in establishing reference.

In PM's notation, the sentences

He was crying
He has been crying

are represented as

[was{crying}(he)]
[has{been{crying}}(he)]

In the first sentence, the predicate **crying** is specified by the predicate **was** resulting in a fully specified predicate **was{crying}.** The fully specified predicate takes the object description **he** and forms the propositional description **[was{crying}(he)].** In the second sentence, the predicate specifiers **has** and **been** combine with the predicate **crying** to form the fully specified predicate **has{been{crying}}** which then takes the object description **he** as an argument.

It should be noted that at the current level of abstraction, the abstract schemas are inadequate to capture all the syntactic constraints which apply to auxiliary verbs. The abstract schema **pred-spec{pred}** says nothing about where auxiliary verbs occur with respect to other auxiliary verbs or modal auxiliary verbs. The schema is consistent with

[been{has{crying}}(he)]

which does not occur in English. More specific schemas are needed to specify the order of auxiliary verbs. For example, the schema **|subj has been pred$_{pres_part}$|** reflects the specific ordering of **has** and **been** and the subscript $_{pres\_part}$ on **pred** indicates that it must be a **present participle**. Further, the first object description is categorized as the subject in this more concrete schema.

Abverbs and Negatives. Adverbs and adverbial phrases modify predicates and propositional descriptions by providing information about the manner, location or time of events or states. In a logically based treatment of adverbs, Thomason and Stalnaker (1973) suggest that there are two basic types of abverbs: predicate modifiers and sentential modifiers. For example, they claim that the adverb **slowly** in

He walks slowly

is a predicate modifier, whereas the adverb **probably** in

He is probably walking

is a sentential modifier. According to Thomason and Stalnaker, the basic difference is that the subject as well as the predicate (where they use the term **predicate** to mean **the entire verb phrase**) is within the scope of a sentential modifier, whereas only the predicate (or verb phrase) is within the scope of a predicate modifier. This distinction does appear to have some validity. In the first sentence, it seems plausible to suggest that the predicate modifier **slowly** has the predicate **walks** within its scope, whereas in the second sentence, the predicate modifier **probably** appears to have the entire propositional description **he is walking** within its scope. Thus, PM is in general agreement with Thomason and Stalnaker. However, the treatment of predicate modifiers differs in PM in

that predicates do not include any arguments and the scope of predicate modifiers in PM is restricted to the predicate and not the entire verb phrase.

The rest of this section discusses implications of the distinction between predicate and sentential modifiers in sentences containing more than one propositional or predicate modifier. The **Main Predicate Proximity Principle** is put forward as a basis for determining the scope of such modifiers. According to this principle, propositional and predicate modifiers which are closer (in surface position) to the main predicate have smaller scope than modifiers which are further away from the main predicate and on the same side of the predicate (i.e. either to the right or left of the main predicate). Essentially, it says that the closer the propositional or predicate modifier is to the main predicate, the closer the relationship between the modifier and the predicate. This principle is closely related to Givon's **Proximity Principle**:

> (a) Entities that are closer together functionally, conceptually or cognitively will be placed closer together at the code level, i.e. temporally or spatially…
> (b) Functional operators will be placed closest, temporally or spatially at the code level, to the conceptual unit to which they are most relevant. (Givon 1991, p. 89)

In support of the Proximity Principle, Givon states

> The cognitive basis of [the] principle…is fairly transparent. The temporal code-contiguity of conceptually-contiguous or conceptually relevant mental entities reflects the general requirements of associative memory, spreading activation and priming. One cannot for the moment guarantee that conceptually-closer mental entities are stored at contiguous locations in the brain. However, if the activation of a concept indeed primes the activation of closely related concepts, then to code related concepts at contiguous times would in fact guarantee faster processing, given associative memory and priming. (Givon 1991, p.92)

While Givon's cognitive explanation of the Proximity Principle resonates with my own best intuitions, his explanation appears more suggestive than definitive. Further, there are at least two reasons why the Proximity Principle may not always hold. First, there are likely to be marked constructions in which linear order does not correspond to conceptual relatedness. Consider

> **He, unfortunately, left.**

In this sentence, a sentential adverb **unfortunately** is interposed between the subject and the verb. On the assumption that the subject and verb are more closely related conceptually than are the sentential adverb and verb, the Proximity Principle fails to hold. However, since this construction is clearly a marked construction (as is suggested by the punctuation), the Proximity Principle may still be maintained for the unmarked case.

Second, while the Proximity Principle may generally hold along a given dimension, it is important to remember that the linear form of written English encodes meaning along many different and often orthogonal dimensions. Two such dimensions are concerned with (a) the encoding of tense, aspect and modality and (b) the encoding of argument structure. While tense, aspect and modality tend to be encoded by auxiliary verbs in closer proximity to the main verb than subject arguments in English, such information may also be encoded in adverbials which tend to be further from the main verb than subjects and objects. Indeed, many logical treatments insist on just this possibility, treating negation and modality as sentential operators and relying on marked constructions like

It is not true that the man hit the ball

as paraphrases for the more familiar unmarked case

The man did not hit the ball.

If Givon's Proximity Principle is generally true for the unmarked case along all dimensions, then tense, aspect and modality are more closely associated with predicates than are arguments and the cognitive validity of such logical treatments is brought into question. On the other hand, it may be that the Proximity Principle does not apply to the positional encoding of information along orthogonal dimensions and the cognitive validity of the logical position can be maintained.

In what follows, I will tentatively assume the validity of the **Main Predicate Proximity Principle**. This principle is primarily concerned with the relative surface position of predicate specifiers and predicate and propositional modifiers and it is assumed that that positioning is largely orthogonal to the positioning of subjects and objects. Further, the Main Predicate Proximity Principle is not without its problems (some of which will be discussed in due course). However, its acceptance reduces significantly the number of possible representations for sentences containing multiple propositional and predicate modifiers and simplifies the processing mechanism considerably. In short, PM accepts the principle as generally valid, but subject to exception (with exception often marked by punctuation in written English). To see how the principle works, consider the sentence

He is not slowly walking

In this sentence, the adverb **slowly** is closer to the main predicate **walking** than is the negative **not**, and, therefore has smaller scope than the negative. On the other hand, in the sentence

He is not walking slowly

The relative scooping of **not** and **slowly** is undetermined by this principle, since they are not on the same side of the main predicate.

This principle applies to all propositional and predicate modifiers and has important consequences. For example, consider the sentence

He does not walk.

Based on this principle, the negative **not** has smaller scope than the auxiliary **does**. Assuming **does** is always a predicate modifier, only one representation is possible since **not** must necessarily be a predicate modifier (i.e. it cannot be a sentential modifier):

[does{not{walk}}(he)]

On the other hand, it might be argued that **does** is a predicate specifier whereas **not** is a predicate modifier and that predicate specification is orthogonal to predicate modification. In this case, it can be argued that **not** could still be a sentential modifier and is not limited to being a predicate modifier. This possibility will not be further considered and it will be assumed that predicate specification and predicate modification are non-orthogonal with respect to the Main Predicate Proximity Principle.

Thomason and Stalnaker (1973) argue that the adverb **slowly** is always a predicate modifier. However, Chafe (1970) disagrees. He provides the sentences

Bob spoke slowly
Slowly Bob spoke

and argues that **slowly** functions as a sentence adverb in the latter sentence. According to Chafe (1970, p. 307), this sentence means "that the total event was slow in unfolding, not just that the speaking was slow." There does appear to be a difference in meaning here which is even more obvious in

He stopped walking slowly
Slowly, he stopped walking

In the first sentence **slowly** may either modify the predicate **walking** (my preferred reading) or the entire propositional description **he stopped walking**, whereas in the second sentence **slowly** appears to modify the entire propositional description. The dispreferred reading of the first sentence can be reinforced by punctuation. Consider

He stopped walking…slowly.

By delaying the appearance of the adverb, it may be possible to convert it into a sentential modifier. While this is essentially a processing consideration, it can be seen that the delay following the verb **walking** might signal the system to proceed with the processing of the verb without waiting to see if the subsequent word is a predicate modifier. Thus, when the adverb **slowly** is finally encountered, the verb **walking** will have already been incorporated as the argument of **stopped** and it will not be separately available for the adverb to modify.

Adverb fronting has a similar effect. Since there is no predicate available for the adverb to modify at the time it is processed, its processing must be delayed. Further, since the subject of the main predicate occurs between the adverb and the predicate, the subject is likely to be instantiated into the main predicate forming a propositional description before the relationship between the adverb and predicate is established. Fronting should therefore have the effect of converting adverbs which might otherwise be predicate modifiers into sentential modifiers.

The usefulness of the distinction between predicate and sentential modifiers in conjunction with the Main Predicate Proximity Principle becomes apparent when we consider sentences containing multiple adverbs and negation on both sides of the predicate. In such sentences, the scope of the adverbs with respect to each other must be determined. Consider the sentence

He does not walk frequently.

Since **does** and **not** occur to the left of the main predicate and **frequently** occurs to the right where it can be either a predicate or a sentential modifier there are at least two possible representations

[does{not{frequently{walk}}}(he)]

where **frequently** is inside the scope of **does not** and

[frequently([does{not{walk}}(he)])]

where **frequently** is a sentential modifier outside the scope of **does not**. The first representation corresponds to a reading in which the person referred to by **he** is not a frequent walker, and the second representation corresponds to a reading in which this person frequently does something other than walking.

For the sentence

He does not walk slowly

where it may be assumed that **slowly** can only be a predicate modifier when it occurs to the right of the main predicate, **slowly** appears to occur within the scope of **does not** (on my preferred reading). This can be represented by

[does{not{slowly{walk}}(he)]

The alternative reading in which **slowly** has wider scope than **does not** (but is still a predicate modifier) leads to

[slowly{does{not{walk}}(he)]

However, it is unclear how to interpret this representation (i.e. can one slowly not do something?).

Up to now we have assumed the validity of the Main Predicate Proximity Principle. However, there are reasons to question its validity. According to this principle, the auxiliary **is** has greater scope than the negative **not** in the sentence

He is not going

Logical treatments tend to want to put negatives outside of the sentences in which they occur making them logical operators rather than predicates. Allowing this possibility, we might represent this sentence as

[not([is{going}(he)])]

where the scope of the auxiliary is within the scope of the negative. However, there are two basic arguments against this position. In the first place it violates Jackendoff's **Grammatical Constraint** (as well as Givon's **Proximity Principle**). If negatives always have scope over auxiliaries, why do they occur between auxiliaries and main predicates and not vice versa? In other words, why isn't the preferred surface order in English

He not is going (or "Not he is going" or even "He is going…not!")

where the closer relationship between the auxiliary and verb is captured in the surface structure? In English, it is not acceptable to use the negative **not** with a past tense verb without also including a variant of the auxiliary verb **do**, and in this construction the negative must occur between the auxiliary verb and the past tense verb. Thus, the sentence

He not went

is not well-formed in English, and the sentence

He did not go

is strongly preferred. Second, English provides for the very sort of non-sentential negation that logical approaches disallow in any case. Negation may be morphologically marked as it is in the adjective **unhappy** or it may be an inherent part of the meaning of a lexical item as it is for the verb **to lose**. Thus, the logical treatment of negatives as sentential operators does not seem to offer a strong argument against the Main Predicate Proximity Principle.

On the other hand, there are constructions in English which suggest the need to relax this principle. Consider the sentence

He is, unfortunately, gone.

In this sentence **unfortunately** functions as a comment on the sentence **he is gone**. It seems unreasonable to suggest that it occurs within the scope of the auxiliary, despite its position in the sentence. In English, there are numerous occasions when such comments can interrupt otherwise coherent constructions, and they will certainly have to be dealt with. Fortunately, written English frequently makes use of punctuation to mark such constructions. Of course, punctuation will not always be definitive. However, if we do away with the Main Predicate Proximity Principle, the number of possible representations will increase dramatically. For example, consider the sentence

Unfortunately, Bob does not ever walk slowly.

If the principle does not hold and the five propositional and predicate modifiers can have any scope, then there are 5! or 120 possible representations. If the principle does hold, then the relative ordering of the propositional and predicate modifiers which occur to the left of the main predicate is fixed and there are only 2 possible representations:

[unfortunately([does{not{ever{slowly{walk}}}}(he)])]
[unfortunately([slowly{does{not{ever{walk}}}}(he)])]

Based on the difficulty of constructing a reading for the second sentence, there may be additional limitations at work. For example, the negative **not** may always have wider scope than any predicate modifiers occurring to the right of the predicate.

Let's return to Thomason and Stalnaker's original discussion of predicate and sentential modifiers and reconsider the following sentence in light of the **Main Predicate Proximity Principle**:

He is probably walking.

Since **probably** occurs within the scope if **is** which is a predicate modifier, **probably** is also probably functioning as predicate modifier and not a sentential modifier as Thomason and Stalnaker claim. Thus, this sentence is more like

He could be walking

than

It is probably true that he is walking.

It is probably true that Thomason and Stalnaker were concerned with the appropriate treatment of **probably** within modal logic in according this word the status of a sentential modifier. Unfortunately, the surface structure of English and Jackendoff's **Grammatical Constraint** and Givon's **Proximity Principle** along with PM's **Main Predicate Proximity Principle** argue against such a treatment.

Summing up this section, three important topics have been discussed: (a) the **Main Predicate Proximity Principle**, (b) the distinction between predicate and sentential modifiers, and (c) the relationship between the first two topics and the notion of scoping.

The representations in this section all place the modifying predicate in front of the main predicate. This often leads to representations which distort the surface order of the text. An alternative representation which retains surface order is possible if modifying predicates retain their textual position. For example, the sentence above could be represented as

[unfortunately([does{not{ever{{walk}slowly}}}(he)])]

where **slowly** occurs after **walk** in the representation. Note that the position of the subject argument of the main predicate is still placed after that predicate in this representation. Moving the subject argument to its surface position leads to:

[unfortunately([(he)does{not{ever{{walk}slowly}}}])].

Such representations, although attractive, will not be considered further.

Verb Particles. Verb particles are prepositions which further specify the nature of the verbs they modify, but which do not take an object argument. The prototypical verb particle specifies information about the direction of the action of the verb. For example, the verb particle **up** in the sentence

He picked the ball up

specifies the direction of the action of the verb **picked**. Verb particles have a close relationship with the verbs they modify. They are therefore likely to be predicate modifiers rather than sentential modifiers. Assuming this to be the case, the sentence above is represented as

[up{picked}(he,the ball)]

The close relationship between verbs and verb particles is made explicit in languages like German in which the particle actually forms part of the verb in its infinitive form. For example, the German infinitive **einsteigen** contains the particle **ein** and the verb **steigen** combined together in a single word which in English means "**to get in or on**." While the particle and verb are combined in the infinitive, they occur separately in sentences like

Ich steige der Strassenbahn ein (I am getting on the streetcar).

It is of interest to note that the particle is typically prefixed and not postfixed to the verb in the infinitive form in German. English has a collection of words which appear to behave similarly: **input**, **output**, **outbreak**, **outcast**, **outcome**, etc. There are also words

where the particle occurs after the verb: **breakout**, **breakdown**, **breakaway**, **handout**, **makeup**, etc. In English, the combination of a verb and particle into a single word typically results in the formation of a compound nominal rather than a verb. Verbs and particles can be combined to form compound verbs, but the compounds retain the spacing between the verb and particle in the written form: **break down**, **break out**, **break off**, **make out**, **make up**, etc. This difference in spacing may say little about the lexical status of verb-particle combinations. Since the meaning of most such combinations is not a simple composition of the meaning of the individual verb and particle, learning their meanings typically means learning the meanings of the combinations. Indeed, a good dictionary is replete with verb-particle entries. Consider these selected meanings of (a) **break down**: to become inoperative through breakage or wear; (b) **break out**: to become affected with a skin eruption; (c) **break off**: to stop abruptly; (d) **make out**: to neck; and (e) **make up**: to reconcile. These examples are not unusual. Essentially then, verb-particle combinations are compound lexical items whose meaning is likely to be directly associated with the combination itself. The meaning of the compound is typically not a compositional function of the meaning of the parts, although the meaning is likely to be semantically motivated in the sense of Lakoff (1987).

To capture the nature of verb-particle combinations, PM assumes that they form lexical compounds and represents this by connecting them with an underscore. Thus,

[up{picked}(he,the ball)]

becomes

[picked_up(he, the ball)]

and the sentence

Fortunately, he did not break the door down

is represented as

[fortunately([did{not{break_down}}(he, the door)])]

There is no well-formed representation in which the particle has scope over any propositional or predicate modifiers occurring to the left of the main predicate. Given the close affinity of verb-particle combinations and the proximity principle, it should not be possible for another propositional or predicate modifier to occur between the verb and particle. Consider the sentence

He did not break the door quickly down

Since the adverb **quickly** occurs between the verb and particle, it should cause problems for interpretation and this sentence is assumed to have a marked surface order. On the other hand

He did not break the door down quickly

is readily interpretable and may be represented by

[did{not{quickly{break_down}}}(he, the door)]

Likewise the occurrence of the object description **the door** between the verb and particle does not cause problems for interpretation. In general, the location and influence of argument descriptions is independent of the location and influence of propositional and predicate modifiers. Thus, any number of propositional and predicate modifiers may occur between the subject and the main predicate without influencing the instantiation of the subject as an argument of the predicate. It has been stated that this is not the case with regard to the object of the main predicate. Specifically, adverbs do not normally occur between the verb and its object. Thus, the sentence

He hit hard the ball

Sounds awkward and

He hit the ball hard

is preferred. Further, it is well attested in GB Theory that there are constraints on the relative position of verb particles and pronominal and non-pronominal objects such that pronominal objects "must" be coded between verbs and particles, whereas, particles may be coded between verbs and non-pronominal objects as in

He broke it down
He broke down the door

Presumably such constraints stem from the fact that the encoding of argument structure and the encoding of predicate structure are not strictly orthogonal. At the level of description of the basic propositional forms, PM does not have a mechanism for explaining such constraints.

In sum, verb particles are the strongest example of predicate modifiers considered so far. To the extent that the meaning of verb-particle combinations is not a compositional function of the meaning of the individual words, they are likely to behave like compound lexical items rather than separate words.

The infinitive marker *to*. The infinitive marker functions as a predicate modifier when it participates in infinitive phrases like the phrase **to go** in

I want to go

Like verb particles. it has a close relationship with the verb it modifies and for the most part it is assumed that it combines with the verb to form a compound lexical item. Thus, the sentence above is represented as

[want(I_i,[to_go(e_i)])]

Despite the affinity of the infinitive marker to combine with the verb it modifies, there is some evidence to suggest that the marker may combine with the main predicate instead. Consider the sentence

I wanna go => [wanna(I_i,[go(e_i)])]

Where **wanna** is a lexicalized combination of the verb **want** and the infinitive marker **to**. Since the verb **want** has a preference for an infinitive phrase as its second argument, infinitive phrases frequently occur with this verb and it is this frequent occurrence that leads to the possibility of their combination into a single lexical item.

Wh-words. The wh-words in English function to stand in the place of the basic constituents of propositional descriptions: predicates, propositional and object descriptions. The wh-words **who** and **what** stand in the place of object descriptions as in

Who ate the cookie? => [ate(*who*, the cookie)]
What do you want? => [do{want}(you,*what*)]

In addition, the wh-word **what** may also stand in the place of propositional descriptions and predicates as in

What did he say? => [did{say}(he,[*what*])]
He what? => [*what*(he)]

The wh-words **where**, **when**, **why** and **how** stand in the place of propositional modifiers as in

Where did he go? => [*where*([did{go}(he)])]
Why did he do it? => [*why*([did{do}(he,it)])]
How did he do it? => [*how*([did{do}(he,it)])]
When did he do it? => [*when*([did{do}(he,it)])]

In each of these cases the wh-word is a propositional modifier which takes a propositional description for its argument.

Question formation requires consideration of structural considerations (e.g. auxiliary inversion and the use of the periphrastic **do**) which are not captured by the basic propositional forms. Based on these basic forms the following sentence is well-formed:

Where he went.

While this sentence is clearly ungrammatical (as an isolated sentence), it is also just as clearly interpretable. The ungrammaticality results from a discrepancy between the actual form of the sentence and the preferred form for question formation in English (as would be represented in specific schemas for question formation). The interpretability of the sentences results from the availability of more abstract schemas which allow for its interpretation.

Wh-words are assumed to be the variables in PM's system of representation and for them to be an adequate set of variables, they must be capable of standing in the place of the major categories in PM. Looked at from a different perspective, the range of use of wh-words serves as an indicator of the categories which (as a minimum) should exist in PM.

In this regard, perhaps the strongest evidence in support of the existence of something like a **VP** constituent in English stems from the use of the wh-word **what** to elicit what Quirk, Greenbaum, Leech and Svartvik (1972) call the predication (i.e., the verb + objects and complements less the auxiliary verb). According to Quirk et al. (1972, p. 52), the wh-word **what** is typically used to elicit a predication as a response. Consider the sentence (taken from Quirk et al.)

He had given the girl an apple

for which the question

What had he done?

can be used to elicit the predication

Given the girl an apple

as a response. Further, Quirk et al. note that the verb itself cannot typically be elicited in this manner. Consider the sentence (again taken from Quirk et al.)

They make him chairman every year

for which the question

What do they him the chairman every year?

cannot be used to elicit the response

Make.

This use of the wh-word **what** provides strong evidence for the existence of predications. Nonetheless, predications are assumed to be incomplete units of meaning in PM. This does not mean they cannot occur in English text, but that from a relational perspective,

predications are elliptical constructions. In PM, predications can be represented as relational structures which contain an empty predicate specifier and empty subject argument as in

[e_{spec}{give}(e_{subj},the girl,an apple)]

where $\mathbf{e_{spec}}$ represents the empty predicate specifier and $\mathbf{e_{subj}}$ represents the empty subject argument.

Pred(Prop$_{head}$,Obj) and Pred{Pred$_{head}$}(+Obj).

This class of predicate is closely related to the class of propositional and predicate modifiers discussed above. The major difference is that these predicates modify propositional descriptions and predicates by relating them to object descriptions which specify the time, location, direction or manner of occurrence of the propositional description or predicate. The prototypical member of this class is the preposition. Traditionally, prepositions are treated as the major constituents of prepositional phrases which are in turn the modifiers of main clauses (or noun phrases). The traditional grammatical treatment ignores the basic relational character of prepositions. Logical treatments often treat prepositions as relations between two object arguments, but fail to allow for their treatment as modifiers of propositions or predicates. Prepositions typically relate locations or times to actions, events, states or entities. The action, event, state or entity being modified is the head of the resulting construction, but this does not change the relational nature of the preposition. Consider the sentence

John played tennis on Tuesday => [on([played(John,tennis)]$_{head}$,Tuesday)]

The main predicate **played** is the head of the sentence in that it is what the entire sentence is primarily about (i.e., an event of **playing** involving a **player** and a **playee**). Since the main verb is the most salient element of the sentence, many researchers assume that the representation for the sentence should give the main verb a prominent status. Using static two-dimensional tree representations, this can be accomplished by making the verb the root node of the tree and representing prepositional phrases as subordinate to the main verb and further removed from the root node (as is done in **Dependency Grammar**). Figure 1.1a provides an example of such a treatment. While this does succeed in highlighting the status of the main verb, it makes it difficult to properly represent the relational status of prepositions since the main verb forms part of one of the arguments of the preposition and is relationally subordinate to it. The problem is that such representations attempt to encode more than one dimension of information along a single dimension of representation. That is, they attempt to encode both saliency (or head-modifier relationships) and relational structure (or dependency structure; or constituency) in terms of the subordinate-superordinate links in a tree representation. The corresponding representation in PM (see Figure 1.3b) encodes purely relational information. Since relational status and saliency need not coincide, they cannot be easily represented by position in some two-dimensional tree structure. In PM, tree structure

position is used to represent relational information and some other representational mechanism is needed to represent saliency (e.g. the subscripting of the head of the resulting relational structure to mark its saliency).

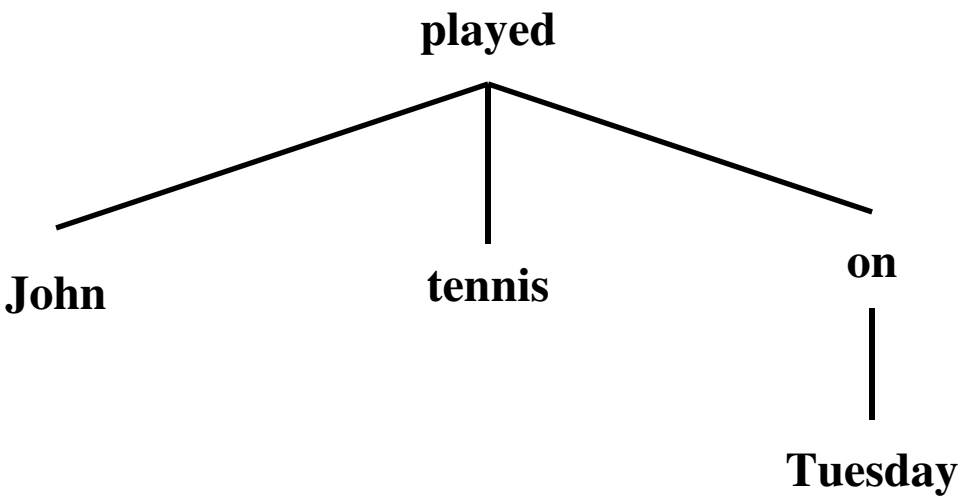


Figure 3.1a: Dependency Grammar

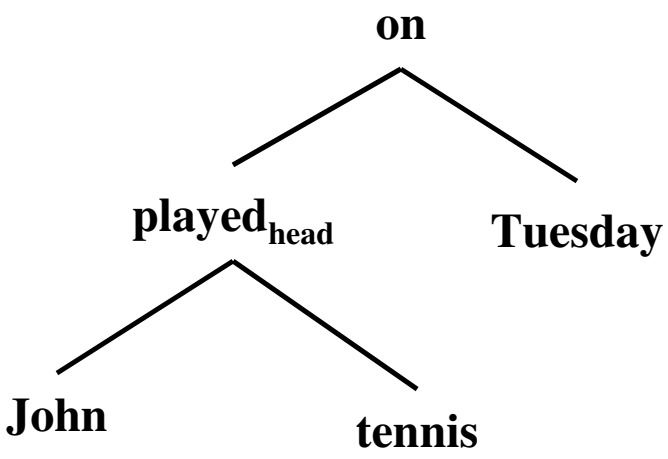


Figure 3.1b: PM Tree Representation

The argument over whether the basic sentence structure is subject-predicate or subject-verb-object is based in part on the assumption that two-dimensional representations are adequate to represent the structure of language. (The **Exclusionary Fallacy** is also at work here.) Subject-predicate representations capture the saliency of the subject relative to other arguments of the predicate. Subject-verb-object representations capture the basic relational structure of sentences. Given the relational focus of PM, SVO representations are assumed to be central. However, the importance of the subject-predicate distinction is recognized, even if an adequate means for representing this distinction has not been developed. By way of contrast, the two-dimensional tree representations of **Transformational Grammar** (Chomsky, 1957, 1965) were focused on the representation of subject-predicate structure, and they were unable to adequately represent relational structure. **Government and Binding Theory** (Chomsky, 1981), in shifting from a two-dimensional system of representation to a multi-dimensional system which represents various linguistic principles and constraints along different dimensions, is better able to represent both subject-predicate structure and relational structure. In this regard, Government and Binding Theory is a more fully explicated system of representation than PM.

The treatment of prepositional phrases as propositional modifiers is not without its problems. Consider the sentence

He hit the ball over the fence.

On my preferred reading of this sentence, the prepositional phrase **over the fence** refers to the location or trajectory of the object **the ball** and not to the location of the entire action. One possible solution is to suggest that the preposition **over** functions as a predicate modifier which has the effect of increasing the number of arguments of the main predicate as represented by the schema **pred{pred}(+obj)**. This can be represented as

[over{hit}(he, the ball, the fence)]

In this representation, an act of "hitting over" occurred involving a **hitter**, a **hittee**, and an object or location reflecting the **effect** on the hittee.

The **pred{pred}(+obj)** schema is also supported by sentences involving intransitive verbs. Consider,

He went over the fence

where the availability of this schema results in the following representation:

[over{went}(he,the fence)]

as opposed to the more complex

[over([went(he)],the fence].

On the other hand, if this schema were available for use with ditransitive verbs, the result would be a schema with a single complex predicate and four arguments. Consider

He sold me it for $50.

which could be represented as

[for{sold}(he,me,it,$50)]

instead of

[for([sold(he,me,it)],$50)]

Presumed processing or other cognitive limitations make the use of the **pred{pred}(+obj)** schema with ditransitive verbs unlikely.

Revisiting the dative construction with the preposition **to**, a similar representation can be put forward. Consider

He gave the ring to her

which can be represented as

[to{gave}(he,the ring,her)]

instead of the more complex

[to([gave(he,the ring)],her)].

Pred(Obj,Prop).

Propositional Attitudes. At the level of representation under discussion in this chapter, the order of arguments is explicitly encoded, whereas the position of the predicate relative to those arguments is not. There is a category of verb, called propositional attitude, which establishes a relationship between an individual (i.e. the subject) and a proposition (i.e. the propositional object). The treatment of propositional attitude verbs is an important topic in the study of logic and in the philosophy of logic (e.g., Quine, 1980, 1981, 1986). The propositional attitude verbs create severe complications for an existentially-based truth-functional semantics—complications related to the concept of referential opacity and to the de dicto/de re distinction. According to Quine (1986, p.33),

> The idioms both of propositional attitude and of modality are notoriously unclear from a logical and philosophical point of view.

Quine (1986, p.33) further suggests that,

> We should be within our rights in holding that no formulation of any part of science is definitive so long as it remains couched in idioms of propositional attitude and modality.

Unfortunately, whereas descriptions of scientific theories may be structured so as to avoid the use of propositional attitudes and modalities, natural language, more generally, is replete with such constructs and they will have to be dealt with. Indeed, propositional attitudes are an important concern of many logically informed systems of linguistic and/or mental representation (e.g., Barnden 1988, 1990; Barwise & Perry, 1983; Cresswell, 1985; Jackendoff, 1983; Richard, 1990; Schiffer, 1987; Wilks & Bien, 1983). However, no attempt to provide a treatment of propositional attitude verbs which addresses the problems of referential opacity and the de dicto/de re distinction will be made here, in part, because the topic of propositional attitudes is a difficult one which I do not fully understand, and, in part, because I believe that such a treatment will require the consideration of nonlinguistic aspects of meaning.

I will only note that, in PM, it is assumed that the processing of an input sentence leads to the parallel construction of both a linguistic and a corresponding nonlinguistic representation. It is the existence of these dual representations which offers hope for an eventual treatment of propositional attitudes. For example, linguistic representations provides the basis for the **de dicto** reading of sentences, whereas nonlinguistic representations provide the basis for the **de re** reading. Further, linguistic representations may be treated as referentially opaque, whereas nonlinguistic representations are not. In essence, I believe that referential opacity and the de dicto/de re distinction are primarily concerned with reasoning, and have to do with whether reasoning occurs over linguistic or nonlinguistic representations, or both.

As an example of the kinds of problems presented by propositional attitude verbs consider the sentence

Tom mistakenly believes that Dr. Smith is an undertaker.

The problem is that it is clear from this sentence that **Tom** would not use the object description **Dr. Smith** to refer to Dr. Smith since Tom doesn't know that Dr. Smith is in fact a doctor. What Tom mistakenly believes is that the person referred to by the object description Dr. Smith is an undertaker. The linguistic representation of the sentence as

[mistakenly{believes}([Tom,is(Dr. Smith,an undertaker)])]

fails to capture this basic fact (which requires a de re reading of the sentence). However, the nonlinguistic representation which is constructed in paralled with the linguistic representation is assumed to contain a representation of the referent that Tom believes to be an undertaker. Nonetheless, it is still the case that the combined representation says nothing (explicitly) about Tom's relationship to the object description Dr. Smith.

Of the logically informed approaches to the linguistic or mental representation of propositional attitudes mentioned above, Barnden's (1988, 1990) is perhaps most compatible with PM. Barnden (1988, p. 32) suggests a

> …shift…away from the prevailing formalist approach in AI (and philosophy)…towards an alliance with the concerns of the more cognitive-oriented linguists and philosophers.

Barnden later states (1990, p. 3),

> It is remarkable that in the extensive discussions of the technical nature of representations of propositional attitudes in the philosophical and AI literature, little attention has been given to how people actually view mental states.

In this regard, Barnden (1990, p. 4) claims that

> Commonsense models of mind are almost always metaphorical. Ideas can be viewed as fighting battles, minds can be viewed as having compartments, agents can be viewed as having worlds.

In highlighting the importance of metaphor for the representation of (and reasoning about) propositional attitudes and mental states, Barnden makes reference to the research of Lakoff (1987), Lakoff and Johnson (1980), and Johnson (1987)—research which has also been of fundamental importance in the development of PM. It is the cognitive orientation of Barnden's research and its emphasis on the grounding of abstract mental states in more concrete metaphorical language (which is in turn ground in experience) that is most consistent with the basic assumptions of PM.

Perceptual and Conceptual Verbs. What are described as propositional attitude verbs in logic and philosophy are often called perceptual and conceptual verbs in psychology. Of particular interest is the fact that such verbs can be used to describe situations in which what is perceived or conceived of is either an entire propositional description or a simple object description. Thus, such verbs can function to establish a relation between either two object descriptions or between an object description and a propositional description. For example, the perceptual verb **see** takes an object description for its second argument in the sentence

> **I see the boy**

and a propositional description for its second argument in

> **I see the boy is eating**.

The fact that the second argument to a perceptual or conceptual verb can be either a propositional or object description has important implications for the processing mechanism. Some of these processing implications are addressed in Chapter 5.

The propositional argument to these verbs can take on different forms. In the simplest case the propositional description is a complete clause and its representation is the same as that of the sentence in isolation. For example, the sentence

He believes you like him

can be represented as

[believes(he,[like(you,him)])]

If the sentence contains a complementizer as in

I believe that he likes you,

the complementizer can be treated as a propositional modifier and the sentence can be represented as

[believes(he,[that([like(you,him)])])]

The propositional arguments of many of these verbs can (and often prefer) to occur in reduced forms—especially when the subject of the main verb is also the subject of the propositional argument as in the sentence

I want to eat.

In this sentence, the verb **want** establishes a relation between the subject **I** and the propositional description **to eat** with the subject of the propositional description being understood to be the same as the subject of the main verb. This can be represented by

[want(I_i,[to_eat(e_i)])]

In the representation of such verbs, we can further specify the basic propositional form to reflect the infinitival phrase status of the propositional description, giving

pred(obj,$prop_{infp}$).

where the subscript $_{infp}$ marks the propositional description as an infinitive phrase. The representation of verbs like **want** is complicated by the occurrence of sentence like

I want him to eat

in which there is a second object description **him** in the sentence. In my preferred reading of this sentence, the subject wants the referent of the pronoun **him** to do the eating. Jackendoff's **Grammatical Constraint** argues against the representation of this sentence as

[want(I,[to_eat(him_{subj})])]

since the pronoun **him** is functioning as the subject of the verb **eat** despite its objective case marking in this representation. The surface structure of this sentence suggests a schema for **want** of the form **pred(obj,obj,$prop_{infp}$)** leading to the following representation:

[want(I,him_i,[to_eat(e_i)])]

where the indexed notation has the advantage of not requiring the objective case pronoun **him** to explicitly function as the subject of the verb **to eat**.

There is an alternative (if dispreferred) reading of the sentence in which the subject of the verb **to eat** is co-referential with the subject of the verb **want** with the pronoun **him** functioning as the object of the verb **to eat**. This meaning is more explicitly suggested in

I want him_i to eat (him_i).

This dispreferred reading can be represented as

[want(I_i,[to_eat(e_i,him)])]

or with three arguments as

[want(I_i,him_k,[to_eat(e_i,e_k)])]

Despite the occurrence of two elliptical arguments in the embedded propositional description in the latter representation, the three argument treatment of the verb **want** is supported by the object position and objective case marking of the pronoun. It corresponds to the notion of "someone wanting somebody to do something".

Continuing the discussion of verbs whose propositional arguments have reduced forms, there is a group of verbs (often called copular verbs) which appear to take reduced propositional forms. Consider the verb **appears** in the sentence

It appears that he likes me.

In this sentence the verb **appears** establishes a relation between the object description **it** and the propositional description **that he likes me**. The surface realization argues strongly for this treatment despite the fact that the pronoun **it** is little more than a meaningless filler argument. On the other hand, for the sentence

He appears to like me

the verb **appears** seems to be functioning more like a predicate modifier and can be represented by

[appears{to_like}(he,me)].

For this representation to work, **appears** must also be fulfilling the role of predicate specificer since the infinitive **to like** cannot stand on its own without such a specification. Since the two argument use of **appears** seems to be necessary to deal with the sentence with the non-referential **it**, such a schema is likely to be available. On the other hand, the treatment of **appears** as a predicate modifier/specifier accords well with the meaningful consequences of its use and a schema corresponding to this use is also likely to be available.

The reduced propositional forms which occur in constructions including this class of predicate are of interest to PM's system of representation. It has been suggested by Jespersen (1965) that such reduced forms behave in many ways like substantives (i.e. object descriptions). Given PM's commitment to the distinction between propositional and object descriptions, the existence of constituents with an ambiguous status is cause for concern. For example, consider the sentences

I like that I am eating
I like to eat
I like eating
I like eats

PM's system of representation requires that the object of the verb **like** be classified as a propositional or object description in each case. But where should the line between propositional and object descriptions be drawn? Actually, there is no rigid line between propositional and object descriptions, only preferences. All of the above forms are used as object descriptions in the following sentences:

That I am eating is nice
To eat is nice
Eating is nice
Eats are nice

PM must provide some means for **reifying** (or **objectifying**) propositional descriptions and treating them as object descriptions in constructions like these. Ultimately, what determines the treatment of such propositional forms are the argument preferences of the relational elements. The prototypical propositional description contains a tensed verb along with its associated arguments and the prototypical object description contains a determiner and a head noun, but these categories are not assumed to be rigidly fixed. Rather, there is a continuum of propositional descriptions to object descriptions (Cohen

1984 uses the term **predicative referring expression** to refer to intermediate forms) and these forms interact with the preferences of relational elements in the construction of representations. Further, relational elements may prefer specific forms along this continuum (as is the case for the verb **want**), rather than preferring propositional and object descriptions more generally. Such preferences reflect a level of representation below that which the basic propositional forms address.

Pred(Obj,Obj,Prop).

This category of predicate is exemplified by what are sometimes called double complement verbs. For example, the communicative verb **told** in the sentence

He told me you like her

establishes a relation between the object descriptions **he** and **me** and the propositional description **you like her**. That relation essentially involves the subject informing the object about the action or state to which the propositional description refers. This can be represented as

[told(he,me,[like(you, her)])].

A similar treatment is possible for verbs of causation like **made**. The sentence

He made me give her the money

can be represented as

[made(he,me $_i$,[give(e_i, her, the money)])].

As discussed above for the verb **want**, the objective case marking of the pronoun **me** suggests its treatment as an object of the verb **made** resulting in a three argument treatment. Notionally we have "someone made somebody do something". The verb **cause** behaves similarly. Consider

He caused me to have an accident

Structurally, the only difference is that **cause** prefers an infinitive phrase for its second complement whereas **made** prefers a verb phrase without the infinitive or auxiliary (i.e., a **predication** according to Quirk et al.):

[cause(he,me_i,[to_have(e_i,an accident)])].

Pred(Prop$_{head}$,Prop$_{head}$), Pred(Prop$_{head}$,Prop$_{head}$,Prop$_{head}$), Pred{Pred$_{head}$,Pred$_{head}$}, Pred{Pred$_{head}$, Pred$_{head}$,Pred$_{head}$}.

These categories of predicate are exemplified by the conjunction (the term conjunction will be used to refer to both conjunction and disjunction). At the propositional level of representation, PM makes no distinction between coordinate and subordinate conjunction except to the extent that that distinction is reflected in the meaning of the conjunction itself. The treatment of conjunctions as predicates in PM can be contrasted with their treatment as logical operators in the predicate calculus. PM does not posit the existence of a special class of logical operator, preferring to treat the English words which roughly correspond to the logical operators for negation, conjunction and implication as ordinary predicates. For example, the sentence

He cried and I laughed

is represented as

[and([cried(he)]$_{head}$,[laughed(I)]$_{head}$)]

where **[cried(he)]** and **[laughed(I)]** are propositional descriptions which are conjoined by the predicate **and**. Likewise, the sentence

He cried because I laughed at him

is represented as

[because([cried(he)]$_{head}$,[at([laughed(I)$_{head}$],him)])]
[because([cried(he)]$_{head}$,[laughed_at(I,him)]$_{head}$)].

There is a small class of correlative conjunctions (e.g., **either…or**, **whether…or**) which present problems for PM in that the main predicate is effectively expressed by two separate words which are interspersed between the propositional descriptions they conjoin. These conjunctions are better represented on a level at which the surface order of predicates is explicitly taken into account. Thus, the sentence

Either you give me the book or I will take it

could use the propositional form

|either(prop)$_{head}$or(prop)$_{head}$|

to construct the following representation:

[either([give(you,me,the book)]$_{head}$)or([will{take}(I,it)]$_{head}$)]

In general, the proper treatment of conjunctions is known to be a serious problem for most systems of representation. The frequent occurrence of ellipsis in constructions containing conjunctions is one reason for this difficulty. Further, the elliptical elements may differ in form from the explicitly represented elements to which they correspond. Consider the sentence

I am stronger than you are.

which can be represented by

[than([am{stronger $_i$}(I)]$_{head}$,[are{e $_i$}(you)]$_{head}$)]

However, in this representation the elided equivalent is **strong** and not **stronger** which has a different meaning. Further, even the second auxiliary is unnecessary as in

I am stronger than you.

How should this be represented?

[than([am{stronger}$_i$(I)]$_{head}$,[e$_i$(you)]$_{head}$)]
[am{stronger_than}(I,you)]

The relational structure of such constructions is yet to be worked out fully.

I have debated internally over the treatment of conjunctions in sentences like

The boy and the girl ate.

One suggestion is to treat this sentence as a conjunction of propositional descriptions leading to a representation of the form

[and([e$_i$(the boy)]$_{head}$,[ate$_i$(the girl)]$_{head}$)]

This treatment accords well with the logically based desire to treat conjunctions as logical operators operating over propositions. It does not, however, accord well with the **Grammatical Constraint**. The surface structure suggests that the conjunction **and** conjoins the two object descriptions **the boy** and **the girl** and not two propositional descriptions. Consider the sentence

The girl and the boy rode their bicycles.

In order to represent this sentence as a conjunction of propositional descriptions, we must break apart the object description **their bicycles** leading to a representation of the form

[and([e$_i$(the girl,her bicycle)]$_{head}$,[rode(the,boy,his bicycle)]$_{head}$)]

On the other hand, if we allow for conjunctions of object descriptions, this sentence can be represented more transparently by

[rode(and(the boy,the girl),their bicycles)].

This treatment of the conjunction **and** is discussed further when the representation of object descriptions is considered.

While conjunctions often conjoin entire propositional descriptions, the reality is that they can conjoin almost any category of constituent. Consider the sentence

He hit and kicked the wall.

The most straightforward representation for this sentence allows the conjunction to conjoin the two predicates **hit** and **kicked** leading to the representation:

[and{hit,kicked}(he, the wall)].

The validity of conjoined predicates is also strongly suggested by

The square is below and to the right of the circle.

This can be represented as

[is{and{below,to(the right)of}}(the square, the circle)]

where **to the right of** is represented by the specialized schema **|pred-spec{to(the right)of}(obj,obj)|** or **|(obj)pred-spec{to(the right)of}(obj)|.**

Consider the sentence

He ran and jumped the wall.

This can be represented by

[and([ran[he$_i$]$_{head}$,[jumped(e$_i$, the wall)]$_{head}$)]

Likewise

He hit and she kicked the wall

can be represented as

[and([hit(he,e$_i$)]$_{head}$,[kicked(she,the wall$_i$)]$_{head}$)].

Although conjunctions can conjoin constituents of most any type, it is assumed that all of the conjuncts must be of the same type—even though this fact may be hidden by the ellipsis of various elements of the conjuncts. This assumption is challenged by the sentence

He went before me

on the reading "he went before I went". The main problem is that the pronoun **me** is in the objective case, although it should be acting as the subject of the elided propositional description **I went**. The syntactic structure of this sentence strongly suggests that **me** is functioning as the object of the preposition **before** and not as the subject of an elided propositional description following the conjunction **before**.

It is probably the case that the conjunction of three propositional descriptions is supported—at least as long as the individual propositional descriptions do not exceed the capacity of the processing mechanism. Thus,

He ate, I slept and she worked

can make use of the **pred(prop$_{head}$,prop$_{head}$,prop$_{head}$)** schema leading to

[and([ate(he)]$_{head}$,[slept(I)]$_{head}$,[worked(she)]$_{head}$)].

This schema does not violate the three argument limit for propositional descriptions, although conjunctions of complex propositional descriptions are likely to cause problems for the processing mechanism. Likewise the schema **pred{pred$_{head}$,pred$_{head}$,pred$_{head}$}** can be used to conjoin

He hit, kicked and bit the opponent

leading to

[and{hit$_{head}$,kicked$_{head}$,bit$_{head}$}(he,the opponent)].

Pred(Prop,Prop,Prop,…) and Pred{Pred,Pred,Pred,…}.

It is generally assumed that conjunctions can be used to conjoin any number of arguments. However, there is likely to be some limit to how many such descriptions can be separately maintained in short term memory. That number need not be as small as two or three, however, it is unlikely to be larger than four or five. For conjunctions involving more than four or five elements, some means of separately conjoining subsets of the elements is likely to be needed. Given the need for such a capability to handle large lists of conjuncts, it may be that this capability comes in to play after as few as three conjuncts which is consistent with the proposed limit of three arguments for predicates in written English. Thus, the sentence

Tom ate, Dick slept, Mary laughed and Harry cried

could be represented as

[and$_i$([e$_i$([ate(Tom)],[slept(Dick)],[laughed(Mary)])],[cried(Harry)]]

where **e$_i$** represents an empty conjunction of the first three propositional descriptions and is co-indexed with **and$_i$**.

A similar capability is also needed to handle lists of conjoined predicates. Consider,

It is red, white, blue, purple and yellow

which can be represented as

[is{and$_i${e$_i${red,white,blue},purple,yellow}(it)]

assuming a limit of three conjuncts and using the **pred{pred,pred,pred}** schema.

Chapter 4: The Representation of Object Descriptions

Numerous researchers have put forward propositional analyses of English (see especially Miller and Johnson-Laird, 1976, and Miller, 1978). Most of these analyses focus on the consideration of the verb as the main predicate of the proposition and on the subject and objects of the sentence as the arguments to the predicate. PM is compatible with such approaches, but it takes the additional step of suggesting that the arguments of predicate-argument structures may themselves have an internal relational structure. This step is fairly straightforward for arguments which are themselves propositional descriptions, but, it is further suggested that object descriptions like **the red balloon** in

The red balloon burst

have a basic relational structure, and it is in this regard that PM differs from most other propositional systems of representation. In PM, the basic difference between the sentence

The balloon is red

and the noun phrase

The red balloon

is not so much a difference in relational structure as it is a difference in (a) what the expressions are used to **refer** to, (b) what is **salient** and what isn't, (c) what is **presupposed** and what isn't, and (d) what functions as the **head** of each expression. Both the sentence and the noun phrase explicate the property of redness of a balloon, but the sentence is used to predicate this property of a balloon and in so doing refers (or may be used to refer) to a particular situation, whereas the noun phrase presupposes this property of a balloon and in so doing refers (or may be used to refer) to a particular balloon. The sentence in predicating the property of redness of a particular balloon, makes that property salient. The predicate may be said to be the head or most important element of the constructions in which it participates, whereas the presupposed relation in a noun phrase may be said to be a modifier rather than a head. To distinguish these two different uses of relations, PM chooses to call the presupposed relations in object descriptions functions rather than predicates.

This chapter examines the relational structure of object descriptions. The suggestion that object descriptions have a basic relational structure may at first seem odd in that object descriptions are descriptions of objects and entities which are non-relational. However, except in the case of very basic object descriptions (e.g. descriptions consisting of a single pronoun or proper noun), it can be seen that most object descriptions contain relational elements. For example, the preposition **in** can be used as a relational predicate as in the sentence

The man is in the car

or it can be used as a relational function as it is in the noun phrase

The man in the car.

In both cases, the preposition **in** functions to establish a locational relationship between two object descriptions. The relational nature of these two expressions can be represented as

[is{in}$_{head}$(the man,the car)]
(in(the man$_{head}$,the car))

where the outer ( )'s around the second representation mark it as an object description and the subscript $_{head}$ marks the head of the propositional and object descriptions.

Whereas functions are the relational elements of object descriptions, terms are the base level non-relational elements of object descriptions. Terms are linguistically non-relational in that they are linguistically complete units which may be related to other terms via relational units, but which do not in and of themselves evoke any such relations.

The basic categories used in PM's representation of object descriptions and their correspondence to parts of speech and grammatical categories is shown below:

Object Description **=> Noun Phrase, Pronoun, Proper Noun,**
Conjunctions of the above

Function Description **=> Determiner, Adjective, Preposition, Adverb,**
Verb Participle, Predeterminer
Conjunctions of the above

Term Specifier **=> Determiner**
Conjunctions of the above

Term Modifier **=> Adjective, Preposition, Verb Participle,**
Conjunctions of the above

Function Modifier **=> Adverb**
Conjunctions of the above

Object Description Modifier **=> Adverb, Prepositional Phrase, Predeterminer**
Conjunctions of the above

Term Description **=> Noun, Pronoun, Proper Noun,**
Conjunctions of the above

Terms.

Terms are a key component of object descriptions in that they provide much of the descriptive content which is used in the determination of the referents of such descriptions. For this reason, the referential aspects of object descriptions are often assumed to inhere in terms. The assumption that terms determine referents and not the object descriptions in which they occur has been the source of considerable confusion. For example, the term **cat** is often described in extensional terms as referring to the set of all cats. This position has always struck me as suspect given the singular status of the word **cat** and the availability of a plural form **cats** for use in expressions which refer to more than one cat. In fact, the preferred way to refer to the set of all cats in English is via use of the plural word **cats** without a determiner as in

Cats are mammals.

In this example, the term **cats** functions as an object description which is being used to refer to the set of all cats (or at least as many cats as can be mentally entertained). On the other hand, the occurrence of a determiner like **the** before a plural noun like **cats** is typically used in expressions which refer to a subset of such entities as in

The cats are hungry.

Finally, in the sentence

The cat is a mammal

the singular status of the expression **the cat** suggests that a single prototypical or representative cat is being referred to and not the set of all cats. In PM, terms refer as part of object descriptions and do not in and of themselves have extensions. Of course, an object description may consist of a single term (as in the first example). In this case the term and the object description of which it is the only element are not distinct. Nonetheless, it is the object description (or term functioning as an object description) which refers. This position is consistent with a claim put forward by di Sciullo and Williams (1987) to the effect that

> word meanings are 'generic' or 'nonreferential'…specific reference to things, times, or truth-values is a phrase-level and sentence-level, not a word-level assignment process… (Pinker, 1989, p. 184).

Object descriptions typically contain specifiers which indicate that they are intended to refer, whereas terms in isolation do not. Thus, a common noun like **cat** typically requires specification to indicate that it is intended to refer as part of an object description. On the other hand, proper nouns and pronouns are inherently and contextually specified, and as such they can occur as the only elements of object descriptions. This gives pronouns and proper nouns the possibility of being at once terms and object descriptions. In this

respect, pronouns and proper nouns function much like subclasses in an object oriented representation. That is, their basic type is that of a term, but they can also function as object descriptions, and when they do they inherit the behavior of object descriptions. In terms of their distribution in English, they appear to function most often as full object descriptions and they do not exhibit the typical distributional characteristics of terms. For example, they do not typically occur with specifiers as in

The he
The Mr. Allan.

Of course, this restriction is not without exception and counterexamples like

The Tom I told you about yesterday
The other he

can be constructed. Further, in German, determiners are frequently used in expressions containing proper nouns as in

Die Helga ("the" Helga)
Der Gerhard ("the" Gerhard).

That such expressions do not often occur in English suggests the preferred treatment of proper nouns and pronouns as object descriptions in English. Essentially, pronouns and proper nouns are terms that are typically, immediately promoted to object descriptions during processing after which they do not exhibit the behavior of terms—although they may not be immediately promoted in some atypical contexts.

Typically, terms correspond to nouns in written English. However, any word can be used as a term under certain circumstances. In fact, the text you are reading is full of atypical uses of words as terms since much of the discussion is about these words, and in this context, they do not perform their typical use. Consider

The word *quickly* **is an adverb**

where **quickly** is being used as a term even though its typical use is as a function or predicate modifier. Further, multiple word units may also function as terms and the individual words of such units need not be nouns—especially if the multiple word unit is a fixed or idiomatic expression such as **man of the cloth** or **jumping jack**. To say that such expressions function as terms does not mean that they have no internal structure. Rather, it suggests that they are encoded and/or manipulated as single lexical units, despite the fact that they do have internal structure. Such lexical units need not be encoded in the mental lexicon. For example, in the case of novel compound noun constructions, there is likely to be some process available for the online recognition and manipulation of such compounds as units, even though they are not encoded in the mental lexicon. Consider the expressions

Needle valve stem
Document control station
Hotel lobby elevator operator.

These expressions are interesting in that they do not contain any relational elements to help in determining the nature of the relationships which exist between the individual terms. In the absence of relational information, these multiple word units are assumed to form compound lexical items without internal relational structure. The last expression above can be represented as

hotel_lobby_elevator_operator

where the underscores reflect the treatment of this expression as a single lexical item. This does not mean that the compound lexical item is prestored in memory or recognized as a whole. Rather, it suggests that the result of processing of the individual words is the construction of a compound lexical item which may or may not subsequently be stored in memory as a separate term. If we add relational elements to the original expression, it can be restated as

the operator of the elevator in the lobby of the hotel.

In this case, the relational units can be used in determining the nature of the relationships between the individual terms. In PM, this can be represented by

(of(the operator $_{\text{head}}$,in(the elevator,of(the lobby,the hotel))))

where **(** **)**'s are used to circumscribe the object descriptions which are the arguments of the functional elements. As is the case for the compound lexical item, this construction may or may not subsequently be stored in memory as a separate unit. In general, it is assumed that the more structurally complex and less frequently occurring a construction is, the less likely it is to be stored separately in memory.

There are reduced argument forms of many relational units which may function as terms. Such is the case for the word **hit** in the object description

The powerful hit

and the word **pounding** in

The pounding of his heart.

The meaning of such words, when used as terms, need not differ from their meaning, when used as predicates or functions. What differs is not basic meaning, but the expectation for the explicit occurrence of the arguments of the relational unit in the written text in the context of an object description. Of course, some mechanism for

converting these words from their more typical use as predicates to terms (and thereby suppressing the expectation for the occurrence of the typical arguments) is needed.

When the arguments to a verb participle functioning as a term are mentioned in an object description, additional relational elements (typically prepositions) are needed to bind those arguments to the participle. Consider the expression

The giving of the prize to the winner.

In this example, the participle **giving** is functioning as a term and the explicit expression of the arguments to the participle requires the inclusion of the prepositions **of** and **to** to relate them to the participle.

Functions.

Functions are the linguistically relational components of object descriptions and as such are largely responsible for determining the relational structure of such descriptions. In PM, functions (like predicates) can be classified in terms of the number and type of arguments they take. It will be argued below that there are three basic types of arguments to functions: **terms**, other **functions**, and **object descriptions**. Further, it will be assumed that functions take at most two arguments—with the exception of conjunctions which can take (at least) three arguments—and that the arguments to a function must be of the same type. Additionally, it is assumed that the type of the function argument combination depends on the type of the arguments such that an object description combines with a function and forms an object description, a term combines with a function and forms either a complex term or an object description, and a function combines with a function to form a function. Finally, it is assumed that one or more of the arguments acts as the head of the resulting function argument structure. Given these assumptions, the following functional types are possible:

Func<Term$_{head}$>	**=> Term**
Func<Term$_{head}$,Term>	**=> Term**
Func<Term$_{head}$,Term$_{head}$>	**=> Term**
Func<Term$_{head}$, Term$_{head}$,Term$_{head}$>	**=> Term**
Func-Mod{Func$_{head}$}	**=> Func**
Func-Mod{Func$_{head}$,Func$_{head}$}	**=> Func**
Func-Mod{Func$_{head}$,Func$_{head}$,Func$_{head}$}	**=> Func**
Func-Spec<Term$_{head}$>	**=> Obj**
Func(Obj$_{head}$)	**=> Obj**
Func(Obj$_{head}$,Obj)	**=> Obj**
Func(Obj$_{head}$,Obj$_{head}$)	**=> Obj**
Func(Obj$_{head}$,Obj$_{head}$,Obj$_{head}$)	**=> Obj**

In this notation, **func** is a function, **func-mod** and **func-spec** are subtypes of function corresponding to function modifiers and term specifiers, **obj** is an object description, **term** is a term, and the subscript $_{\textbf{head}}$ marks the head of the resulting description. Terms

are further identified by bracketing them with **<>**'s. The arguments of a function which are themselves functions are bracketed with **{ }**'s. Arguments which are full object descriptions are bracketed with **( )**'s. Using this notation, several object descriptions and their corresponding PM representations are shown below:

Old man	**=> <old<man>$_{head}$>**
The man	**=> (the<man>$_{head}$)**
The old man	**=> (the<old<man>$_{head}$>)**
The very old man	**=> (the<very{old}<man>$_{head}$>)**
The very small old man	**=> (the<very{small}<old<man>$_{head}$>>)**
The verb small very old man	**=> (the<very{small}<very{old}<man>$_{head}$>>)**

Determiners perform a function for object descriptions similar to the function that the auxiliary verbs perform for propositional descriptions. Both serve to complete the description of which they form a part by providing specifications which serve to fix the reference of the description. This correspondence provides a basis for generalizing about the structure of propositional and object descriptions in a way similar to the generalization put forward in **X-bar Theory** (see the description in Sells 1985). It suggests the existence of three levels of representation: (1) a base level, (2) an intermediate unspecified level above the base level, and (3) a fully specified level. For propositional descriptions, the base level is the predicate, the intermediate level is the unspecified propositional description, and the fully specified level is the specified propositional description. For object descriptions, the base level is the term, the intermediate level is the unspecified object description, and the fully specified level is the fully specified object description.

The examples below explicate the possible forms:

Func<Term$_{head}$>$_{Term}$	**old man**
	<old<man>$_{head}$>
Func<Term$_{head}$,Term >$_{Term}$	**can of beans**
	<of<can $_{head}$,beans>>
Func<Term$_{head}$,Term$_{head}$>$_{Term}$	**prince and princess**
	<and<prince $_{head}$,princess $_{head}$ >>
Func<Term$_{head}$,Term$_{head}$,Term$_{head}$>$_{Term}$	**man, woman and child**
	<and<man $_{head}$,woman $_{head}$,child $_{head}$ >>
Func-Spec<Term$_{head}$>$_{Obj}$	**the man**
	(the<man >$_{head}$)
Func(Obj$_{head}$)$_{Obj}$	**all the men**
	(all(the<men >$_{head}$))
Func(Obj$_{head}$,Obj)$_{Obj}$	**the man in the park**
	(in(the<man>$_{head}$,the<park>))
Func(Obj$_{head}$,Obj$_{head}$)$_{Obj}$	**the man and the woman**
	(and(the<man>$_{head}$,the<woman>$_{head}$))

Func(Obj$_{head}$,Obj$_{head}$,Obj$_{head}$)$_{Obj}$	**the man, the woman and the child**
	(and(the<man>$_{head}$,the<woman>$_{head}$,the<child>$_{head}$))
Func-Mod{Func$_{head}$}$_{Func}$	**very old …**
	very{old$_{head}$}
Func-Mod{Func$_{head}$,Func$_{head}$}$_{Func}$	**black and white …**
	and{black$_{head}$,white$_{head}$ }
Func-Mod{Func$_{head}$,Func$_{head}$,Func$_{head}$}$_{Func}$	**red, white and blue …**
	and{red$_{head}$,white$_{head}$,blue$_{head}$ }

The first four forms are subscripted with $_{Term}$ to indicate that the completed form has the status of a term. The next five forms are subscripted with $_{Obj}$ to indicate that the completed form has the status of an object description. The last three forms are subscripted with $_{Func}$ to indicate that the completed form will have the status of a function. The head of each form is also marked by the subscript $_{head}$. Redundant <>'s around terms are eliminate (e.g. **<of<<can>$_{head}$,<beans>>> => <of<can$_{head}$,beans>>**).

Func<Term$_{Head}$>$_{Term}$.

The typical example of a function which takes a single term for its argument an forms a term is the attributive adjective. The functional or attributive use of an adjective differs structurally from the predicative use in at least three respects. First, the argument to a predicate adjective typically occurs before it in English word order, whereas, the argument to an attributive adjective typically occurs after it. Consider the position of the adjective **red** in

The red book	**=> (the<red<book>$_{head}$>)**
The book is red	**=> [is{red}$_{head}$(the<book>)]**

Second, the argument to a predicative adjective is a complete object description, whereas, the argument to an attributive adjective is a term. Third, multiple attributive adjectives can occur in a single object description without being conjoined, whereas, only a single predicative adjective typically occurs in a propositional description without conjunction. Consider

The big old blue rug	**=> (the<big<old<blue<rug>$_{head}$>>>)**
The rug is big, old, and blue	**=> [is{and{big,old,blue}$_{head}$}(the<rug>)]**

Despite these structural differences, attributive and predicative adjectives perform a similar relational function. That is, they typically explicate some characteristic or property of some entity—with the predicative use predicating the property and the attributive use presupposing it. The structural differences noted above serve to mark the distinction between predication and presupposition.

In their functional use, verb participles behave very much like attributive adjectives. They typically take a single term as an argument with that argument occurring after the participle in the surface text. For present participles used as functions, the term which

functions as the argument of the participle corresponds to the subject argument of the particle when used predicatively in an active construction. Consider

The running bull => (the<running<bull>$_{head}$>)
The bull is running => [is{running}$_{head}$(the<bull>)]

For passive participles, the term which functions as the argument of the participle corresponds to the subject argument of the participle when used predicatively in a passive construction. Consider,

The kicked ball => (the<kicked<ball>$_{head}$>)
The ball was kicked => [was{kicked}$_{head}$(the<ball>)]

Quirk, Greenbaum, Leech, and Svartvik (1972, p. 910) also suggest that there are a small number of active past participles which can be used attributively. In this case the argument to the participle corresponds to the subject argument of the participle when used predicatively in an active construction.. Consider

The vanished treasure => (the<vanished<treasure>$_{head}$>)
The treasure vanished => [vanished$_{head}$(the<treasure>)]
(taken from Quirk et al., 1972, p. 910).

It may be that this form is limited to verbs which have an intransitive use, since the past participle is not distinguished from the passive participle for verbs which are transitive (an auxiliary verb is needed to mark this distinction).

In its functional use, a verb participle takes a single term for an argument despite the fact that the verb participle may take multiple arguments in its predicative use. As is suggested above, just which argument the verb participle takes in its functional use is well determined.

The close correspondence between attributive adjectives and verb participles is evidenced by their distribution in object descriptions with multiple premodifiers. According to Quirk et al. (1972), participles typically precede adjectives of provedance or style as in

Some interlocking Chinese designs
=> (some<interlocking<Chinese<designs>$_{head}$>>)
(Quirk et al., 1972, p. 923)

and follow adjectives of color as in

A black dividing line => (a<black<dividing<line>$_{head}$>>)
(Quirk et al., 1972, p. 923).

At the level of representation under consideration, PM is unable to explain the preferred ordering of different types of adjectives relative to verb participles (or the preferred

ordering of different types of adjectives relative to each other). However, PM does capture the close correspondence between adjectives and participles in classifying them both as functions which take a single term as an argument and form a complex term. Since complex terms can themselves function as the arguments to similar functions, PM allows the kind of recursive construction of object descriptions which is evident in English. Indeed, Quirk et al. (1972, p. 916) note that "…there is good evidence that multiple modification follows a recursive process…" They provide the examples

His [last (brilliant book)]
His [brilliant (last book)]

and suggest that the first means "…that of several brilliant books we are speaking only of his last one…" whereas the latter means "…his last book was brilliant without commitment to whether any of his other books were" (Quirk et at., 1972, p. 916). In PM, these expressions are represented as

(his<last<brilliant<book>$_{head}$>>)
(his<brilliant<last<book>$_{head}$>>)

respectively, reflecting their recursive relational structure and providing different structures to represent the different interpretations of these expressions. By way of contrast, a system of representation (e.g., the predicate calculus) which represented the relationships between the attributive adjectives nonrecursively would not provide structurally distinct representations for these two expressions. Possible predicate calculus like representations would be

∃x: His(x) & Last(x) & Brilliant(x) & Book(x)
∃x: His(x) & Brilliant(x) & Last(x) & Book(x)

Since the order of propositions is not significant in predicate calculus representations, these representations are not structurally distinct and fail to reflect a difference in meaning between the two expressions. Further, these representations fail to distinguish between the predicative and functional use of relations. They are also unable to distinguish compound functions containing adverbs (i.e. functions that modify functions) from compound functions containing just adjectives and participles (i.e. functions that modify terms). There are alternative formulations of logic which address these limitations of the predicate calculus, but like the predicate calculus, they violate Jackendoff's **Grammatical Constraint** in requiring significant reordering of the basic structure of the sentences they represent.

Func<Term$_{Head}$,Term>$_{Term}$ and Func<Term$_{Head}$,Term$_{Head}$>$_{Term}$.

There is a functional use of prepositions to establish a relationship between two terms. Examples of this use include

Can of beans => **<of<can$_{head}$,beans>>**
Book on crime => **<on<book$_{head}$,crime>>.**

In the resulting representations the first term is the **head** (i.e. what the expression as a whole is about). Thus, the first expression is primarily about a **can** and the second expression is primarily about a **book**. However, this does not change the basic relational nature of the prepositions **of** and **on**.

Although prepositions can apparently be used to establish a relationship between two terms, they more typically establish relationships between two object descriptions. In fact, in the examples above the second term **beans** is plural and can function as an object description and the term **crime** is essentially a mass noun and can also function as an object description. Consider

Beans are good => **[are{good}(beans)]**
Crime is bad => **[is{bad}(crime)]**

Thus, although I believe prepositions can be used to relate terms, I have yet to come up with a convincing example. The examples above are not unlike newspaper headlines where function words are often eliminated to save space. More complete expressions would include a determiner. Consider,

A can of beans => **(of(a<can>$_{head}$,beans) or (a<of<can$_{head}$,beans>>)**
A book on crime => **(on(a<book>$_{head}$,crime) or (a<on<book$_{head}$,crime>>)**

where the preposition could be represented as establishing a relationship between either two object descriptions or two terms. Providing emphasis may help determine the preferred form. Consider

A…can of beans
A can…of …beans

where the ellipses emphasize one possibility over the other.

Conjunctions are the most liberal of the relational elements in terms of the different type and number of arguments they take and in terms of the relational categories in which they participate. It has already been suggested that conjunctions may conjoin propositional descriptions, predicates, and object descriptions. It is argued below that conjunctions can also be used to conjoin terms and functions as well. Consider

The king and queen of Camelot.

In one possible relational structure for this expression the conjunction **and** takes the two terms **king** and **queen** for arguments and forms a complex term:

<and<king$_{head}$,queen$_{head}$>>

This complex term can then function as the argument of **the** forming the object description

(the<and<king$_{head}$,queen$_{head}$>>)

which in turn can function as the head argument of **of** forming

(of(the<and<king,queen>>$_{head}$,Camelot))

Of course, this is not the only possible representation for this expression, but it does have certain advantages. First, there are no elliptical elements in the representation. Second, the determiner **the** and the preposition **of** are treated normally (within PM). Third, allowing conjunctions to conjoin terms is not inconsistent with their generally liberal relational behavior.

If we allow for the occurrence of elliptical elements, this expression can be represented as a conjunction of object descriptions as in

(of(and(the$_i$<king>$_{head}$,e$_i$<queen>$_{head}$),Camelot))

where **e$_i$** represents an elliptical determiner that is "co-referential" with **the$_i$**. Of course, this is not really co-reference since determiners in and of themselves do not refer—rather it is more like elimination of a second determiner, with the first determiner filling its specifier role. In general, conjunctions are known to support many different types of ellipsis, and it may be that the ellipsis of a redundant determiner is also supported.

The representation of expressions like **the king and queen of Camelot** has interesting referential implications. If we represent the expression

The king and the queen => (and(the<king>$_{head}$,the<queen>$_{head}$)

as a conjunction of object descriptions with each object description referring to a distinct entity, then this expression clearly refers to two distinct entities. On the other hand, if we represent the expression

The king and queen => (the<and<king$_{head}$,queen$_{head}$>>)

as a conjunction of terms and a single object description, then how many entities are we referring to? The plural status of the expression suggests that we are still referring to two

entities, although we may be doing so in a manner which emphasizes their unity in a way which the preceding expression doesn't.

In the discussion above, both of the arguments of the conjunction are treated as heads of the resulting structure. Treating both arguments as heads seems reasonable given that there is no basis for preferring one argument over the other in a conjoined construction. Given the multiple heads, plural agreement with the main predicate is supported. However, in the case of disjunction, there is singular agreement with the main predicate. Consider

The king or the queen is coming =>
[is{coming}$_{head}$(or(the<king>$_{head}$,the<queen>$_{head}$))]

which suggests that the disjunction must somehow be contributing to determination of the agreement of the overall structure. One possibility for accounting for these agreement differences is to suggest that the conjunction (or disjunction) functions as the head of the resulting structure. Given the limited semantic content of the conjunction or disjunction and its use as a function (as opposed to a term or object description), its treatment as the head of the resulting structure would be atypical.

Func-Spec<Term$_{Head}$>$_{Obj}$.

This category of function typically provides the specification needed to convert terms into full-fledged object descriptions. The prototypical member of this category is the determiner.

The relational treatment of determiners reveals a major difference between PM's system of representation and most other linguistic alternatives. Only a few researchers (e.g., Hudson, 1984; Langacker, 1987) have hinted at a similar linguistic treatment. Most other systems of representation treat determiners as modifiers of nouns with a purely subordinate non-relational status. Indeed, PM's relational treatment of determiners can be challenged. Determiners are not your typical relations. They do not express concrete properties of objects or concrete relations between objects. Rather, they provide information about the definiteness and specificity of object descriptions.

That determiners are linguistically relational is strongly suggested by the fact that some determiners do not occur as isolated constituents. The occurrence of one of these determiners requires the occurrence of a term for that determiner to specify. Such expressions as

I want a… **=> [want(I,a<…>$_{head}$)]**
The… **=> (the<…>$_{head}$)**

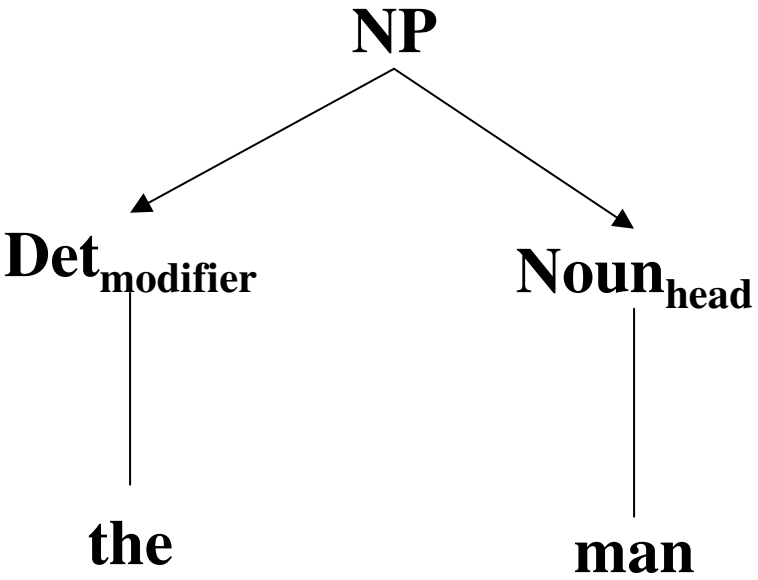
call out for the occurrence of a term to complete the expression. On the other hand, some other determiners can function as terms and object descriptions as well as functions and

do not evoke the strong sensation of incompleteness when they occur in isolation. Consider

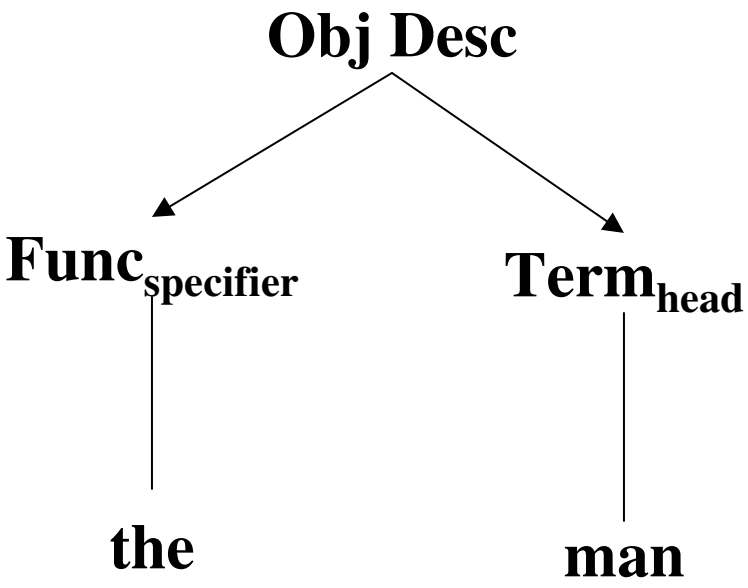
I want that **=> [want(I,that)]**
I want that book. **=> [want(I,that<book>)]**

In the first sentence, the word **that** is functioning as a complete object description. In this use it is linguistically non-relational and such determiners (in this use) are called demonstrative pronouns. Like other pronouns, they are inherently specified (or deictic), and it for this reason that they can function as complete object descriptions. On the other hand, in the second sentence, **that** is a function which establishes the definiteness of the term **book**. The dual functionality of words like **that** clouds their linguistically relational status when used as determiners.

In a traditional analysis of a noun phrase like **the man** hierarchical structure is used to reflect the constituency of the structure. In this case, the determiner **the** and the noun **man** combine to form a noun phrase (NP). This hierarchical structure may be further annotated to show that **man** is the head (or most salient element) of the noun phrase and that it is modified (or specified) by the determiner **the**.



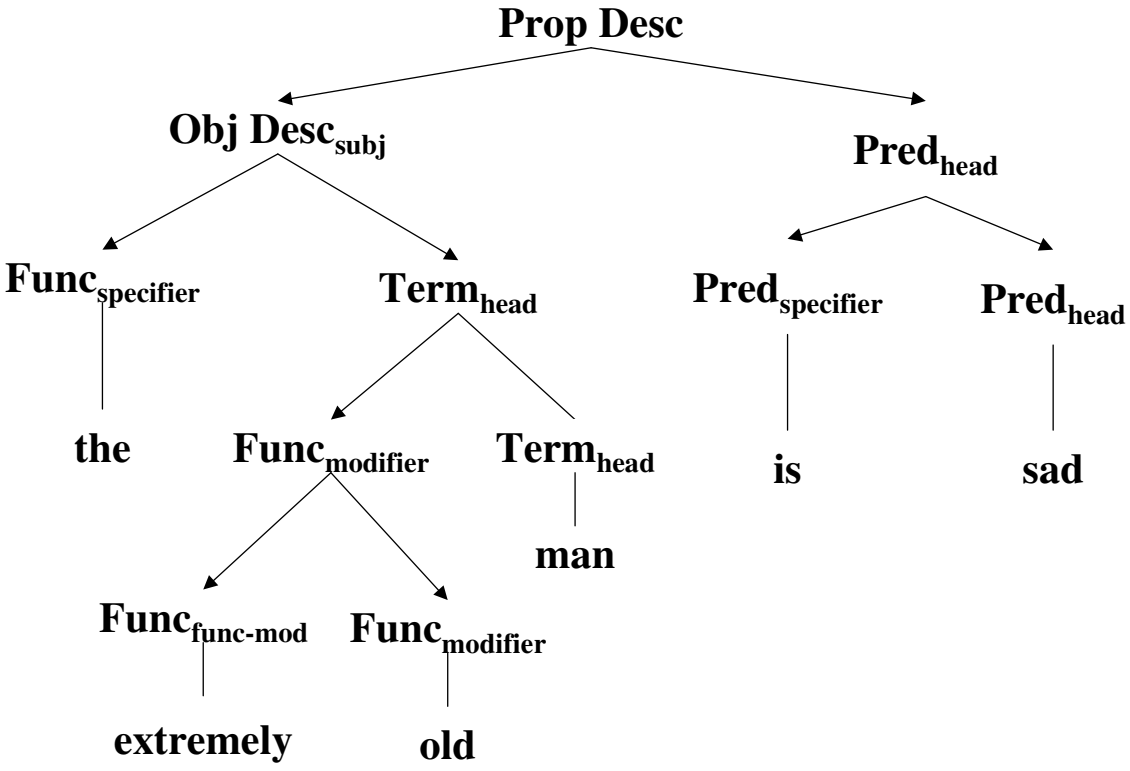
In PM, it is relational structure which is highlighted hierarchically and the salience of the noun **man** is expressed by subscripting it with $_{\textbf{head}}$ to reflect that salience as in


Obj Desc
Func specifier
Term head
the
man

However, given the modest number of categories in PM, it is possible to use the available bracketing notations: ( )'s (object description), **< >**'s (term), **[ ]**'s (propositional description), and **{ }**'s (function and predicate modification) to identify the possible categories as in:

The extremely old man is sad => [is{sad}$_{head}$(the<extremely{old}<man>$_{head}$>)]

which could be more graphically represented as:



The use of different forms of bracketing and subscripting makes it possible to represent relational structure and head/modifier relationship in a linear sequence of tokens.

PM's treatment of determiners reveals a major difference with the predicate calculus. In PM, determiners are not translated into existential or universal quantifiers which operate over entire sentences as the predicate calculus does. Rather, they are treated as functions within the expressions in which they occur. PM's treatment is in accord with Jackendoff's (1983) **Grammatical Constraint** and retains the close correspondence between surface form and relational structure which this constraint espouses.

$Func(Obj_{Head})_{Obj}$.

There is a class of function in English which takes a full object description as an argument. The prototypical member of this class is called a pre-determiner. Pre-determiners are words which can precede determiners in noun phrases. They typically have a quantifying function which contributes to the specification of the object description. For example, in the phrase

All the men

The object description **the men** functions as the argument of the pre-determiner **all**, forming an object description which is represented as

(all(the<men>$_{head}$))

Some pre-determiners can also be used as straight determiners, reinforcing the suggestion that they contribute to the specification of object descriptions. Consider the expression

All men => (all<men>$_{head}$).

Some pre-determiners can also function as terms and object descriptions, and when they do a preposition like **of** is required to bind them to any subsequent object description. Consider,

All of the men => (of(all$_{head}$,the<men>))

in which the pre-determiner **all** is bound to the object description **the men** by the preposition **of** with **all** functioning as the head of the expression.

Not all pre-determiners can be used as determiners, nor can all determiners be used as pre-determiners. For example, the determiner **the** does not have a pre-determiner use. As a result, phrases like

The some men

do not occur.

An alternative treatment of pre-determiners might suggest that they modify determiners and not object descriptions. In this alternative treatment the expression

All the men

could be represented as

(all{the}<men>)

Where **{ }**'s are used to show that the determiner **the** is functioning as the argument of the pre-determiner **all**. If this alternative treatment is viable, then a similar treatment of auxiliaries is also suggested. Consider

He could have gone

which could be represented as

[could{have}{gone}(he)]

where **could** takes **have** as its argument and not **have{gone}.** This treatment is complicated by other components of the predicate. Consider,

He could not have gone

which might be represented as

[could{not{have}}{gone}(he)]

Allowing for this possibility (in addition to the original treatment) would complicate the system of representation (see the discussion of scoping of predicate modifiers in Chapter 3). There is not sufficient motivation at this point to justify this complication and it will not be considered further (at this time).

Since pre-determiners take an object description and form an object description, multiply predetermined expressions should be possible. However, pre-determiners tend to constitute a mutually exclusive set of quantifiers, and multiply pre-determined expressions like

All both the men

do not occur. On the other hand, pre-determiners are not always mutually exclusive. For example, while the expression

Half all the men => (half(all(the<men>$_{head}$)))

sounds awkward if interpretable, the expression

Half of all the men => (of(half$_{head}$,all(the<men>)))

is entirely acceptable (to me). For similar reasons, pre-determiners do not occur with quantitative determiners as would be the case if the expressions

All some men

could occur.

Pre-determiners tend to occur with determiners in relatively fixed patterns. Such patterns are likely to be separately encoded in memory as compound lexical items. For example, the patterns

All the …
All of the …
Half of the …

occur frequently enough to be good candidates for lexicalization. The argument preferences of these lexicalized expressions can be represented as

all_the<Term>$_{head}$
all_of_the<Term>$_{head}$
half_of_the<Term>$_{head}$
one_of_the<Term>$_{head}$
all_of(Obj$_{head}$)
half_of(Obj$_{head}$)

where underscores reflect the lexical status of the compounds. These lexicalized forms or schemas represent a specialization of the basic forms which are the focus of this chapter. Despite this focus, much of our knowledge of language is assumed to be represented by lexical specializations of the basic forms.

An interesting result of this lexicalization process is to allow the last term to be the head of the expression. Consider

One of the men => (one_of_the<men>$_{head}$)

If **men** is the head then we would expect plural agreement with the verb as in

One of the men are coming => [are{coming}(one_of_the<men>$_{head}$)]

instead of

One of the men is coming => [is{coming}(of(one$_{head}$,the<men>)].

Treatment of the latter term as a head (or as the basis for verb agreement) is a common "mistake" in such expressions.

Func(Obj,Obj_{Head})$_{Obj}$ and Func(Obj_{Head},Obj_{Head})$_{Obj}$

The typical members of this category are the preposition and the conjunction. Consider the expression

The notion of a proposition

This expression contains the preposition **of** which establishes a relation between the object descriptions **the notion** and **a proposition** and can be represented as

(of(the<notion>$_{head}$,a<proposition>))

The resulting construction can itself be combined recursively with other constructions. Consider

The man on the hill with a telescope.

There are two prepositions in this expression which combine three object descriptions and there are two possible representations:

(with(on(the<man>$_{head}$,the<hill>),a<telescope>))
(on(the<man>$_{head}$,with(the<hill>,a<telescope>)))

corresponding to

The man on the hill … with a telescope
The man on … the hill with a telescope

The system of representation is adequate to represent these two possibilities, but the determination of which representation is appropriate entails a consideration of processing issues which are discussed in a later chapter. Essentially, if the processing mechanism decides to instantiate the object description **the hill** as the second argument of **on** then the first representation will be created, and if the processing mechanism delays the instantiation of **the hill** until the occurrence of the preposition **with** and then instantiates this object description as the first argument of **with**, then the second representation will be created.

Conjunctions are the other prototypical member of this category. For example,

The men and the women

can be represented as

(and(the<men>$_{head}$,the<women>$_{head}$)).

This resulting construction can itself be recursively conjoined with other object descriptions as occurs in the expression

The man and the woman or the child

For which the following two representations are possible:

(and(the<man>$_{head}$,or(the<woman>$_{head}$,the<child>$_{head}$)))
(or(and(the<man>$_{head}$,the<woman>$_{head}$),the<child>$_{head}$)).

The first representation corresponds to the reading in which **the woman** and **the child** are disjoined and this disjunction is conjoined with **the man**. The second representation corresponds to the reading in which **the man** and **the woman** and conjoined and this conjunction is disjoined with **the child**.

Although it is assumed that all the arguments of a conjunction are equally salient and treated as heads, the nature of the conjunction influences the agreement status of the result. Consider

The man and the woman are here =>
[are{here}(and(the<man>$_{head}$,the<woman>$_{head}$))]
The man or the woman is here =>
[is{here}(or(the<man>$_{head}$,the<woman>$_{head}$))].

In the case of a disjunction, the grammatical status of the object description is singular and not plural, despite the occurrence of two separate object descriptions. Given the conflicting indications of plurality in the disjunction of object descriptions, there is likely to be considerable variability in usage. And the earlier sentence including both a conjunction and disjunction is even more likely to show this variability:

The man and the woman or the child are coming
The man and the woman or the child is coming
The man or the woman and the child are coming
The man or the woman and the child is coming.

I suspect that the plurality of such object descriptions is problematic regardless of which reading is intended and subject-verb agreement would not be decisive in determining the structure.

Conjunctions and prepositions can be intermixed in object descriptions as in

The men and the women of the delegation

which can be represented by

(of(and(the<men>$_{head}$,the<women>$_{head}$),the<delegation>))

(and(the<men>$_{head}$,of(the<women>$_{head}$,the<delegation>))).

The first representation corresponds to the reading in which both **the men** and **the women** are members of **the delegation**, whereas the second representation corresponds to the reading in which only **the women** are members of **the delegation**.

From a relational perspective, prepositions and conjunctions can both be used to establish relations between object descriptions. However, they differ in terms of the saliency of the object descriptions they relate. There is an asymmetry in the saliency of the arguments of a preposition which does not exist for conjunctions. In PM, this is represented by the subscripting of only the first argument of the preposition with $_{head}$, whereas for the conjunction both arguments are subscripted.

In referential terms, we can say that the overall reference of an object description is to the head of that description, with reference to other objects being internal to the description. Since conjunctions allow for the occurrence of multiple heads, object descriptions containing conjunctions will typically refer to multiple entities. Consider

The man and the boy
The queen of England

The conjoined expression as a whole refers to two different entities **the man** and **the boy**. The expression containing the preposition **of** refers to two different entities as well, **the queen of England** and **England**. However, reference to **England** is internal to the construction, and the overall reference of the construction is to a single entity **the queen of England**.

Func(Obj_{Head},Obj_{Head},Obj_{Head})$_{Obj}$ and Func(Obj_{Head},Obj_{Head},Obj_{Head},…)$_{Obj}$.

Despite the two argument limit for other functional types, conjunctions appear to be capable of conjoining at least three and perhaps four or five object descriptions—subject to limitations of short-term memory and the processing mechanism. Consider,

The man, the woman and the child =>
(and(the<man>$_{head}$,the<woman>$_{head}$,the<child>$_{head}$).

On the other hand, consider

The man at the store that I told you about, the woman in the house across the street that likes to read books, the boy by the park with the new bicycle, the girl in the blue polka dot dress on the stage who is singing, the dog with the broken leg lying down in the street, and the cat with the rat in its mouth…

Is it really the case that the processing mechanism is capable of maintaining these complex object descriptions in short-term memory until they can be conjoined together? Perhaps, but only if each complex object description can be chunked during processing so that short-term memory is not overloaded. And if the individual complex object descriptions must be chunked into units prior to occurrence of the conjunction, then it is also possible that multiple chunked object descriptions may themselves be chunked before that conjunction occurs. Thus, it is likely to be the case that for long lists of conjuncts, some mechanism for chunking together subsets of those conjuncts is available prior to actual occurrence of the conjunction. This chunking together has the effect of retaining a cue in short-term memory to facilitate the subsequent retrieval of the conjuncts from long-term memory. The alternative, is that the individual conjuncts will drop out of short-term memory and will have to be retrieved from long-term memory when the conjunction occurs. This latter process is likely to be error prone since the conjuncts which are no longer available in short-term memory (and for which no cue is available) are unlikely to be easily retrieved from long-term memory.

Func-Mod{Func}.

The prototypical member of this category is the adverb when used in an object description. Consider

The extremely sad story

In this expression the adverb **extremely** combines with the adjective **sad** to form the complex function **extremely{sad}**. The relational status of the complex function is determined by the adjective **sad**. Since **sad** takes a term for its argument, the complex function **extremely{sad}** does likewise. **Extremely{sad}** takes the argument **story** and forms a complex term that is specified by the determiner **the** as in:

(the<extremely{sad}<story>$_{head}$>).

The fact that an adverb cannot typically occur in the absence of an adjective or verb participle in object descriptions supports the treatment of adverbs as function modifiers. For example, expressions like

Extremely story

do not often occur. There do appear to be cases where words which are normally considered to be adverbs can take terms for arguments. Consider

The very day => (the<very<day>$_{head}$>)

In this expression, it might be suggested that **very** is functioning as an adjective rather than an adverb. However, this is apparently a specific characteristic of the adverb **very** and not a general characteristic of most adverbs.

Func-Mod{Func,Func} and Func-Mod{Func,Func,…}.

The promiscuous conjunction is the prototypical example of a function that takes two or more functions as arguments. Consider

The red, white and blue flag

which can be represented straightforwardly as

(the<and{red,white,blue}<flag>$_{head}$>)

Variants of this representation which restrict **and** to conjoining terms or worse—object descriptions—are highly elliptical:

(the<and<<red<e_{i1}>>,<white<e_{i2}>>,<blue<$flag_i$>$_{head}$>>)
(and(the$_k$<red<e_{i1}>>,e_k<white<e_{i2}>>,e_k<blue<$flag_i$>$_{head}$>))

Such highly elliptical representations reveal the virtue of adhering to the **Grammatical Constraint**. On the other hand, there are likely to be processing limitations which preclude an unbounded number of arguments to conjunctions, including conjunctions which conjoin functions, and some means for chunking together subsets of the arguments which may involve elliptical relations is needed.

Other Possible Types in Object Descriptions.

In the preceding discussion it has been assumed that the arguments of functions are necessarily of the same type. However, this assumption can be challenged. Consider

The prince and princess.

If conjunctions can conjoin arguments of different types then this expression can be represented as

(and(the<princess>$_{head}$,<princess>$_{head}$))

where the first argument is an object description and the second argument is a term. However, if conjunctions can conjoin mixed argument types, then the number of possible forms involving conjunctions increases to the point where it is probably not reasonable to suggest having schemas for all the possible forms and some more generic type independent form for conjunctions would need to be available.

Perhaps the best example of a function which appears to take arguments of mixed type is the possessive marker **'s**. Consider the expression

John's book.

If we assume the proper noun **John** is functioning as an object description and **book** is functioning as a term, then the obvious treatment of the possessive marker is as a function of the form

func(Obj,<Term>).

Accepting this treatment, the expression above can be represented as

(s_{poss}(John,<book>))

What should be the head of this structure? Grammatical agreement suggests that the latter term is the head. Consider,

The twins' book is on the table =>
[is{on}$_{head}$(s_{poss}(twins,<book>$_{head}$),the<table>)]

where agreement is with the singular term **book** and not the plural term **twins**.

This treatment of the possessive marker can be contrasted with the alternative form of such expressions which involve the preposition **of**. Consider the expression

The book of John

where the preposition **of** takes two object descriptions and forms

(of(the<book>$_{head}$,John)).

Note that the head of this object description is the term **book** which is consistent with the treatment of the possessive marker above.

In a mixed argument treatment, the preposition **of** can be treated as taking a term and an object description as arguments, leading to the possible representations

(the<(of(<book>$_{head}$,John))>)
(the<of<<book>$_{head}$,John>>)

The first representation is problematic since the determiner **the** does not take an object description for its argument, just a term. The second representation is problematic since the object description **John** combines with **of** to form a term and not an object description. In general, the mixing of argument types leads to such problematic representations.

The above treatment of the possessive marker suggests that the requirement that the arguments of a function be of the same type may need to be relaxed. However, that relaxation may be specific to the possessive marker and need not apply more generally.

There is an alternative treatment of the possessive marker in which it can be treated as a function which combines with an object description to form a function that takes a term for an argument. This can be represented as

(John's<book>$_{head}$)
(s_{poss}{John}<book>$_{head}$)

where the first representation treats the combination as a lexicalization and the second representation attempts to reflect the structure of the combination. In this treatment, the possessive marker is essentially a **functionizer**. That is, it is a function which converts an object description into a function. Further, the special status of the possessive marker does not require relaxation of the no mixed arguments restriction. However, it does require introduction of a new type of function (i.e. a function that takes an object description and forms a function). This can be represented schematically as

func(obj)<term $_{head}$>.

The **functionizing** capability of the possessive marker is akin to the suggested **predicatizing** capability of the copular verb **to be** in

He is a man => is(a<man>)(he).

There are reasons for suggesting that mixed representations are not valid. In the first place, it is not obvious what the referential status of such representations would be. How many entities are being referred to in a conjunction of object descriptions and a term? Second, if we allow functions to take mixed argument types, then the number of possible representations increases considerably. Unless it can be shown that the increased number of representations corresponds to differing interpretations, then mixed argument types can be avoided without loss in representational capacity. On the other hand, it is probably the case that expressions involving functions taking mixed argument types can be constructed, although such expressions are not likely to be commonly occurring in English. Consider

The prince, the princess and duke

Such object descriptions may result from the mixing of expressions which do not themselves include functions taking mixed argument types. Thus, the above expression may have resulted from the mixing of the expressions

The prince, the princess and the duke
The prince, princess and duke

Neither of which by themselves include mixed argument types.

Chapter 5: The Relationship between Surface Form and Meaning

Introduction

PM takes a strong stand in arguing that there is a very direct correspondence between surface form and meaning. This claim is important given PM's commitment to the direct interpretation of surface text into representations of meaning. However, PM is primarily concerned with a consideration of the relational aspects of meaning, and with the representation of propositional or relational structure. Since there are many non-relational aspects of the relationship between surface form and meaning, PM does not provide an overall explanation of that relationship. PM's system of representation effectively abstracts away from such considerations. Nonetheless, it will be argued that PM's system of representation can be used as is in the development of language comprehension systems. That argument is based on the assumption that the determination of relational structure is the most crucial element of language comprehension. Many non-relational aspects of the relationship between surface form and meaning can be ignored without major loss in comprehension. It will also be argued that generation of grammatical English requires the consideration of grammatical details which may often be ignored during comprehension. PM's system of representation does not provide for the representation of such grammatical details. However, it will be argued that PM's system of representation is compatible with the more detailed grammatical treatments of Jespersen (1984, 1965) and Quirk, Greenbaum, Leech and Svartvik (1985, 1972), and that such grammatical details could be integrated into PM.

Some Non-relational Aspects of the Relationship between Surface Form and Meaning

In a book entitled *Grammar and Meaning, a Semantic Approach to English Grammar*, Howard Jackson (1990) presents a description of English grammar which focuses on the relationship between surface form and meaning. This book is in many ways a summary of Quirk, Greenbaum, Leech and Svartvik's (1985) *A Comprehensive Grammar of the English Language*. Included among the topics discussed are subject-verb agreement, the distinction between mass and count nouns, the distinction between common and proper nouns (and pronouns), the treatment of person, number, and gender, the treatment of definiteness and specificity, and the treatment of mood, tense and aspect. Most of these topics have not been discussed, or have been discussed only peripherally in this manuscript. It is my claim that such considerations involve aspects of meaning which are largely orthogonal to, or at least at a level of detail below, considerations of relational structure. But can such considerations safely be ignored in a project which is ultimately concerned with the development of functional and cognitively plausible natural language

processing systems? Perhaps not. However, there are arguments which can be made in support of the approach adopted.

In the first place, although PM does not explicitly deal with such phenomena, the fact that PM representations contain the actual linguistic tokens which were used to encode such grammatical information—rather than relying on the use of metalinguistic tokens which abstract away from such information—affords the possibility of an eventual treatment in PM.

In the second place, there is psychological evidence which suggests that human language comprehension does not depend on the resolution of various grammatical details (which would presumably be required if language comprehension involved the construction of detailed syntactic representations corresponding to input text). At least for a time during the 70's, many psycholinguists (e.g., Fodor, Bever and Garrett, 1974) "…rejected the hypothesis that grammatical rules are used in comprehension" (Tanenhaus, 1988, p. 15). More recently, Johnson-Laird (1983, p. 333) argues against the construction of syntactic structures during comprehension, suggesting that "…there is no need and no evidence for any representation of syntactic structure." In essence, structural information is useful only to the extent that it facilitates the determination of meaning and can otherwise be ignored. And since grammatical errors don't contribute to the determination of meaning, they are likely to be ignored (at least when they do not **interfere** with the determination of meaning). In this regard, Johnson-Laird refers to the results of an experiment by Scott Warman in which subjects were presented with sentences containing grammatical errors and notes that "…remarkably, they very rarely notice any error…" (1983, p. 333). He also presents an online demonstration that a sentence containing a subject-verb agreement error can be read and understood by subjects (in this case the readers of his book, including the writer of this manuscript on more than one occasion) without awareness of the grammatical error contained in the sentence. We have all had the experience of identifying grammatical errors in texts on second and third reading which were completely missed on first reading, without effect on comprehension. This is especially disconcerting when the reader is also the writer of the text in question. A colleague of mine from China who speaks and apparently comprehends English quite well, has a great deal of difficulty getting subjects to agree with verbs in her written work. If she has such difficulty with subject-verb agreement even when given as much time as needed to get it right, it seems highly unlikely that she makes extensive use of such information during comprehension. Indeed, it is likely to be the case that foreign speakers of English make little use of numerous grammatical details, since their generally poor command of English makes the use of such information unreliable or unavailable. In conversations with a non-native speaker of English, I noticed that she had adopted the strategy of using a single verb form in her speech. Thus, she would say **I knows**, **she knows**, and **Graham and Alan knows**. I assume she had adopted this strategy because either she doesn't know or she has difficulty in using the correct forms. While I noticed her strategy, her failure to use the correct verb form had little effect on my ability to comprehend what she was saying. In my own experience with foreign languages, I find myself unable to make use of many grammatical details. For example, given my limited knowledge of German grammar, I am frequently unable to provide the correct form of the

definite determiner (e.g. **der**, **die** or **das**). I have noticed on occasion that I resort to use of the corrupted form **de** in my speech as a way of getting around this problem. I am also frequently unable to take advantage of the information provided by the case marking on nouns. This can certainly lead to failures in comprehension on my part, since my default assumption that the first noun phrase (or argument) is in the nominative case (i.e., the subject in English) frequently fails to obtain in German (in part because the case markings make word order less critical for comprehension by fluent speakers of German). Nonetheless, I am able to comprehend many German sentences despite my poor command of the German case marking system. Although grammatical errors of non-native speakers are especially abundant, native speakers of English are likely to exhibit similar behaviors on a smaller scale. Knowledge of language is accumulated over time based on experience and use. Knowledge of low level grammatical details is likely to be heavily overlearned and well entrenched among adult native speakers of a language. Nonetheless, we all produce and encounter grammatical errors, and yet such errors seldom prevent comprehension or communication of meaning.

In an interesting book on child language acquisition, Radford (1990) suggests that English speaking children of less than 24 months of age typically do not exhibit any productive use of the grammatical markings corresponding to determiners, inflections, complementizers and case. With regard to determiners, this means that they are unable to make use of the distinction between terms and object descriptions and they use terms referentially in ways that adults typically do not. For example, the following are recorded utterances from early child English (taken from data collected by Radford):

Wayne in bedroom
Car gone
Mommie eat cookie.

Radford's basic thesis is that early child English, unlike adult English, is lexically and thematically based and lacks functional (i.e., purely grammatical) categories. However, adult English, like early child English, allows similar constructions in numerous contexts. Consider

Education opportunities open (newspaper heading)
Stainless steel cover standard (product catalog)
Proceed home station (Naval message database).

Further, adults have little difficulty in comprehending the utterance of their young children (at least those utterances which only lack grammatical markers). Essentially, child grammar is more primitive or basic than adult grammar. Child grammar fails to make use of certain grammatical distinctions which are common in adult grammar. Adult grammar doesn't replace child grammar, it refines and extends it to allow for the encoding of more subtle distinctions of meaning. In this regard, natural language comprehension systems which insist on compliance with the grammatical details of fully specified adult English will be unable to process the more primitive utterances of early child English and will also be unable to process adult English which happens not to be

fully specified grammatically. The inability of such systems to process early child English leaves the close relationship between child and adult grammar unexplained. Further, the inability of such systems to process adult English which is not fully specified limits their usefulness. Whereas an important goal of linguistics has been stated to be the description of grammars of languages which generate all and only the grammatical sentences of a language (e.g. Chomsky, 1957, 1965), an important goal of any language comprehension system must be the comprehension of all meaningful utterances. Natural language parsers which are constructed in pursuit of the linguistic goal are unlikely to prove especially useful in pursuit of the goal of a comprehension system.

Finally, within the field of Artificial Intelligence, the highly successful comprehension systems of Wilks (1972, 1975a) and Schank (1975) (as implemented by Riesbeck 1975) were based on the claim that semantics and not syntax should drive the comprehension mechanism. Both of these systems did make use of some structural information, but that information was limited and was integrated with the semantic component of the comprehension system. The success of Wilks' and Schank's systems demonstrates the feasibility of the approach adopted in this work. As a practical matter, given the difficulty of building language comprehension systems, the development of such systems should proceed from the treatment of those aspects of language which most directly impact the determination of meaning to a treatment of those aspects whose impact is less direct. Low level grammatical details, while well understood from a linguistic perspective, have minimal impact on the determination of the basic propositional content of English sentences.

The computer implementations of the theories of Wilks and Schank demonstrate the viability of a direct interpretation of English text into meaning representations. PM has itself been used as the theoretical basis for the development of the English analysis component of a sentence (or lower level constituent) based English-Japanese Machine Translation (MT) system. That analysis component operates in two stages: (a) an initial analysis of the input sentence (or lower level unit) into a PM based representation, and (b) the subsequent mapping from the PM representation to a language independent interlingual representation. The final version of the English-Japanese system contained several thousand English words and their Japanese equivalents, and operated over a collection of manuals which contain descriptions of high quality plumbing valves for sale to industry. These descriptions tend to be terse, and often lack various grammatical markers like determiners and auxiliary verbs. They are frequently noun phrases, prepositional phrases or subjectless (and auxiliary verbless) sentences. Fortunately, the PM based parser does not require the inclusion of such grammatical markers nor does it require the input to be in the form of a sentence. It accepts whatever input it gets, identifying relational and non-relational elements and constructing representations in which the non-relational elements are appropriately instantiated as the arguments of the relational elements.

If we accept the basic use of language to communicate information or meaning, then it follows that grammatical information will prove useful just to the extent that it contributes to the determination of meaning. Grammatical information which does not

contribute to that determination can safely be ignored without loss of meaning. It is a basic contention of this thesis that most forms of surface variation **do** contribute to meaning. However, it is also an assumption that languages redundantly encode information. As such, the determination of propositional structure (and meaning more generally) can proceed with reasonable success in ignorance of certain details of grammar, especially when such details redundantly encode information. It is not that such information is not potentially useful, but that a reasonable level of performance is attainable without its consideration. For example, in the majority of English sentences, subject-verb agreement contributes minimal non-redundant semantic information (English surface order strongly marks the subject position). Further, subject-verb agreement does not always follow the expected pattern, and too strong a reliance (or insistence) on subject-verb agreement can lead to problems. Consider

The beans are cooked
A lot of beans were cooked
The beans is cooked.

The first sentence follows the expected pattern. However, the second and third sentence do not. In the second sentence, one could argue that it is the word **beans**, the object of the preposition **of**, which agrees with the verb, and not the head of the noun phrase. Alternatively, one could argue that the meaning of the word **lot** includes the notion of plurality despite the lack of an overt grammatical marking, and that the verb agreement is in accord with the meaning of the word **lot**. This latter argument is consistent with the occurrence of the sentence

A lot were cooked ("a lot was cooked" sounds odd to me)

In the third sentence, the subject fails to agree with the verb, but the sentence can still be interpreted despite this agreement "error". We would expect a language comprehension system to be able to analyze these latter two sentence despite their agreement problems (in these examples surface order can be used to identify the subject). On the other hand, there are cases where subject-verb agreement provides non-redundant information which can be used to resolve ambiguities during language comprehension. Consider

Flying planes is fun → **[is{fun}([flying(e,planes)]$_{obj}$)]**
Flying planes are fun → **[are{fun}(flying<planes>)]**

In the first sentence, subject-verb agreement suggests the gerundive as opposed to participial treatment of the word **flying** (the head of the constituent) leading to a reading in which the act of flying planes is fun. In the second sentence, **flying** is modifying **planes** (the head of the constituent) and it is the planes (which happen to be capable of flying) which are fun.

Further, subject-verb agreement may prove useful in determining the propositional structure of sentences like

Horses, the boy likes **=> [likes(the<boy>,horses)]**
The boy, horses, likes **=> [likes(the<boy>,horses)]**
Horses, the boy, like **=> [like(horses,the<boy>)]**

Since the location of the arguments in these sentences are non-standard, surface order cannot be used to distinguish subjects from objects and only subject-verb agreement provides the discriminating capability. On the other hand, one should not overstate the usefulness of subject-verb agreement, which is often indecisive, as in

The horse, the boy likes **=> [likes(the<horse>,the<boy>)]**
[likes(the<boy>,the<horse>)]

or redundant, as in

Horses, he likes **=> [likes(he,horses)]**

(where the pronoun **he** is marked for the subjective case).

Indeed, most systems of language comprehension which make use of grammatical information make the mistake of relying too heavily on it. For example, if only count nouns can occur with determiners or enumerators, then sentences like the following (in which a determiner occurs with a mass noun) should not occur:

Give me 3 ketchups (i.e. 3 packets of ketchup)
He has a milk every day for lunch (i.e., a half-pint of milk)

The fact is that they do occur. The occurrence of a determiner or enumerator with a mass noun suggests a semantic individuation which does not normally hold for such words. A comprehension system which disallows such constructions is too restrictive to be generally useful. On the other hand, a comprehension system which ignores the difference between count and mass nouns will be unable to adequately represent this aspect of meaning.

The distinction between plural and singular nouns interacts with the count/mass distinction in interesting ways. Mass nouns typically only occur in the singular, whereas count nouns can be either singular or plural. By violating the subject-verb agreement when the subject is a plural count noun it is possible to emphasize the mass nature of what is otherwise a collection of objects. This is one possible explanation of what occurs in the sentence

The beans is cooked.

In general, most grammatical generalizations are violable, and such violations may have semantic consequences. Systems of language comprehension which rely too heavily on compliance with grammatical generalizations (treating them as exceptionless rules) will fail to be able to analyze a significant portion of input text. The assumed

exceptionlessness of such grammatical generalizations is a vestige of the linguistic argument that semantic explanations of linguistic phenomena are inadequate and only structural (or formal) explanations are capable of the kind of necessary and sufficient description of linguistic phenomena to which linguistics aspires. Unfortunately, the last forty years of linguistic research has made it abundantly clear that purely structural descriptions are no more necessary or sufficient than the semantic descriptions they were intended to supercede.

The Asymmetry between Comprehension and Generation

While it is desirable for a language comprehension system to be able to deal with exception to various grammatical generalizations, it is just as desirable for a language generation system to generate grammatical as well as meaningful statements. Thus, whereas many grammatical details can be ignored with minimal loss to language comprehension, language generation requires a more explicit consideration of such details. In this regard, language generation may be a more difficult problem than language comprehension. From a psychological perspective, I believe that generation of grammatically correct language is considerably more difficult than comprehension. However, from an Artificial Intelligence perspective, generation is typically assumed to be far easier than comprehension since the representations which are the basis for generation tend to be fully specified and lacking in the ambiguity which is inherent in natural language (the input to the comprehension system). Generation of English output from PM representations is especially easy since the representations contain the actual lexical items which occurred in the original English input. These two disparate positions can be reconciled if we accept that the linguistically-based propositional representations of PM form the basis for the construction of nonlinguistic representations which endure in long term memory, whereas the linguistically-based propositional representations do not. Johnson-Laird (1983) provides considerable psychological evidence in support of just his position. If generation begins with nonlinguistic representations and not PM-like propositional representations then generation becomes a more difficult process. Finally, the differences between comprehension and generation suggested above weaken the prospects for building fully bi-directional or symmetrical NLP systems. While both comprehension and generation will make use of relational information, it is less clear that they will make equivalent use of low level grammatical information. Further, the process of constructing nonlinguistic representations from linguistic representations is not symmetric with the reverse process. The mapping between linguistic and nonlinguistic representations is such that nonlinguistic representations tend to be more fully explicated than linguistic representations and the construction of nonlinguistic representations from linguistic representations is only partially compositional and therefore not fully reversible.

Some Grammatical Approaches which are Compatible with PM

Since PM does not address the grammatical details discussed above, it is important to point to treatments which are at least compatible with PM's approach and which might be integrable with PM in the development of a more complete system. As it turns out, "traditional" grammar, with its focus on the relationship between meaning and form, and on its acceptance of the partial productivity of language (as reflected in the separate listing of exceptions to grammatical generalizations) is more compatible with PM then the more formalized linguistic theories which have evolved out of Transformational Grammar. In particular, Jespersen's (1984, 1965) grammar and the grammar of Quirk, Greenbaum, Leech, and Svartvik (1985, 1972) are largely compatible with PM.

Jespersen's Grammar

The system of grammar described in Jespersen's culminating work entitled *Analytic Syntax* (republished 1984) and in his earlier *Philosophy of Grammar* (1965) is an example of a grammatical treatment which provides an analysis of English at a level of grammatical detail below that of PM, but one which is highly compatible with PM. It is a "traditional" grammar in the sense that "…it is now a standard reference work…" Jespersen (1965, end page), and in that it predates the revolutionary introduction of Transformation Grammar. Jespersen's grammar is not without its own unique set of terms and assumptions, and its introduction was considered "…a radical innovation in linguistics research when it was first published…" (Jespersen 1965, end page), but it did not reject the prevailing linguistic assumptions of the time and it was not revolutionary in the sense of Transformational Grammar. For example, in Jespersen's system of representation, he makes use of the "traditional" functional categories Subject (**S**), Verb (**V**), Direct Object (**O**), and Indirect Object (**IO**). These functional categories participate in a collection of schemas which are used to describe the structure of sentences in a range of different languages. Thus, Jespersen represents the structure of the sentence

I ordered him to fire

as

S V IO O(I)

Where **(I)** indicates that the direct object is an infinitive construction. Jespersen's schemas can be included in PM's hierarchy of schemas with only minor modification. The schema above can be represented in PM as

$$|\mathbf{obj}_{\mathbf{subj}}\ \mathbf{pred}_{\mathbf{verb}}\ \mathbf{obj}_{\mathbf{io}}\ \mathbf{prop}_{\mathbf{o(i)}}|$$

where the propositional categories are subscripted to reflect the functional categories (and structural subcategories) that Jespersen uses. This schema is a specialization of the more general propositional schema

pred(obj,obj,prop)

It should be noted that Jespersen treats infinitive phrases as substantives or nominals which is why he considers the infinitive phrase in the sentence above to be the direct object. In PM, substantives typically correspond to object descriptions rather than propositional descriptions (but see the discussion of objectification below). The possibility of directly including Jespersen's schemas in PM's hierarchy of schemas follows from two basic correspondences between Jespersen's system of representation and PM: (a) the correspondence between Jespersen's functional categories and PM's propositional categories, and (b) the correspondence between Jespersen's central notion of **rank** and PM's recursive structural descriptions. With regard to the notion of rank, Lyons (1968, p. 327) (preferring the term **degree** to rank) notes that

> For Jespersen, nouns were categories of the first degree, verbs (including 'adjectives') were categories of the second degree; and adverbs were categories of the third degree.

Jespersen (1984, p. 123) claimed that it is noteworthy that in the expressions

The dog barked furiously => [furiously$_3${barked$_2$}(the<dog$_1$>)]
The furiously barking dog => (the<furiously$_3${barking$_2$}<dog$_1$>$_{head}$>)

the word **dog** has rank 1, the words **barked** and **barking** have rank 2, and the word **furiously** has rank 3. Based on this observation, he claimed that the rank of a lexical item does not depend on whether it participates in a **nexus** (i.e. propositional description) or a **junction** (i.e. an object description), although the rank does depend on the manner in which the lexical item participates in that nexus or junction.

In PM, terms (e.g. nouns) and object descriptions (e.g. noun phrases) are typically descriptions of degree or rank 1, predicates which take object descriptions for arguments (e.g. main verbs and predicative adjectives) and functions which take terms for arguments (e.g. verb participles and attributive adjectives) are typically of degree or rank 2, and predicates which modify predicates and functions which modify functions (e.g. adverbs) are typically of degree or rank 3. However, PM eliminates Jespersen's system of rank numbering in favor of non-numeric recursive structural descriptions. The elimination of numeric ranks avoids certain criticisms that have been levied against Jespersen's notion of rank. Consider

Fortunately, the house is very inexpensive =>
[fortunately$_?$[is$_2${very$_3${inexpensive$_2$}}(the<house$_1$>)].

What is the rank of the adverb **fortunately** in this sentence? Since it is a sentential modifier and not a predicate modifier, a rank of 4 is suggested. However, in the following example, Jespersen assigns the sentential modifier **no doubt** a rank of 3:

> **No doubt, the meeting will be a great success => 3(21) S V P(21)**
> **(Jespersen, 1984 p. 31, using his rank notation)**

In this example, the overall rank of **no doubt** is 3 (internally **no** has a rank of 2 and **doubt** a rank of 1). Jespersen also treats the noun phrase **a great success** as a **predicatized** nominal as represented by **P(21)**. Apparently, Jespersen gives a rank of 2 to the entire nexus (i.e. propositional description or **SVP**) which results in a rank of 3 for **no doubt**. Thus, Jespersen assigns a rank of 3 to all three typical uses of adverbs: sentence modifier, predicate modifier, and function modifier. On the other hand in the noun phrase

> **A not particularly well constructed plot => $5^{n}4321$ (Jespersen, 1984 p. 9)**

Jespersen gives a rank of 5 to **not** (the superscript ^{n} reflects negation) and 4 to **particularly**, arguing that **particularly** modifies **well** which has a rank of 3 and thus **particularly** should have a rank of 4, and that **not** modifies **particularly** and thus **not** should have a rank of 5.

Despite assigning a rank of 5 to **not** Jespersen treats a **junction** (i.e. object description) as a whole as having a rank of 1. He also appears to treat a **nexus** (i.e. propositional description) as a whole as having a rank of 2. Essentially, Jespersen assigns the rank of the head of the junction and nexus to the overall structure. Thus, since the head of a junction is a noun (or a word acting as a noun) of rank 1, the junction has a rank of 1. And, since the head of a nexus is a verb or predication with a rank of 2, the nexus has a rank of 2.

How can we make sense of assigning a rank of 3 to the sentential modifier **no doubt** and a rank of 5 to the adverb **not**? In Jespersen's earlier work *The Philosophy of Grammar* he stated that "it is needless to distinguish more than three ranks, as there are no formal or other traits that distinguish words of these … orders [i.e. 4, 5,…] from tertiary words." (Jespersen, 1984, p. 111). In English when a word modifies an adverb, it is itself an adverb as are **not** and **particularly** in the example. In *Analytic Syntax*, since his rank numbers make it possible to distinguish different levels of adverbial modification without having to create terms to represent those levels, he allows them in. An alternative to these lower order ranks is to combine the modifying adverbs so that additional ranks are not needed as in

> **(a<not$_3${particularly$_3${well$_3${constructed$_2$}}}<plot$_1$>>$_1$) $_1$**
> **2(3 2(3 2(3 2))) 1**

Such nested rank representations are difficult to read and Jespersen tried hard to avoid them. Essentially, **well$_3$** and **constructed$_2$** combine with a combined rank of 2, then

particularly$_3$ and **well constructed$_2$** combine with a rank of 2, then **not$_3$** and **particularly well constructed$_2$** combine with a rank of 2 and finally **not particularly well constructed$_2$** and **plot$_1$** combine with a rank of 1.

Besides issues with the rank of adverbs in this example, what about the rank of the determiner **a**. Jespersen does not separately provide ranks for determiners, preferring to consider them part of the nouns they accompany. Further, Jespersen gives auxiliary verbs a rank of 2, essentially treating them as verbs rather than predicate modifiers and resulting in multiple words of rank 2 in sentences containing predicate adjectives as in **is$_2$ very$_3$ inexpensive$_2$** above. Further, McCawley in Jespersen (1984, p xv) provides the following counterexample:

The furious barking of the dog =>
(of(the<furious$_2$<barking$_1$>$_{head}$>,the<dog$_1$>))

in which the word **barking** has rank 1 and word **furious** has rank 2, in arguing that "I [McCawley] see no plausible way in which consistent notion of rank could make all three of these construction parallel as regards rank" Jespersen (1984, p. xv). The only real concern in McCawley's example is the treatment of the word **barking**. The word **furious** is an adjective and it unproblematically has a rank of 2. Adjectives can be converted to adverbs in English by the addition of the suffix **–ly**. **Furiously** is such an adverb and it unproblematically has a rank 3.

In PM it is not assumed that a given lexical item will have the same rank in all constructions in which it participates (nor does Jespersen make this assumption despite McCawley's suggestion to the contrary). Thus, the word **barking** has rank 2 in the sentence **the dog$_1$ is$_2$ barking$_2$ furiously$_3$** (where it is being used as a predicate) and rank 1 in the noun phrase **the furious$_2$ barking$_1$ of the dog$_1$** (where it is being used as a term). **Barking** is a word which is typically used to predicate a property of some entity. In its typical use in English, it will occur as the main verb (a predicate in PM) and the entity of which it is predicated will occur as the subject. However, in English there are less typical uses of **barking**. In one less typical use, the word **barking** is **objectified**. Objectification focuses attention on the property itself, allowing the word to be used like a nominal (a term in PM) and eliminating the need to specify the entity to which the property is attributed. The noun phrase **the furious$_2$ barking$_1$ of the dog$_1$** exhibits this less typical use. In another less typical use, **barking** occurs as a modifier (a function in PM) of an associated noun. The noun phrase **the furiously$_3$ barking$_2$ dog$_1$** exhibits this less typical use. Finally, consider

The furious$_2$ barking$_2$ dog$_1$ => (the<furious<barking<dog>$_{head}$>>)

In this example, **furious** modifies **dog** (or more correctly **<barking<dog>$_{head}$>**) and not **barking** and both **furious** and **barking** have rank 2.

The typical uses of words are based on their inherent meaning. Many words which express relations (especially actions) are typically expressed as main verbs functioning as

predicates, and the entities they relate are expressed as subjects and objects. However, there are less typical uses of relations in which they are not predicated and in which not all of the entities they relate are explicitly expressed. And they may even be objectified and used non-relationally. Words which express properties may either be used predicatively or attributively. Less typically they may be objectified and used non-relationally. Words which name objects and entities are typically used non-relationally.

Given the above we can make sense of Jespersen's notion of rank in terms of PM by noting that non-relational words or words used non-relationally are of rank 1, that relational words with take object descriptions or terms for arguments are of rank 2, and that words which modify propositions, predicates or functions are of rank 3. Thus, nouns in their typical use as terms are rank 1, verbs, adjectives and preposition in their typical use as predicates and functions are rank 2, and adverbs in their typical use as proposition, predicate or function modifiers are rank 3.

Jespersen's Rank	**Jespersen's Functional Categories (Nexus)**	**PM's Propositional Categories**	**PM's Object Categories**	**Part Of Speech**
1	**S** **O** ***O*** **(IO)**	**Object Description**	**Term**	**Noun** **Pronoun** **Proper Noun**
2	**V** **P**	**Predicate**	**Function**	**Verb** **Adjective** **Preposition**
3	**3**	**Predicate and Propositional Modification**	**Function Modification**	**Adverb**

Jespersen's Basic Categories	**PM's Basic Categories**
Junction	**Object Description**
Nexus	**Propositional Description**
Subjunct (Tertiary)	**Function, Predicate & Propositional Modification**

In general, English provides numerous ways in which higher order relational entities like verbs and adjectives can be used as though they were lower order entities. The verb **kick** is typically transitive in taking two object descriptions. However, there are constructions in English in which one or both of the arguments are not explicitly expressed. In its use as a predicate, consider

The home team kicked the ball => [kicked(the<home_team>,the<ball>)]

The home team kicked **=> [kicked(the<home_team>)]**
Kick the ball! **=> [kick(e_i,the<ball>)]**
Kick! **=> [kick(e_i)].**

The first sentence reflects the typical use of **kick**. The second sentence makes no mention of the object of the verb. The third sentence eliminates the subject as a way of marking the imperative construction. The fourth sentence is the imperative version of the objectless sentence. In its use as a function, consider

The kicking team **=> (the<kicking<team>$_{head}$>)**
The kicked ball **=> (the<kicked<ball>$_{head}$>)**

The first expression contains the explicit expression of the relation **kicking** and the subject of that relation—**team** (the present participle **kicking** determines the subjective status of the term **team**). The second expression contains the explicit expression of the relation and the object of the relation—**ball** (the passive particle **kicked** determines the objective status of the term **ball**—i.e. the subject of the passive use of **kicked**). Finally, in the expression

The kick **=> (the<kick>$_{head}$)**

only the relation itself is explicitly expressed.

While it makes sense to have constructions which do not explicitly mention the participants in various relations, it makes less sense to suggest that terms and object descriptions may be treated as though they were relations (without significantly changing the meaning of the non-relational unit). Thus, whereas a verb may be used as a term without seriously affecting its meaning, using a noun as a predicate should have just such an effect. Consider

The old dog was lazy **=> [was{lazy}(the<old<dog>>)]**
The old dog the young **=> [dog(the<old>,the<young>)]**
The man shouted **=> [shouted(the<man>)]**
The shout was loud **=> [was{loud}(the<shout>)]**

The predictival use of the word **dog** focuses attention on doglike behavior or activity (i.e., some relation in which dogs participate rather than dogs as objects). On the other hand, the term use of the word **shout** merely focuses attention on the relation itself and not on some object which can participate in that relation. Also consider

The cheat was caught **=> [was{caught}(the<cheat>)]**
The cheat was uncovered **=> [was{uncovered}(the<cheat>)]**
The man cheated on his taxes **=> [on{cheated}(the<man>,his<taxes>)]**
[on([cheated(the<man>)]),his<taxes>)]

In the first sentence, the word **cheat** can be taken to mean 'someone who cheats'. Of course, English provides the highly productive capability for adding the morpheme **-er** to verbs in order to express participants as is the case for the word **cheater**. Why this ending is not required for words like **cheat** and **snitch** is an interesting question. In the second sentence **cheat** can be taken to mean 'the act of cheating'. Although this use is not common, it corresponds to the use of **rip-off** in **the rip-off was uncovered**. The third sentence represents the typical predictival use of **cheat**. I believe that **cheat** has the same basic meaning in the second and third sentences and a different meaning in the first sentence—despite the fact that in the first two sentences **cheat** is used as a term and in the third sentence it is used as a predicate. That is, meaning distinctions and part of speech distinctions need not correspond. Further, words whose most typical use is predictival can be used as terms in (at least) two ways: (a) without change in meaning and without explicit mention of the participants in the relation, and (b) with a shift in meaning such that the word is used to refer to a participant in the relation and not to the relation itself. On the other hand, words whose most typical use is nominal can be used as predicates only via a shift in meaning away from the object to which the noun normally refers and towards some relation (or collection of relations) in which that object participates.

English provides a highly productive capability for the conversion of adjectives into adverbs via the addition of the morpheme **–ly** to the adjective form. Unlike the addition of the **–er** morpheme which affects the basic meaning of words to which it is attached via a change in reference, the addition of the morpheme **–ly** is rank rather than meaning affecting. The conversion of the adjective **quiet** into the adverb **quietly** primarily results in a change in rank. Both **quiet** and **quietly** express the property of quietness, but adjectives are typically used to predicate this property of objects, whereas adverbs are typically used to predicate the same property of predicates or propositions. Consider

He ate quietly => [quietly{ate}(he)]
He is quiet => [is{quiet}(he)]

which might be paraphrased as "he ate in a quiet manner" and "he behaves in a quiet manner". Not all adverbs are marked with the morpheme **–ly**. When they are not they tend to have the same form as the corresponding adjective. Consider

He runs fast => [fast{runs}(he)]
He is fast => [is{fast}(he)]

The fact that both the adjective and adverb have the same form is highly suggestive of a correspondence in meaning.

The close correspondence in meaning between adjectives and adverbs may help explain why the learning of the proper grammatical use of such words is difficult. I have given up on the use of the adverbs "firstly" and "secondly" to introduced enumerated sentences, preferring to use the adjectives "first" and "second" despite the grammatical "incorrectness" of doing so—because use of the adverbs feels stilted and unnatural to me.

And I still remember not being able to distinguish adverbs from adjectives when studying grammar in "grammar" school.

Prepositions in English can be used in two rather different ways without a change in meaning. Consider

He danced on the floor => **[on([danced(he)]$_{head}$,the<floor>)]**
He is on the floor => **[is{on}(he,the<floor>)]**

In the first sentence, the preposition **on** takes the propositional description **he danced** as its first argument, and in the second sentence it takes the object description **he** as its first argument. The difference in these sentences is a difference in use or rank and not in basic meaning. In both sentences **on** expresses the same locative relation, but in the first sentence this relation is expressed between and action and an object (or location) and in the second sentence it is expressed between two objects (or an object and a location).

It should also be the case that nouns used as adjectives undergo a shift in meaning similar to that for nouns used as verbs. However, there are several interacting factors which make it difficult to demonstrate this effect. Consider

The flag pole => **(the<flag_pole>)**
The grass skirt => **(the<grass_skirt>)**

It is not at all obvious that the nouns **flag** and **grass** are being used as adjectives in these phrases. Rather, the nouns appear to form compounds with the nouns they modify, such that the nature of the relationship between the nouns is left unexpressed. English appears to allow extensive use of such compounding. Presumably, the meaning of such compounds is resolved via reference to nonlinguistic representations (i.e., if I have or can construct some nonlinguistic representation of a flag flying on a pole, then I can work out the meaning of flag pole). Further, the names of many objects and entities reflect a salient characteristic or function of that object or entity, in which case the word used to name the object or entity can be used as both a noun or an adjective (e.g. the nouns **light** and **glaze**). Nonetheless, in compound noun expressions the rightmost noun typically determines the overall essence of the compound and essentially functions as the head. Thus, a **flag pole** is essentially a **pole** and a **grass skirt** is essentially a **skirt**.

The above discussion rests on the fundamental question of just what it means to be a noun, adjective, verb or other part of speech. The traditional grammatical definitions for the parts of speech include a mixture of semantic and structural considerations. Such definitions have been severely criticized and attacked within the field of modern linguistics, especially with respect to their semantic content. The basic argument against the semantic definition of parts of speech centers on the failure of such definitions to be either necessary or sufficient. However, there has always been a minority of linguists who accept (or at least accommodate) the semantic or notional basis of the definition of parts of speech (e.g. Chafe, 1970; Givon, 1983, 1989; Jespersen, 1965, 1984; Langacker, 1987; Lyons, 1968, 1977). Lakoff (1987) and Taylor (1989) have stongly defended the

notional basis of grammatical categories. Lakoff suggests that the reason previous attempts to provide notional definitions for the parts of speech failed, is because the principles put forward in such attempts were considered to be absolute. Thus, such principles as

> **Actions are expressed as verbs**
> **States are expressed as adjectives**
> **Physical objects are expressed by nouns (or noun phrases)**

were put forward as absolutes and shown to be wrong by counterexamples (1987, p. 491). Lakoff makes use of prototype theory in suggesting that syntactic categories, like categories more generally, are based on notions of centrality and prototypicality, and are not absolute categories with all inclusive defining principles as is assumed in many linguistic treatments. Once a position like that of Lakoff is adopted, the basic semantic character of syntactic categories can be realized and is not subject to rejection by the production of a small number of counterexamples. Lakoff goes on to suggest that variation within categories may not always be predictable, but it is for the most part semantically motivated nonetheless.

PM accepts the arguments of Lakoff and Taylor (as well as those of their predecessors) and suggests that most words belong to a "typical" word class based on meaning, but allows that such words may be used in less typical ways. This is especially true of words which are used to express relations. In the typical use of a word which expresses a relation, one expects to see an explicit expression of the participants in that relation (within certain linguistic or cognitive limitations). However, there are likely to be less typical uses of the word in which the explicit expression of one or more of the participants to the relation does not occur. Further, in the typical use of a relation, one expects the word to be marked for such features as tense, mood and aspect in English. However, there are likely to be less typical uses of the word in which the explicit expression of such features does not occur. In the case of words expressing non-relations, there is no relation being expressed and, therefore, no participants in need of expression. Further, one of the prototypical structural features of words which express non-relations is there lack of marking for mood, tense and aspect. Such features are tied up with notions of existence and dynamiticity. Prototypically, nouns are assumed to express objects and entities which exist over time, unchanged, and for which mood, tense and aspect marking would be redundant. Prototypically, verbs are assumed to express events which are instantaneous and for which tense and aspect markings provide additional information about the nature of the event.

It has been suggested that the approach of Jespersen, as described in his *Analytic Syntax* provides a level of grammatical analysis which is more specific than, and yet compatible with, PM's system of representation. However, Jespersen's own system of representation ignores certain details of grammar. According to Jerspesen (1984, p. 94)

> …a great many grammatical things are not symbolized:
> *Number:…*

> *Tense:…*
> **Person:…**
> *Gender or sex:…*
> *Degrees of comparison*:…
>
> Further the symbols disregard the ordinary division into *word-classes* (*parts of speech*); S [subject] may be a substantive [noun] or a pronoun or an adjective or an infinitive or a whole clause, and similarly with O [direct object], *O* [indirect object],…, etc.

Thus, inclusion of Jespersen's schemas into PM's system of representation still does not provide a treatment of these grammatical details. If the claim that such details are largely orthogonal (or subordinate) to propositional structure is valid, then one possible approach to dealing with such considerations is to treat them as features which are associated with the appropriate elements of propositional representations, but which do not otherwise affect propositional structure. Thus, for example, the subject of sentence might have features associated with it which specify the person, number and gender of the subject as a whole, but which are not otherwise structure determining. This approach provides a basis for distinguishing between features and categories within PM. Those elements of linguistic representation which determine propositional structure are members of categories, whereas those elements which do not determine structure are features which are associated with the structure determining elements. Arguing in terms of constituent structures within a Transformational Grammar framework, Lyons (1968, p. 333) puts forward a similar position

> …the base-component of a transformational grammar for any language will comprise two 'subcomponents'. The first…would account for the categorical combination of lexical items. The second would contain rules associating features of tense, mood, aspect, number, definitiveness, etc. at various levels of the constituent-structure generated by the categorical component.

The distinction between categories and features is dependent on which levels of representation are described in structural terms and which are described in featural terms within a particular system of representation. At a given level of description, there will be a collection of base level elements which are members of various categories. These base level elements can be further distinguished within a given category in structural terms via the introduction of various subcategories, or in featural terms via the introduction of features which are not category determining. The decision whether to describe some level of representation in structural or featural terms rests in part on the assumed structural complexity of that level of description. For example, if we assume that words are structurally complex (consisting of structural combinations of morphemes) then we will describe words in terms of the structural combinations of subcategories of morphemes (as in done in morphology). On the other hand, if we assume (or at least decide to treat) words as structurally simple then we can describe words of a given

category in terms of featural differences among the members of that category (as if often done in syntax).

The acceptance of word-level linguistic units is important in the above discussion. PM's acceptance of the validity and importance of "word-level" units is more in line with traditional grammatical treatments than modern linguistic theory. In general, PM assumes that words are the base level units of linguistic description in English and are members of various linguistic categories which are in turn subcategories of higher level propositional categories. This does not mean that words are not structurally complex, but in PM's system of representation they are typically treated as linguistic wholes which may be marked for various grammatical features. Thus, the processing of a structurally complex word will typically result in the representation of the word as a structurally simple linguistic unit which may be associated with various linguistic features. That processing may require no more than the lookup of the structurally complex word in the mental lexicon, or it may involve the morphological analysis of the word to extract the featural information.

The introduction of features to mark various grammatical aspects in PM representations raises the interesting possibility of adding other "features" to specify such things as the word sense or the root form of words, and perhaps even the referent of arguments. In the absence of a model for the representation and processing on nonlinguistic representations, such "features" may be needed for the development of language processing systems given the current "state-of-the-art". While the use of such features is not theoretically motivated, their use does have some interesting practical consequences. For example, unlike systems of representation which force the resolution of the meaning of lexical items, the featural approach to representing word sense allows the possibility of leaving the word sense feature undetermined (or partially determined) without precluding the determination of the relational structure of the input. This may actually be of some theoretical importance, since humans have the ability to process sentences containing unknown words whose contribution to relational structure can be determined (in context), but of which they don't know the meaning.

Quirk, Greenbaum, Leech and Svartvik's Grammar of English

Besides Jespersen's grammar, PM is oriented towards the type of grammatical treatment of English put forward by Quirk, Greenbaum, Leech and Svartvik (1972, 1985), Greenbaum and Quirk (1990) and Jackson (1990). Their grammar is traditional in the sense that it largely rejects the theoretical apparatus of Transformational Grammar, preferring instead to rely on linguistic assumptions about the relationship between form and meaning which largely predate Transformational Grammar. Quirk et al. (references to Quirk et al. in this section are to Quirk et al., 1985, unless otherwise stated) describe their grammar in three cycles, beginning with an overall survey of basic clausal forms and continuing on to successively more detailed analyses of the grammatical details of English. At the highest level, their description of English makes use of the functional categories **subject** (S), **verb** (V), **object** (O), **complement** (C), and **adverbial** (A). They

suggest that the following seven basic functional patterns serve to capture the major clausal forms in English:

SV
SVO
SVC
SVA
SVOO
SVOC
SVOA.

Quirk et. al's **complement** and **adverbial** categories are interesting in that they correspond to multiple structural categories:

Complement	**=>** noun phrase, adjective phrase, or a clause with nominal function
Adverbial	**=>** adverb, adverb phrase, adverbial clause, noun phrase, or prepositional phrase (Quirk et. al 1972, p. 349)

Each functional category is an obligatory element of the forms in which they participate. That is, the clause is incomplete without the obligatory element. Non-obligatory elements (e.g. optional adverbs, prepositional phrases, auxiliary verbs, conjunctions) are not included in the basic functional forms.

By way of contrast, PM makes use of three propositional categories predicate (**pred**), propositional description (**prop**), and object description (**obj**) in arguing that there are nine basic propositional forms and four basic predicate modification forms. The nine basic propositional forms and four basic predicate modification forms are repeated below along with a subcategorization in terms of the functional categories of Quirk et al.

1. pred(obj)	$\|\mathbf{obj}_{\mathbf{Subj}}\ \mathbf{pred}_{\mathbf{Verb}}\|$
2a. pred(obj,obj)	$\|\mathbf{obj}_{\mathbf{Subj}}\ \mathbf{pred}_{\mathbf{Verb}}\ \mathbf{obj}_{\mathbf{Obj}}\|$
2b. pred(obj,obj)	$\|\mathbf{obj}_{\mathbf{Subj}}\ \mathbf{pred}_{\mathbf{Verb}}\ (\mathbf{obj}_{\mathbf{Obj}})_{\mathbf{Comp}}\|$
2c. pred(obj,obj)	$\|\mathbf{obj}_{\mathbf{Subj}}\ \mathbf{pred}_{\mathbf{Verb}}\ (\mathbf{obj}_{\mathbf{Obj}})_{\mathbf{Adv}}\|$
3a. pred(obj,obj,obj)	$\|\mathbf{obj}_{\mathbf{Subj}}\ \mathbf{pred}_{\mathbf{Verb}}\ \mathbf{obj}_{\mathbf{Obj}}\ \mathbf{obj}_{\mathbf{Obj}}\|$
3b. pred(obj,obj,obj)	$\|\mathbf{obj}_{\mathbf{Subj}}\ \mathbf{pred}_{\mathbf{Verb}}\ \mathbf{obj}_{\mathbf{Obj}}\ (\mathbf{obj}_{\mathbf{Obj}})_{\mathbf{Comp}}\|$
3c. pred(obj,obj,obj)	$\|\mathbf{obj}_{\mathbf{Subj}}\ \mathbf{pred}_{\mathbf{Verb}}\ \mathbf{obj}_{\mathbf{Obj}}\ (\mathbf{obj}_{\mathbf{Obj}})_{\mathbf{Adv}}\|$
4. pred(obj,prop)	$\|\mathbf{obj}_{\mathbf{Subj}}\ \mathbf{pred}_{\mathbf{Verb}}\ \mathbf{prop}_{\mathbf{Comp}}\|$
5. pred(obj,obj,prop)	$\|\mathbf{obj}_{\mathbf{Subj}}\ \mathbf{pred}_{\mathbf{Verb}}\ \mathbf{obj}_{\mathbf{Obj}}\ \mathbf{prop}_{\mathbf{Comp}}\|$
6. pred($\mathbf{prop}_{\mathrm{head}}$)	
7. pred($\mathbf{prop}_{\mathrm{head}}$,obj)	
8. pred($\mathbf{prop}_{\mathrm{head}}$,$\mathbf{prop}_{\mathrm{head}}$)	
9. pred($\mathbf{prop}_{\mathrm{head}}$,$\mathbf{prop}_{\mathrm{head}}$,$\mathbf{prop}_{\mathrm{head}}$)	

1a. $pred_{Adv}$ {$pred_{head}$}(obj) **|obj_{Subj} $pred_{Verb}$ $pred_{Adv}$|**
1b. $pred_{Verb}${$pred_{Adj}$}(obj) **|obj_{Subj} $pred_{Verb}$ ($pred_{Adj}$)$_{Comp}$|**
1c. $pred_{Adv}$ {$pred_{head}$}(obj,obj) **|obj_{Subj} $pred_{Verb}$ obj_{Obj} $pred_{Adv}$|**
1d. $pred_{Verb}${$pred_{Adj}$}(obj,obj) **|obj_{Subj} $pred_{Verb}$ obj_{Obj} ($pred_{Adj)Comp}$|**
2a. $pred_{Prep}${$pred_{head}$}(+obj) **|obj_{Subj} $pred_{Verb}$ ($pred_{Prep}$ obj_{Obj})$_{Adv}$|**
2b. $pred_{Prep}${$pred_{head}$}(obj,+obj) **|obj_{Subj} $pred_{Verb}$ obj_{Obj} ($pred_{Prep}$ obj_{Obj})$_{Adv}$|**
3. pred{$pred_{head,}pred_{head}$}
4. pred{$pred_{head,}pred_{head,}pred_{head}$}

As the above comparison shows, there is a direct correspondence between five of the propositional forms of PM and the functional forms of Quirk et. al. There is also a correspondence between two of the predicate modification forms and the functional forms **SVA, SVC, SVOA** and **SVOC**. The remaining four propositional forms and two predicate modification forms reflect non-obligatory clausal modifications which are not captured by the functional forms.

The preceding discussion can be given some concreteness by considering the sample sentences which Quirk et al. (1972, p. 53??? Not there!!! Probably 1985) provide as representative of their clausal forms:

SV	**Someone (S) was laughing (V)**
SVO	**My mother (S) enjoys (V) parties (O)**
SVC	**The country (S) became (V) totally independent (C)**
SVA	**I (S) have been (V) in the garden (A)**
SVOO	**Mary (S) gave (V) the visitor (O) a glass of milk (O)**
SVOC	**Most people (S) consider (V) these books (O) expensive (C)**
SVOA	**You (S) must put (V) all the toys (O) upstairs (A)**

The corresponding PM representations are shown below:

[was{laughing}(someone)]
[enjoys(my<mother>,parties)]
[became{totally{independent}}(the<country>)]
[have{been{in}}(I,the<garden>)]
[gave(Mary,the<visitor>,of(a<glass>,milk))]
[consider{expensive}(most<people>,these<books>)]
[must{upstairs{put}}(you,all(the<toys>))]

Summarizing the relationship between the functional categories of Quirk et al. and the propositional categories of PM, we have:

subject	**=> object description, objectified propositional description**
object	**=> object description, objectified propositional description**
verb	**=> predicate**
adverbial	**=> object description, predicate modifier, predicate,**

propositional description
complement => object description, predicate, propositional description

The functional categories subject and object are prototypically object descriptions. The functional category verb corresponds to PM's predicate. Quirk et al. note that their functional use of the term verb is problematic in that this word is also used to refer to a particular part of speech. In fact, Jackson (1990) substitutes the name predicator (P) for verb in his classification which is otherwise the same as that of Quirk et al. The correspondence between the remaining two functional categories and PM's propositional categories is more flexible. Complements and adverbials may correspond to each of the propositional categories. That is, a complement may be a propositional description, a predicate or an object description and the same is true for adverbials. Adverbials may differ from complements in that they can also function as predicate modifiers.

Explaining the nature of the correspondence between the functional categories (especially the categories complement and adverbial) and the propositional categories requires a more detailed consideration of the notions of **objectification** and **predicatization**. Earlier it was noted that PM treats infinitive phrases as reduced propositional descriptions (i.e. propositional descriptions which are missing an explicit expression of the subject and the tense). It seems relatively clear that such phrases do express propositions. That is, an infinitive construction expresses an action or state of affairs even though that action or state may not be fixed in time and even though not all of the participants in that action or state may be explicitly expressed. However, it was also noted that Jespersen treated infinitive phrases as substantives, effectively according them the status of object descriptions. Indeed, infinitive phrases do appear to have a status intermediate between that of a full propositional description and an object description. Further, despite the fact that the functional categories subject and object typically correspond to object descriptions, there are constructions in English in which subjects and objects have the form of propositional descriptions. For example, consider

That he died is sad => [is{sad}(that([died(he)])].

In this sentence the constituent **he died** is a full propositional description. How can we explain the occurrence of a propositional description as the subject of the sentence? Two treatments are suggested: (a) allow the predicate **is{sad}** to take a propositional description for its argument, or (b) allow the relative pronoun **that** to function to convert what would otherwise be a propositional description into an object description. The first option is consistent with the treatment of the clause **that he died** as a propositional description in

I believe that he died =>
[believe(I,[that([died(he)])])]
[believe(I,that([died(he)]))]

The second option captures the notion of **objectification** (i.e. the treatment of a propositional description as though it were an object description). It might seem

reasonable to suggest that whenever a relative pronoun introduces a propositional description, that description is objectified and treated as an object description. However, this suggestion implies that the sentences

I believe he died => [believe(I,[died(he)])]
I believe that he died => [believe(I,that([died(he)]))]

have different propositional structures (under the assumption that the expression **he died** functions as a propositional description in the sentence without the relative pronoun). It may be more reasonable to suggest that unless a construction allows for the occurrence of a propositional description without a relative pronoun, the propositional description is probably being objectified and has the status of an object description. Based on this criterion, the predicate **is{sad}** does not take a propositional description, since sentences of the form

He died is sad

do not typically occur in English. Further the occurrence of the sentence

To die is sad => [is{sad}([to{die}(e_i)]$_{obj}$)]

suggests the treatment of the infinitive phrase **to die** as an objectified propositional description. However, the sentences

I know I'm going => [know(I,['m{going}(I)])]
I know to go => [know(I_i,[to{go}(e_i)])]

suggest the treatment of the infinitive phrase **to go** as a non-objectified propositional description. As has generally been argued to be the case elsewhere, both options are allowed. That is, clauses introduced by a relative pronoun and infinitive phrases may either be treated as non-objectified propositional descriptions or as propositional descriptions which have been objectified. And it may even be the case that subordinate finite clauses which are not introduced by a relative pronoun may be treated as objectified propositional descriptions under some circumstances.

The existence of objectified propositional descriptions provides a basis for explaining the difference between sentence pairs like the following:

Flying planes are dangerous
Flying planes is dangerous.

In the first sentence, the word **flying** is a function which takes the term **planes** as its argument and forms an object description

(flying<planes>).

Since **planes** is the head of this construction and is plural, its use as the subject argument leads to **are{dangerous}** giving:

[are{dangerous}(flying<planes>)]

In the second sentence, the word **flying** is a predicate with takes the object description **planes** as its argument and forms a propositional description

[flying(e_i,planes)]

which is subsequently objectified and used as the singular subject argument of **is{dangerous}** giving

[is{dangerous}([flying(e_i,planes)]$_{obj}$)]

If a process for the objectification of predicates and propositional descriptions exists, it may also be the case that there is a converse process for the predicatization and/or functionization of terms and object descriptions. This is one possible way of treating predicate nominals like:

He (S) is (V) a man (C) => [is{(a<man>)$_{pred}$}(he)]

In this sentence, it can be argued that the object description **a man** is predicatized. To predicatize an object description means to use it as an index into a set of relations and properties which can then be predicated of (or attributed to) some other object or propositional description. The relations and properties indexed by the object description are predicated *en masse* of the entity which is the subject of the predication. This approach has the advantage of allowing the object description to be recognized as such initially (as the structure of the argument suggests it should be) and then subsequently to be used predicatively. It is this process of predicatization which allows the functional categories complement and adverbial to have the form of an object description. Thus, in the above sentence, Quirk et al. regard **is** as the main verb and **a man** as a complement (and not an object) which is predicated of the subject, and in the sentence

Queen Victoria (S) considered (V) him (O) a genius (C) =>
[considered{(a<genius>)$_{pred}$}(Queen Victoria,him)]

They regard the noun phrase **a genius** as a complement which is predicated of the object **him**.

In general, PM assumes the validity of the **Grammatical Constraint** in suggesting that form determines meaning. Expressions which have the form of propositional descriptions will be recognized as such despite the fact that they may subsequently be objectified, and expressions which have the form of object descriptions will be recognized as such despite the fact that they may subsequently be predicatized. Further, it is assumed that there are constraints on the processes of objectification and

predicatization such that not every propositional description can be objectified and not every object description can be predicatized. If these processes were generally unconstrained, then the basic distinction between propositional and object descriptions might be called into question.

The basic functional forms proposed by Quirk et al. assume what might be called the unmarked or canonical word (or phrase) order in English. Quirk et al.'s survey of English contains a discussion of systematic correspondences between these unmarked forms and certain marked or noncanonical forms with which they are associated. They note that "Such correspondences are sometimes described in terms of transformational rules…" (Quirk et al., 1985, p. 57), but do not themselves make use of this theory. Indeed, determining the relationship between canonical and noncanonical structures was an important consideration in Transformation Grammar (TG) (Chomsky, 1957, 1965). Transformation Grammar assumed that deep structure was canonical and that noncanonical surface structures were generated from deep structures via the application of various transformations to deep structures. Lexical Functional Grammar (LFG) (Bresnan, 1978, 1982) did away with many of the transformations of TG arguing that both canonical and noncanonical surface structures could be lexically generated. PM agrees, in part, with LFG in arguing that frequently occurring surface forms are likely to be directly encoded as schemas in the mental lexicon. If this assumption is valid, then there are likely to be various surface structure variants for which it is difficult to determine which variant is canonical and which is noncanonical. Indeed, there were frequent arguments within TG over just which surface structure variant was transformationally related to deep structure. There were also some rather surprising suggestions, as for instance Fillmore's (1968) suggestion that all surface cases were marked with a preposition in deep structure, or Bach's (1968) suggestion that all nouns were transformationally related to relative clauses in deep structure.

One of the early assumptions of TG was that transformations were meaning preserving. Thus, surface variants derived from the same deep structure were assumed to be equivalent in meaning. While this assumption was quickly shown to be false, it continues, to this day, to be an unexpressed default assumption of many linguistic discussions. In part, this oversight is due to the fact that TG'ers explicitly reject considerations of meaning in their linguistic analyses (when it is convenient to do so). However, it is an assumption of this work that most surface variation, including the variation attributable to differences between canonical and noncanonical structure, is meaningfully motivated. In support of a similar position, Pinker (1989) provides an extensive account of the meaningfulness of the following four alternations:

(1) dative

- **a. John sent a package to the border/boarder**
- **b. John sent the boarder/*border a package**

(2) causative

- **a. Sally made the ball bounce**
- **b. Sally bounced the ball**

(3) locative

a. Irv loaded hay into the wagon

b. Irv loaded the wagon with hay

(4) passive

a. *Two hundred pounds is weighed by John (pp. 48-50).

A basic point of his thesis is that determining the grammaticality of various forms of these alternations requires consideration of the semantic relationship between the verb and its argument (Pinker allows prepositional phrases to function as arguments to verbs). No purely structural rule can succeed in isolating all and only the grammatical sentences which include these alternations (a basic objective of TG). For example, Pinker (1989, p. 64) claims that "…passivization converts a predicate meaning 'X acts on Y' to a new predicate meaning 'Y is in the circumstance of X acting on it'. If there is no 'acting on' there is no passivization." which explains why verbs like **weigh** do not have a passive form. The basic assumptions of PM are very much in line with the suggestions of Pinker and very much in contrast with the autonomy of syntax assumption of TG. Structure cannot be studied effectively in isolation from meaning.

Other Approaches to the Study of the Relationship between Form and Meaning.

There is a school of linguistics called **Cognitive Linguistics**, whose basic principles are very much in line with those of PM and whose theoretical influence on this work is evident in the frequent reference to the writings of Lakoff, Johnson, Taylor, Chafe, Fillmore and especially Langacker. While no comprehensive grammatical treatment of English has yet come out of this school, numerous grammatical treatments of specific topics have been published. For example, Lakoff (1987) provides a detailed study of the **There-Construction** in which he argues convincingly that the grammaticality of various forms of this construction can only be explained on semantic and cognitive grounds. That is, there is no way to account for the data on purely structural grounds. He goes so far as to say

> In cognitively based linguistics, syntax is to a very significant extent (though by no means entirely) dependent on semantics, pragmatics, and communicative function. (1987, p. 488).

Cognitive Linguistics in many ways represents a return to a more traditional form of linguistic theorizing. One in which considerations of structure and meaning go hand in hand. One in which the search for formal linguistic categories which are both necessary and sufficient has been abandoned in recognition of the basis prototypical nature of human categorization (including linguistic categorization). One which rejects the assumption that there is a special language faculty which is separate and distinct from cognition more generally, and one which rejects the autonomy of syntax assumption.

In attempting to integrate PM with more detailed grammatical descriptions of English, it has been suggested that the basic assumptions of PM are more compatible with traditional grammar than **Transformational Grammar** (TG). In general, this is certainly true. However, there are grammatical descriptions within the framework of TG which provide considerable insight into an understanding of the English language. For example, Kaplan's *English Grammar, Principles and Facts* (1989) is an insightful work which makes use of important aspects of TG in its description of English, without accepting the principles of TG wholesale. Thus, Kaplan notes that

> …there are…pervasive connections between semantics and grammar, and no understanding of grammar is possible without familiarity with some rudimentary semantic notions. (1989, p. 32)

Further, TG has itself undergone major transformations in the 1980's, so much so that it is now referred to as **Government and Binding Theory** (e.g., Chomsky 1981, 1982b, 1988). Indeed, Government and Binding Theory (GB Theory) is in many ways further removed from early TG than are the competing linguistic theories **Lexical Functional Grammar** (LFG) and **Generalized Phrase Structure Grammar** (GPSG)—all three of which are descendants of TG (for a description of each of these theories see Sells, 1985). For example, both LFG and GPSG retain a phrase structure grammar component (a key component of TG) which has effectively been replaced in GB Theory by **X-bar Theory**. (In GPSG the phrase structure grammar component has been "generalized" to separate out the linear precedence and immediate dominance aspects of typical phrase structure grammars.) The basic transformation of GB Theory has been away from the description of grammar in terms of necessary and sufficient formal rules (for which phrase structure grammars are well suited) towards a description in terms of interacting principles. Further, GB Theory has somewhat surreptitiously reintroduced considerations of the relationship between form and meaning in its description of grammar, via introduction of thematic relations and in its focus on the binding of coreferential elements. In sum, the basic principles and the manner of linguistic description of GB Theory are far more compatible with PM than was the earlier TG.

However, it should be noted that GB Theory is no longer typically concerned with the sort of detailed grammatical treatment which was common in TG, and it is clear that many grammatical details cannot be explained in terms of the interaction of the high level principles postulated in GB Theory. GB Theory has frequently been criticized on this ground. In defense of GB Theory, Sells (1985, p. 26) notes that

> Language-particular details of descriptions typically go uncharted in GB, for there is no obvious way in which their study would yield interesting hypotheses about the nature of UG [Universal Grammar].

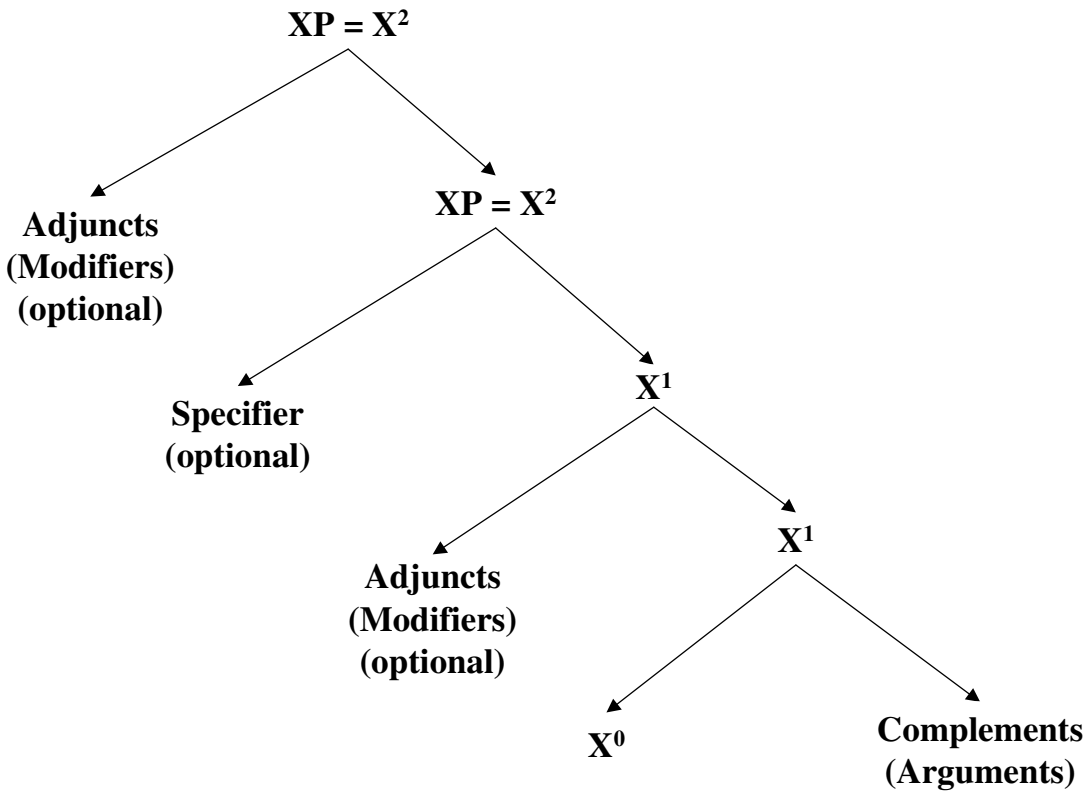
In essence, GB Theory is not concerned with the explication of grammatical details of specific languages, since such details off no insight into the Universal Grammar that all humans are born with and which is the focus of GB Theory.

The high level principles put forward in GB Theory are for the most part constraints on possible linguistic structures, and GB Theory is essentially a constraint based theory. As such, it suffers the fundamental problem of all constraint based theories. If the theory contains strong constraints on possible structures, these constraints will often fail to obtain in specific instances (at least for complex structural systems, like language, which are not describable in terms of exceptionless rules). Such constraints are better called preferences. If the theory contains only weak constraints which are less subject to exception, they will largely underdetermine structure. GB Theory, in its search for language universals, posits only extremely general (or weak) constraints on possible structures. In part to overcome this problem, GB Theory posits the existence of parameters which further constrain possible structures relative to specific languages. But even these parameters are very general in nature, and the possible structures in a particular language are still largely underdetermined.

There does appear to be a correspondence between the X-Bar Theory component of GB Theory and PM. X-Bar Theory does a good job of highlighting head/modifier relationships and constituency structure in a compact notation. In Chomsky (1995, p. 52) X-Bar Theory is reflected in the following rules:

X^2 => X^2 + Adjunct
X^2 => Specifier + X^1
X^1 => X^1 + Adjunct
X^1 => X^0 + Complement

where X^2 = XP (i.e. superscripts are used to reflect the number of bars). That is, a base level constituent X^0 combines with complements (or arguments) to form a level 1 constituent X^1. X^1 combines with adjuncts (or modifiers) without changing levels. X^1 combines with a specifier to form a second level constituent X^2. Finally, X^2 combines with adjuncts (or modifiers) without changing levels. The levels in X-Bar Theory or shown graphically below:


XP = X2
Adjuncts
(Modifiers)
(optional)
XP = X2
Specifier
(optional)
X1
Adjuncts
(Modifiers)
(optional)
X1
X0
Complements
(Arguments)

The table below compares PM to the corresponding X-Bar equivalents for the NP (noun phrase), VP (verb phrase), IP (inflection phrase) and CP (clause phrase) constituents:

X-Bar Noun Phrase	**PM Object Description**	**X-Bar Verb Phrase (VP)/Clause (CP)**	**PM Propositional Description**
N^0	**Term**	**V^0**	**Predicate**
N^1	**Specifierless Complex Term**	**V^1**	**Subjectless, Inflectionless, and Specifierless Propositional Description**
N^2 = NP	**Object Description**	**V^2 = VP**	**Subjectless, and Inflectionless Propositional Description**
		IP	**Subjectless Propositional Description**
		CP $[_{CP}$Spec$[_{C'}$C$[_{IP}$Spec$[_{I'}$ I VP]]]] (Chomsky 1995, p. 55)	**Propositional Description pred(obj,…)**

As the table shows, the relationship between X-Bar Theory and PM is rather strained due in large part to the basic subject-predicate (VP) structure of X-Bar Theory compared to the basic SVO structure of PM and to major differences at the inflection (IP) and clausal (CP) levels. To the extent that X-Bar theory makes the noun the head of the noun phrase (NP) and the verb the head of the verb phrase (VP), X-Bar Theory and PM are in agreement. However, X-Bar Theory introduces an Inflection Phrase (IP) level where the inflection (I) on the main predicate is the head and the VP is the complement. No such level exists in PM since inflection is assumed to modify the main predicate and this modification does not create a new predicate type. Further, at the clausal (CP) level, the subject is the specifier, whereas in PM it is an argument (or complement) of the main predicate, and at the IP level it is unclear just what the specifier is since it is distinguished from the inflection (I), whereas in PM the predicate specifier is the first predictival element (e.g. auxiliary verb or verb). Where X-Bar Theory has three distinct clausal level constituents CP, IP, and VP—PM has only propositional descriptions. Where X-Bar Theory allows nouns in NP's to take prepositional phrase complements, in PM terms in object descriptions are non-relational and do not take arguments. Thus, prepositional phrases always function as modifiers in object descriptions in PM.

X-Bar Theory does suggest one possible extension to PM—the introduction of **propositional specifiers** (as contrasted with predicate specifiers). Clauses functioning as independent sentences do not have a specifier. However, the complementizer **that** could be treated as a propositional specifier in embedded clause constructions like

I know that (specifier?) he likes you.

In PM terms, this would be equivalent to introducing a **propositional specifier** category in addition to the **propositional modifier** category. Nonetheless, treatment of the subject as the specifier of the CP constituent—instead of as an argument to the main predicate—is foreign to a PM based analysis.

Chapter 6: The Processing of Propositional and Object Descriptions

Introduction.

Although PM's processing mechanism is specifically concerned with language processing, it can be generally described in information processing or cognitive psychological terms, since it is assumed that language processing relies on the same basic cognitive apparatus as other types of cognitive processing (Lakoff, 1987), and since it is also assumed that there is no separate language faculty which operates independently of cognition (Fodor 1983). The processing mechanism assumes a model of cognition (e.g. Anderson, 1983, 1976; Anderson & LeBiere 1998; Best, 1986; Bower, 1975; Card, Moran & Newell, 1983; Kintsch 1998) which includes the following three types of memory: (a) sensory store, (b) a limited set of short-term memory buffers, and (c) long-term memory. Operating over these different memories are various automatic and control processes. Input into the processing system is initially and temporarily stored in sensory store. The perceptual information in sensory store in turn activates corresponding representations in long-term memory. Activated long-term memory representations may then be selected and placed in a short-term memory buffer for use in the construction of representations of the input. Representations of the input may subsequently be transferred to long-term memory and may also form the basis for some kind of output behavior.

This thesis is specifically concerned with the processing of written English text. Written English text is input into the processor via the visual modality. Each eye fixation leads to the very short-term storage of visual information in the visual memory store (Rayner & Pollatsek, 1987). This visual information automatically activates associated schemas in long-term memory. A control process selects from among the activated schemas, placing selected schemas in a short-term memory buffer. Another control process attempts to integrate the selected schemas with any preceding schemas which have already been placed in a short-term memory buffer. At the end of the processing of an input text, one of the short-term memory buffers will contain a representation of that text consisting of the schemas which were selected an integrated during processing. A nonlinguistic representation is constructed in parallel with the construction of the linguistic representation (Johnson-Laird, 1983), however, the construction of the nonlinguistic representation will not be addressed in this chapter.

As noted above, the processing mechanism assumes the existence of a small set of short-term memory buffers in which to temporarily store the representations which are constructed during processing (i.e., the representations of specific instances), and a long-term memory where the schemas which are used by the processing mechanism are permanently stored (i.e. the representation of exemplars and prototypes). The schemas which are stored in long-term memory are organized into a tangled hierarchy (Anderson, 1983) from more specific schema to more abstract schema. The schemas in long-term

memory can also be described in terms of the distinction between episodic and semantic memory (Tulving, 1972), with very specific schemas (or exemplars) being described as episodic and more abstract schemas (or prototypes) being described as semantic. An automatic spreading activation (and decay) process operates over this tangled hierarchy of schemas (Anderson, 1984, 1983; Collins & Loftus, 1975, Collins & Quillian, 1969). The processing of a lexical item results in the activation of associated schemas in long-term memory. Concrete and lexically specified schemas are more closely associated with specific lexical items and will tend to be more highly activated by those lexical items than abstract and lexically unspecified schemas. However, a previously activated schema which is less closely associated with a given lexical item, may become more highly activated by that lexical item than a more closely associated schema, if the closely associated schema was not previously activated. In general, the schema which is most highly activated after the processing of the lexical item will be selected by the processing mechanism. In the general case, the selection process may operate automatically, however, there is at least the potential for some control over this process. For example, the most highly activated schema may be rejected by the selection process and a less highly activated schema selected instead.

The processing mechanism operates on the input text from left to right, identifying lexical units via the activation of associated schemas in long-term memory, and selecting from among the activated schemas. The activation and selection of schemas corresponding to the relational units in a piece of text is critical to the processing mechanism, since the relational units determine how selected schemas can be integrated together in the short-term memory buffers. The processing mechanism also makes use of general rules of English word order as a guide to determining how to integrate various schemas. Schemas which are consistent with these general rules of word order need not explicitly specify that information. For example, English word order is such that the argument to a function which takes a single argument typically occurs to the right of that function in the input stream. Functions which follow this general rule can be represented by schemas which do not explicitly specify the location of the argument relative to the function. However, more specific schemas are likely to be associated with functions which do not follow the general rule. Thus, the function **ago** is likely to have a schema associated with it in which the argument is specified to occur before the function as in **a week ago**. The use of general rules of word order in combination with explicitly marked exceptions to the rules is consistent with the position of Pinker (2000).

One automatic and two control processes have been introduced above. They include (a) an automatic spreading activation process, (b) a control process for selecting activated schemas from long-term memory and placing them in short-term memory buffers, and (c) a control process for integrating selected schemas in the short-term memory buffers. The automatic process of spreading activation and the control process by which activated schemas are selected and placed in short-term memory will not be discussed further in this manuscript. Only the output of these two processes will be considered. Anderson (1983) and Anderson and LeBiere (1998) present a treatment of these two processes which is largely compatible with PM. This chapter is primarily concerned with a description of the process of integrating selected schemas in the short-term memory

buffers. That process can be described algorithmically in terms of the individual processing steps required to integrate the schemas which have been selected for further processing. We begin the discussion of this process by walking through the steps involved in the processing of the following English sentence:

The boy likes the girl.

The processing of this sentence begins with the activation and selection of a schema corresponding to the first lexical unit. The word **the** is identified and a schema which reflects its status as a function which takes a term for and argument and forms an object description is selected. (In the remainder of this chapter, I will discuss the activation, selection and integration of schemas in terms of the propositional categories put forward in Chapter 3, and will generally not refer to them as schemas. The distinction between lexical items and the representation of those lexical items will also often be ignored in this discussion.) The word order of English is such that the term that goes with a function like **the** almost invariably occurs to the right of that function in the input text. Thus, the preference is for the function to await the appearance of this term before combining with it to form an object description. As a result of this preference, the function **the** is retained in a short-term memory buffer with its argument uninstantiated and the processing of this function is temporarily halted. The processing of the next lexical unit begins. The word **boy** is identified and determined to be a term. Since the function **the** is awaiting the occurrence of a term, it combines with the term **boy** to form the object description **(the<boy>)**. This object description is retained in a short-term memory buffer for use in subsequent processing. The individual components of the object description (e.g., **the** and **boy**) are not separately maintained in the short-term memory buffer once they are combined, since it is assumed that set of short-term memory buffers has too limited a capacity to retain such individual components and since the separate maintenance of these components in short-term memory buffers would interfere with the processing mechanism. In general, it will be assumed that none of the components of propositional descriptions are separately maintained in memory once they are combined, however, there are reasons for suggesting that the subject may represent an exception to this assumption. For example, separately representing the subject in a short-term memory buffer makes it more salient than the other arguments of a predicate and provides one way of explaining the asymmetry in the status of subjects and objects in English. The processing mechanism continues by identifying the next lexical unit. The word **likes** is identified and is determined to be a predicate which takes two object descriptions for arguments. The word order of English is such that the first object description of predicates like **likes** typically occurs before the predicate in the input text. This means that the first argument to the predicates likes should be available in a short-term memory buffer for instantiation at the time the predicate is encountered. The processing mechanism searches the short-term memory buffers for an object description, identifies the object description **the<boy>** and instantiates it as the first argument of **likes**, forming the partially complete propositional description **likes[the<boy>,Obj]**. The order of search is based on the recency of processing of the schemas in the short-term memory buffers, such that the set of short-term memory buffers function very much like a stack. Thus, if there were two object descriptions separately available in short-term memory

buffers at the time the predicates **likes** was processed, the most recently processed object description would be selected for instantiation as the first argument. Object descriptions which are not separately available in short-term memory buffers (i.e., arguments which have already been instantiated into a relational structure), are typically overlooked by the search mechanism. According to English word order, the second argument of a predicate which takes two object descriptions typically occurs after it in the input text. Therefore, the predicate must await the occurrence of the second object description. The partially completed propositional description is retained in a short-term memory buffer. The processing mechanism continues by identifying and processing the next lexical unit. The word **the** is identified and its functional schema is retrieved from memory. Since the predicate **likes** is expecting an object description and not a function, the function **the** cannot be instantiated as the second argument of **likes**. And since the term which the function **the** take, is expected to occur to its right in the input text, this function must likewise wait to be completed. The processing mechanism continues by identifying the next lexical unit, **girl**, and determines it to be a term. Since the function **the** is expecting a term, it combines with the term **girl** to form the object description **(the<girl>)**. This object description is in turn instantiated as the second argument of the predicate **likes**, forming the propositional description **[likes(the<boy>,the<girl>)]**. At the completion of processing of the input text, this propositional description is retained in a short-term memory buffer for subsequent processing.

Since we will be considering many examples of the processing of English text into propositional descriptions, an abbreviated notation for representing the steps in that processing is introduced. The first step involved in the processing of the preceding example is expressed in this notation as:

the => the<T1>$_{obj}$

On the left hand side of the arrow is the lexical item **the** and on the right hand side is the schema for **the** which is activated and selected for subsequent processing. In this schema, **the** is identified as a function which takes a term for an argument and forms an object description. At the time the schema is selected, the argument to the function is uninstantiated. Uninstantiated arguments are represented as variables beginning with a capital letter (e.g. T), which identifies the type of the variable, and ending in a single digit (e.g., 1) which functions to distinguish the variable from other variables of the same type. The possible types are **T** (term), **F** (function), **PR** (predicate), **O** (object description), and **P** (propositional description). The **<>**'s around T1 also identify the type of T1 as a term. **( )**'s will be used to circumscribe object descriptions and the arguments of propostional descriptions, **[ ]**'s will be used to circumscribe propositional descriptions and **{ }**'s will be used to circumscribe the arguments of predicate and function modifiers. Since the schema for **the** is not yet a fully specified object description, it is not circumscribed by **( )**'s, instead the subscript $_{obj}$ marks the schema as ultimately forming and object description. Functions which combine with terms to form complex terms will be circumscribed with **<>**'s to distinguish them from object descriptions when they are fully specified and subscripted with $_{term}$ when they are not. Partially completed propositional descriptions will be subscripted with $_{prop}$ to reflect their fully specified type. Partially

completed function modifiers will be subscripted with $_{\mathbf{func}}$ and partially completed predicate modifiers will be subscripted with $_{\mathbf{pred}}$ to reflect their fully specified type.

Continuing the processing leads to

boy => <boy>
the<T1>$_{\mathbf{obj}}$ + <boy > => (the<boy>)

The left hand side need not always be a lexical item. It may also consist of a collection of schemas which are integrated as shown on the right hand side. The latter processing step above represents the instantiation of the term **boy** as the argument of the function **the**. Note that until the term **boy** is instantiated into the function **the**, there is no object description. Continuing with the processing gives:

likes => likes(O1,O2)$_{\mathbf{prop}}$

followed by

likes(O1,O2) $_{\mathbf{prop}}$ + (the<boy>) => likes(the<boy>,O2) $_{\mathbf{prop}}$

Continuing to completion we have:

the => the<T2> $_{\mathbf{obj}}$
girl => <girl>
the<T2> $_{\mathbf{obj}}$ + <girl> => (the<girl>)
likes(the<boy>,O2) $_{\mathbf{prop}}$ + (the<girl>) => [likes(the<boy>,the<girl>)]

The final representation for the sentence is a propositional description consisting of the predicate **likes** along with the two object descriptions **(the<boy>)** and **(the<girl>)** which are the arguments of the predicate.

This chapter is primarily focused on the discussion of processing issues relevant to the construction of representations which reflect the basic propositional and object description forms. The processing of more specialized schemas will, in general, not be discussed. However, some processing issues specific to particular lexical items will occasionally be addressed.

The Processing of Object Descriptions

This section presents a discussion of the processing of object descriptions in terms of the functional categories introduced in Chapter 3.

$Func<Term_{head}>_{Term}$, $Func<Term_{head}>_{Obj}$, $Func(Obj_{head})_{Obj}$ and $Func\{Func_{head}\}_{Func}$

Functions that take terms for arguments may either combine with the term to form a complex term or an object description. The argument to these types of function typically occur after the function in the input text and the function is retained in a short-term memory buffer until the argument is available for instantiation into it. A term need not immediately follow such a function. One alternative is for the function to be followed by another function. If this happens both functions must await the occurrence of an argument. If a term follows the second function the term can be instantiated as its argument forming a complex term which can be instantiated as the argument of the first function. In principle, an unbounded number of functions which combine to form complex terms could be stacked up in an expression, however, there is likely to be a cognitive limit on how many such functions can actually occur for a given individual.

The instantiation of the arguments of functions in a short-term memory buffer occurs recursively working from right to left. There are three terminating conditions for this recursive process: (a) when all functions in the short-term memory buffers have had their arguments instantiated, (b) when the argument available for instantiation into a function is not of the required type, and (c) when an argument is available for instantiation into a function, but the most recently processed unit in a short-term memory buffer is not a function (i.e., it is a predicate, propositional description, object description or term), even though there may be a less recently processed function in need of an argument in a short-term memory buffer.

Consider the processing of the expression

The blue book.

The steps in the processing of this expression are shown below:

the => the<T1>$_{obj}$
blue => blue<T2>$_{term}$
book => <book>
blue<T2>$_{term}$ + <book> => <blue<book>>
the<T1>$_{obj}$ + <blue<book>> => (the<blue<book>>)

The immediate instantiation of a term into a function as soon as it is processed works well as long as the term always signals the end of an object description. However, this

need not be the case. In English, there are numerous constructions which violate this assumption. For example, compound terms occur quite frequently. Consider the phrase

The boy king

which consists of the function **the** followed by the terms **boy** and **king**. If we assume the first term always terminates a functional unit, then the occurrence of compound lexical items will cause problems for the processing mechanism. In the above example, the term **boy** will be instantiated as the argument of the function **the** forming an object description. When the term **king** is subsequently encountered, there will be no function available to instantiate it into. The processing system will have to retract the instantiation of **boy** as the argument of **the** and reinstantiate the compound lexical item **boy king** as its argument. The steps required to complete this processing are shown below:

the => the<T1>$_{obj}$
boy => <boy>
the<T1>$_{term}$ + <boy> => (the<boy>)
king => <king>
(the<boy>) + <king> => the<T1>$_{obj}$ + <boy> + <king>
<boy> + <king> => <boy_king>
the<T1>$_{obj}$ + <boy_king> => (the<boy_king>)

In the example, the **underscore** connecting **boy** and **king** reflects its treatment as a compound term. Alternatively, the processing mechanism could delay instantiation of the first term as the argument of the function and wait for a stronger indication that the end of the object description has been reached. In the first approach, it will be necessary to reconstruct the object description in those instances when a second term does occur in the input. In the second approach, no such reconstruction is necessary, although it assumes that it is possible to delay the construction mechanism after occurrence of a term. It may well be the case that humans are capable of adopting either strategy (perhaps based on the effectiveness of the strategy for a given piece of text). For example, when reading a text which contains large numbers of compound nouns (or terms) they may adopt a strategy of delaying construction of object descriptions until some indication that the end of the object description has been reached (e.g. occurrence of a verb, preposition, full-stop). Whereas for simple text containing few compound nouns, they may go ahead and construct object descriptions after occurrence of the first term. Further, for terms which frequently occur in compound term constructions—especially if schemas reflecting such compounds are encoded in memory—the immediate instantiation of the term into a function can be delayed until it is determined if the term is part of a compound. In fact, the frequency of compounding of a given term is likely to have a greater influence on the decision to delay its instantiation than is the overall rate of compounding in a text (K. Paap, personal communication, Jan. 1991).

The above discussion assumes that a function cannot be completed until the term it takes is available for instantiation. Based on this assumption, it is quite possible that the processing of a complex object description will result in the need to retain several

uninstantiated functions in short-term memory buffers at the same time. For example, the phrase

The big blue book

would be processed as follows:

the => the<T1>$_{obj}$
big => big<T2>$_{term}$
blue => blue<T3>$_{term}$
book => <book>
blue<T3>$_{term}$ + <book> => <blue<book>>
big<T2>$_{term}$ + <blue<book>> => <big<blue<book>>>
the<T1>$_{obj}$ + <big<blue<book>>> => (the<big<blue<book>>>)

At the point at which the term **book** is encountered, there are three uninstantiated functions (**the**, **big** and **blue**) resident in short-term memory buffers. If we assume that the short-term memory buffers can only retain about seven distinct elements (Miller, 1956), then the capacity of the short-term memory buffers could easily be exceeded during the processing of complex object descriptions.

Alternatively, it might be suggested that an uninstantiated function can be combine with another uninstantiated function to form a compound uninstantiated function. That is, a function followed by a function might be combined with that function to form a compound function before any terms have been encountered. If we initially restrict the compounding of functions to those that combine with terms to form complex terms (and not object descriptions), then the preceding phrase can be processed as follows:

the => the<T1>$_{obj}$
big => big<T2>$_{term}$
blue => blue<T3>$_{term}$
big<T2>$_{term}$ + blue<T3>$_{term}$ => big<blue<T3>$_{term}$
book => <book>
big<blue<T3>>$_{term}$ + <book> => <big<blue<book>>>
the<T1>$_{obj}$ + <big<blue<book>>> => (the<big<blue<book>>>)

This alternative reduces the number of separate elements which must be retained in short-term memory buffers and increases the processing capacity of the system.

There are functions which modify functions rather than taking terms as arguments. Consider

The black robed judge.

In my preferred interpretation of this phrase, it is the **robe** and not the **judge** which is **black**. The processing of the preferred interpretation for this phrase proceeds as follows:

the => the<T1> $_{\textbf{obj}}$
black => black{F1} $_{\textbf{func}}$
robed => robed<T2> $_{\textbf{term}}$
black{F1} $_{\textbf{func}}$ **+ robed<T2>** $_{\textbf{term}}$ **=> black{robed}<T2>** $_{\textbf{term}}$
judge => <judge>
black{robed}<T2> + <judge> => <black{robed}<judge>>
the<T1> $_{\textbf{obj}}$ **+ <black{robed}<judge>> => (the<black{robed}<judge>>)**

In the preferred interpretation of this expression, **black** functions as an adverb (i.e. function modifier) rather than an adjective, since it modifies the adjective (or participial) **robed** (which is a function) rather than the noun **judge**. In PM, adverbs—when they occur as elements of object descriptions—are functions which take functions as their argument. Of course, **black** normally prefers to be an adjective rather than an adverb and it is unlikely that the processing of this expression is as straightforward as the example shows. Rather, the occurrence of the word **robed** after **black** triggers the preference for the adverbial use which must somehow replace the original preference. Thus, we might modify the processing as follows:

the => the<T1> $_{\textbf{obj}}$
black => black<Ta> $_{\textbf{term}}$
robed => <robed<T2> $_{\textbf{term}}$
black<Ta> $_{\textbf{term}}$ **+ robed<T2>** $_{\textbf{term}}$ **=> black{F1}** $_{\textbf{func}}$ **+ robed<T2>** $_{\textbf{term}}$
black{F1} $_{\textbf{func}}$ **+ robed<T2>** $_{\textbf{term}}$ **=> black{robed}<T2>** $_{\textbf{term}}$
judge => <judge>
black{robed}<T2> $_{\textbf{term}}$ **+ <judge> => <black{robed}<judge>>**
the<T1> $_{\textbf{obj}}$ **+ <black{robed}<judge>> => (the<black{robed}<judge>>)**

The adverbial status of **black** is an interesting consequence of the verbal use of the noun **robe**. Thus, **black** would typically function as an adjective in modifying **robe** as in

The black robe.
The robe is black.

However, since **robed** is itself functioning as a modifier in **the black robed judge**, **black** takes on the adverbial role of modifying a modifier. Note that there is an alternative (if dispreferred) reading of this expression in which **black** modifies **judge** and not **robed**. In this dispreferred reading **black** retains its more typical use and the expression can be processed as followed:

the => the<T1> $_{\textbf{obj}}$
black => black<Ta> $_{\textbf{term}}$
robed => <robed<T2> $_{\textbf{term}}$
judge => <judge>
robed<T2> $_{\textbf{term}}$ **+ <judge> => <robed<judge>>**

black<Ta> $_{\textbf{term}}$ **+ <robed<judge>> => <black<robed<judge>>>**
the<T1> $_{\textbf{obj}}$ **+ <black<robed<judge>>> => (the<black<robed<judge>>>)**

In the resulting representation, the "**robed judge**" is "**black**". Selection of this dispreferred reading can be facilitated by punctuation as in

The black, robed judge

where the comma serves to emphasize the dual modification of **judge** by **black** and **robed**. And use of the conjunction **and** would make the dual modification even more explicit

The black and robed judge

although the conjunction of such disparate properties is unusual.

While the adverbial use of **black** is atypical, it parallels the following expression which contains a more typical adverb:

The quickly falling temperature

The processing of this expression is more straightforward since the typical uses of the words are not violated (at least within the context of an object description):

the => the<T1> $_{\textbf{obj}}$
quickly => quickly{F1} $_{\textbf{func}}$
falling => falling<T2> $_{\textbf{term}}$
quickly{F1} $_{\textbf{func}}$ **+ falling<T2>** $_{\textbf{term}}$ **=> quickly{falling}<T2>** $_{\textbf{term}}$
temperature => <temperature>
quickly{falling}<T2> $_{\textbf{term}}$ **+ <temperature> =>**
<quickly{falling}<temperature>>
the<T1> $_{\textbf{obj}}$ **+ <quickly{falling}<temperature>> =>**
(the<quickly{falling}<temperature>>)

There is a strong preference for the argument to a function to occur to the right of the function in the input text. This is even true for adverbs used functionally—unlike their more promiscuous use as predicates. However, this preference is not universal. Consider

The president elect

in which the function **elect** occurs after the term **president** which it takes as its argument. The occurrence of such constructions presents no difficulty for PM's processing mechanism since it is lexically driven and since it allows functions like **elect** to specify the relative location of their arguments. The processing of this expression is shown below:

the => the<T1>$_{obj}$
president => <president>
elect => <T2>elect$_{term}$
<president> + <T2>elect$_{term}$ => <<president>elect>
the<T1>$_{obj}$ + <<president>elect> => (the<president>elect>>).

Implicit in the processing steps above is the assumption that the term **president** is not immediately instantiated as the argument of the function **the**. Such constructions provide an additional reason not to prefer the immediate instantiation of a term into the preceding function. While adjectives following nouns rarely occur in English, they are the norm in Spanish and occur frequently in French. Thus, the immediate instantiation of a term into the preceding function in Spanish or French is not likely to be an advantageous processing strategy.

In general, it is assumed that the processing mechanism makes use of effective processing strategies which are learned from experience. Effective processing strategies are strategies which lead to the construction of representations which rarely need to be revised. In a language which did not include either compound terms or functions following terms, the immediate instantiation of a term into a function might be an effective processing strategy, since it should not result in the frequent construction of inappropriate structures which must be revised. In the processing of a relational lexical item, if the lexical item has a strong preference for the occurrence of specific types of arguments, then the processing mechanism can make effective use of those preferences. If the preferences of the lexical item are weak, then reliance on those preferences will often lead to mistaken analyses. For example, the lexical item **quickly** has a strong preference to be used as a function that combines with another function within the context of an object description (the occurrence of a determiner is a strong indicator of such a context), whereas, the lexical item **black** has a weaker preference to be used as a function taking a term as an argument, within the same context. In essence, the use of **quickly** is only conditioned by the prior context (i.e. the determiner), whereas, the use of **black** is conditioned by both the prior and subsequent context. For lexical items which are conditioned by the subsequent context, it may not be an effective processing strategy to commit to a particular schema for that lexical item in ignorance of the subsequent context. It was suggested above that the processing of the lexical item **black** leads to the initial inclusion of the schema **black<T1>$_{obj}$** in a short-term memory buffer. If the subsequent input shows this schema to be invalid, it is replaced by a more appropriate schema. However, this may not be an effective processing strategy for this lexical item. An alternative strategy, which does not require positing the existence of any additional schemas, is to suggest that the process which determines which schema to place in short-term memory during the processing of the lexical item may be delayed until after the processing of the subsequent lexical item. Another alternative, which does require positing additional schemas, is to suggest that the processing of the lexical item **black** leads to the selection of a schema which abstracts away from the different uses of this lexical item, and allows this abstract schema to be further specialized by the subsequent input.

So far we have considered functions taking a single argument, where the argument is either a term or another function. Some functions can also take entire object descriptions as their argument. Consider

All the books

which can be processed as follows:

all => all(Obj)$_{obj}$
the => the<T1>$_{obj}$
books => <books>
the<T1>$_{obj}$ + <books> => (the<books>)
all(Obj)$_{obj}$ + (the<books>) => (all(the<books>))

The processing of the predeterminer **all** is fairly straightforward on the assumption that the preferred use of **all** is to take an object description for its argument. However, **all** can also be used as a function which takes a term for an argument, and it can also be used as a full object description (e..g. **all of the books**). Thus, the functional use of **all** is conditioned by the category of the words which occur after it in the input text. The initial selection of a schema for **all** can only be made tentatively at the time this lexical item is processed.

Func<Term,Term>$_{Term}$ and Func(Obj,Obj)$_{Obj}$.

It was suggested in Chapter 4 that for functions taking two arguments, those arguments must be of the same type. It was also suggested that higher level units do not combine to form lower level units—where object descriptions are higher level units than terms. Ignoring head/modifier differences, Chapter 4 introduced two forms of functions taking two arguments:

Func<Term,Term>$_{Term}$
Func(Obj,Obj)$_{Obj}$

Consider the processing of the expression

The prince and princess

which proceeds as follows:

the => the<T1>$_{obj}$
prince => <prince>
and => and<T2,T3>$_{term}$
<prince> + and<T2,T3>$_{term}$ => and<prince,T3>$_{term}$
princess => <princess>
and<prince,T3>$_{term}$ + <princess> => <and<prince,princess>>

the<T1>$_{obj}$ + <and<prince,princess>> => (the<and<prince,princess>>)

As in the preceding section, it is assumed that the term **prince** is not immediately instantiated into the function **the**. Further, it is assumed that the lexical item **and** has the preferred functional form **and<T2,T3>$_{term}$.** This latter assumption is probably incorrect in that **and** is used more often to conjoin entire object descriptions and the functional form **and(O1,O2)$_{obj}$** is likely to be preferred. However, the occurrence of the lexical item **princess** immediately following **and** conditions the preferences of **and** and leads to the selection of a schema for **and** which involves the conjunction of terms rather than object descriptions. Had the processing mechanism selected the latter schema for **and**, the processing of this expression would have initially lead to the construction of the inappropriate structure **and(the<prince>,O2)$_{obj}$**, which would have required revision after the processing of the subsequent term **princess**:

the => the<T1>$_{obj}$
prince => <prince>
and => and(O1,O2)$_{obj}$
the<T1>$_{obj}$ + <prince> => (the<prince>)
(the<prince>) + and(O1,O2)$_{obj}$ => and(the<prince>,O2)
princess => <princess>
and(the<prince>,O2)$_{obj}$ + <princess> => the<T1>$_{obj}$ +
<and<prince,princess>>
the<T1>$_{obj}$ + <and<prince,princess>> => (the<and<prince,princess>>)

In general, structural revision like that above is assumed to be an expensive process which should be avoided by the processing mechanism. The lexical item **and** is the most structurally ambiguous relational element in English, since it can be used in the conjunction of any of the categories in PM. As such, the processing mechanism is unlikely to make a strong commitment to the selection of a particular schema for **and** at the time this lexical item is processed. Rather, it should allow the subsequent input to condition the selection of a schema. For example, if the expression being processed is

The black and white flag

where the lexical items **black** and **white** prefer to be used as functions which take a term for an argument, then given the occurrence of **and** between these lexical items, the schema involving the conjunction of functions should be selected and this expression should be processed as follows:

the => the<T1>$_{obj}$
black => black<T2>$_{term}$
and => and??
white => white<T3>$_{term}$
black<T2>$_{term}$ + and?? + white<T3>$_{term}$ => and{black,white}<T3>$_{term}$
flag => <flag>
and{black,white}<T3>$_{term}$ + <flag> => <and{black,white}<flag>>

the<T1>$_{obj}$ + <and{black,white}<flag>> => (the<and{black,white}<flag>>)

As such examples make obvious, the conditioning of structurally ambiguous lexical items like **and** by the subsequent input is important for the efficient functioning of the processing mechanism. It should also be noted that **and** functions to conjoin the adjectives **black** and **white** in such a way that the resulting complex function takes a single term for an argument. If we throw back in the participle **robed** as in

The black and white robed judge

we get

the => the<T1>$_{obj}$
black => black<T2>$_{term}$
and => and??
white => white<T3>$_{term}$
black<T2>$_{term}$ + and?? + white<T3>$_{term}$ => and{black,white}<T3>$_{term}$
robed => robed<T4>
and{black,white}<T3>$_{term}$ + robed<T4>$_{term}$ =>
and{black,white}{F1}$_{func}$ + robed<T4>$_{term}$ =>
and{black,white}{robed}<T4>$_{term}$
judge => <judge>
and{black,white}{robed}<T4>$_{term}$ + <judge> =>
<and{black,white}{robed}<judge>>
the<T1>$_{obj}$ + <and{black,white}{robed}<judge>> =>
(the<and{black,white}{robed}<judge>>)

where the occurrence of **robed** conditions the rank promotion of **and{black,white}<T3>** to **and{black,white}{F1}**.

As suggested above, conjunctions can also be used to conjoin two object descriptions. Consider

The man and the woman

which can be processed as follows:

the => the<T1>$_{obj}$
man => <man>
and => and??
the => the<T2>$_{obj}$
the<T1>$_{obj}$ + <man> + and ?? + the<T2>$_{obj}$ => and(O1,O2)$_{obj}$
the<T1>$_{obj}$ + man => (the<man>)
(the<man>) + and(O1,O2)$_{obj}$ => and(the<man>,O2)$_{obj}$
woman => <woman>
the<T2>$_{obj}$ + <woman> => (the<woman>)

and(the<man>,O2) $_{obj}$ **+ (the<woman>) => (and(the<man>,the<woman>))**

In the processing of this expression, the instantiation of the term **man** as the argument of the function **the** is delayed until it is determined that **and** is being used to conjoin two object descriptions. Once this determination is made, the object description is created and instantiated as the first argument of **and**.

Conjunctions are not the only type of function which takes two arguments. Prepositions are also members of this category. In fact, the preposition **of** is perhaps the most frequently occurring member of this category. Unlike other prepositions, **of** has a strong preference to be used as a function rather than as a predicate. Consider the expression

The Queen of England

which can be processed as follows:

the => the<T1> $_{obj}$
queen => <queen>
of => of(O1,O2) $_{obj}$
the<T1> $_{obj}$ **+ <queen> => (the<queen>)**
of(O1,O2) $_{obj}$ **+ (the<queen>) => of(the<queen>,O2)** $_{obj}$
England => (England)
of(the<queen>,O2) $_{obj}$ **+ (England) => (of(the<queen>,England))**

The processing of this expression assumes that the preposition **of** prefers to be used as a function which takes two object descriptions for arguments (as opposed to two terms). While it is fairly clear that conjunctions can be used either way, it is assumed that prepositions have a strong preference for object descriptions rather than terms as their arguments. However, consider

The can of beans

Either **beans** is functioning as a full object description, or **of** establishes a relationship between two terms. Assuming the latter and delaying the determination of the schema for **of**, this can be processed as

the => the<T1> $_{obj}$
can => <can>
of => of??
beans => <beans>
<can> + of?? + <beans> => of<T1,T2>$_{term}$ **=> <of<can,beans>>**
the<T1> $_{obj}$ **+ <of<can,beans>> => (the<of<can,beans>>)**

Although **of** appears to take terms for arguments, prepositions more generally probably do not and the processing mechanism can more reliably assume their arguments are object descriptions.

It is of interest to consider the processing of expressions containing multiple functional elements. Consider

The old man and woman

This expression is ambiguous with respect to whether or not the adjective **old** modifies **woman**. This ambiguity is reflected in the following alternative processing steps (and representations):

the => the<T1>$_{obj}$
old => old<T2>$_{term}$
man => <man>
and => and??
woman => <woman>
<man> + and?? + <woman> => <and<man,woman>>
old<T2>$_{term}$ + <and<man,woman>> => <old<and<man,woman>>>
the<T1>$_{obj}$ + <old<and<man,woman>>> => (the<old<and<man,woman>>>)

the => the<T1>$_{obj}$
old => old<T2>$_{term}$
man => <man>
old<T2>$_{term}$ + <man> => <old<man>>
and => and??
woman => <woman>
<old<man>> + and?? + <woman> => <and<old<man>,woman>>>
the<T1>$_{obj}$ + <and<old<man>,woman>>=> (the<and<old<man>,woman>>>)

The latter processing path could be triggered by the affinity of the words **old** and **man** since they frequently co-occur together and are nearly idiomatic.

As another example of an expression containing multiple functional elements consider

The king and queen of Camelot

which can be processed as

the => the<T1>$_{obj}$
king => <king>
and => and??
queen => <queen>

<king> + and?? + <queen> => and<T1,T2> $_{\textbf{term}}$ **=>**
<and<king,queen>>
of => of(O1,O2) $_{\textbf{obj}}$
the<T1> $_{\textbf{obj}}$ **+ <and<king,qieem>> => (the<and<king,queen>>)**
of(O1,O2) $_{\textbf{obj}}$ **+ (the<and<king,queen>>) =>**
of(the<and<king,queen>>,O2) $_{\textbf{obj}}$
Camelot => (Camelot)
of(the<and<king,queen>>,O2) $_{\textbf{obj}}$ **+ (Camelot) =>**
(of(the<and<king,queen>>,Camelot))

The representation above is the only one that is consistent with the constraints adopted at the beginning of the section. For example, consider the following alternative representations:

(of(and((the<king>),<queen>),(Camelot)))
(and(the<king>,of(<queen>,(Camelot)))
(the<of(<and<king,queen>>,(Camelot))>)

In the first alternative, the conjuntion **and** conjoins and object description **(the<king>)** and a term **<queen>.** In the second alternative, the preposition **of** takes a term **<queen>** and an object description **(Camelot).** In the third alternative, the preposition **of** takes a term **<and<king,queen>>** and an object description **(Camelot)** and if it forms an object description, then the determiner **the** takes an object description instead of a term for its argument.

In was suggested in Chapter 3 that certain functions might allow the mixing of arguments, with the possessive marker **'s** being a prime candidate for such a treatment. However, allowing that the possessive marker has such a form does not mean allowing for the existence of the form more generally. Thus, it is tentatively assumed that the occurrence of mixed argument types is specific to the treatment of the possessive marker and does not apply to other functions more generally. Consider

John's book

which can be processed as follows:

John's => (John) + $\textbf{s}_{\textbf{poss}}$**(O1,T1)** $_{\textbf{obj}}$ **=>** $\textbf{s}_{\textbf{poss}}$**((John),T1)** $_{\textbf{obj}}$
book => <book>
$\textbf{s}_{\textbf{poss}}$**((John),T1)** $_{\textbf{obj}}$ **+ <book> => (**$\textbf{s}_{\textbf{poss}}$**((John),<book>))**

On the other hand, if we allow the possessive marker to **functionize** the first argument, then we get:

John's => $\textbf{s}_{\textbf{poss}}${**John**}**<T1>** $_{\textbf{obj}}$
book => <book>

s $_{poss}${**John**}<**T1**> $_{obj}$ + <**book**> => (**s** $_{poss}${**John**}<**book**>)

As a final example of the processing of object descriptions containing multiple functional elements, consider

The man with the sword of steel

which can be processed as follows:

the => the<T1> $_{obj}$
man => <man>
with => with(O1,O2) $_{obj}$
the<T1> $_{obj}$ **+ <man> => (the<man>)**
with(O1,O2) $_{obj}$ **+ (the<man>) => with(the<man>,O2)** $_{obj}$
the => the<T2> $_{obj}$
sword => <sword>
of => of??
steel => <steel>
<sword> + of?? + <steel> => of<T3,T4> => <of<sword,steel>>
the<T2> $_{obj}$ **+ <of<sword,steel>> => (the<of<sword,steel>>)**
with(the<man>,O2) $_{obj}$ **+ (the<of<sword,steel>>) =>**
(with(the<man>,the<of<sword,steel>>))

The conditioning of **of** in this expression to take two terms as arguments avoids what is otherwise a highly ambiguous form. Consider

The man with the question on the economy
The man with the question on the podium

In which the prepositions **with** and **on** prefer to take full object descriptions for arguments. Structurally there are two distinct possible representations for each of these expressions. My preferred interpretation of each leads to the following:

with(the<man>,on(the<question>,the<economy>))
on(with(the<man>,the<question>),the<podium>)

On the other hand consider

The man with the question on dancing
***The man with the question on podium**

Apparently when **on** functions to combine two terms instead of object descriptions (if in fact **dancing** is functioning as a term), only one representation is supported since the alternative violates the constraints on possible structures discussed above:

with(the<man>,the<on<question,dancing>>)

Ultimately, determination of the preferred structures for representing object descriptions with multiple functional elements hinges on considerations of meaning which are not discussed in detail in this manuscript. While I would like to be able to claim that PM representations are capable of representing differences in meaning with have structural manisfestations, exactly how the processing mechanism determines which structure is preferred in a given context is an open area of research.

The Processing of Propositional Descriptions

The processing of propositional descriptions entails a consideration of effective processing strategies similar to those used in the processing of object descriptions. In this section, processing strategies relevant to each of the basic propositional forms will be considered.

Pred(Obj)

The typical examples of predicates of this class are members of the grammatical categories intransitive verb and predicate adjective. Based on the word order of English, the arguments to such predicates typically occur prior to the predicate in the input text and should therefore be available for immediate instantiation into the predicate at the time the predicate is processed. As an example of the processing of intransitive verbs, consider

The boy cried

Which can be processes as follows:

the => the<T1>$_{obj}$
boy => <boy>
cried => cried(O1)$_{prop}$
the<T1>$_{obj}$ + <boy> => (the<boy>)
cried(O1)$_{prop}$ + (the<boy>) => [cried(the<boy>)]

The processing of this sentence introduces no new processing considerations.

As was noted in Chapter 3, predicate adjectives typically occur in sentences which contain an auxiliary verb to mark tense. The processing of the sentence

He is sad

can proceed as follows:

he => (he)

is => is{PR1}
is{PR1} + sad => sad(O1) $_{prop}$
is{PR1} $_{pred}$ + sad(O1) $_{prop}$ => is{sad}(O1) $_{prop}$
is{sad}(O1) $_{prop}$ + (he) => is{sad}(he)

The processing of this sentence assumes that the auxiliary verb **is** takes the predicate **sad** for an argument and forms a complex predicate **is{sad}**. Otherwise, the processing of this sentence introduces no new considerations. Of course, the auxiliary **is** can also function as a "**predicatizer**" of a subsequent object description. Consider,

He is a man

which superficially has two object descriptions **he** and **a man**. If **is** functions to convert the second object description into a predicate nominal, this sentence can be processed as follows:

he => (he)
is => is{PR1}
a => a<T1> $_{obj}$
man => <man>
a<T1> $_{obj}$ + <man> => (a<man>)
is{PR1} + (a<man>) => is{(a<man>)$_{pred}$}(O1) $_{prop}$
is{(a<man>)$_{pred}$}(O1) $_{prop}$ + (he) => is{(a<man>)$_{pred}$}(he)

The alternative is to treat **is** as a predicate which takes two arguments instead of one. This treatment will be considered in the next section.

Predicate adjectives differ from attributive adjectives in that predicate adjectives expect an object description to occur before them in the input text, whereas attributive adjectives expect a term to occur often them in the input text. The presence of a determiner or auxiliary verb preceding an adjective in an expression or sentence is a strong determiner of the status of the adjective. Verb participles behave very much like adjectives in this regard, except that they are not restricted to taking a single object description in their use as a predicate.

Pred(Obj,Obj)

The typical examples of predicates of this class are members of the grammatical category transitive verb. Prepositions also have such a use. Such predicates expect their first argument to occur before them in the input text and the second argument to occur after them. Consider

He hit the ball

Which contains the transitive verb **hit** and can be processed as follows:

he => (he)
(he) + hit => hit(O1,O2) $_{prop}$
(he) + hit(O1,O2) $_{prop}$ => hit(he,O2)
the => the<T1> $_{obj}$
ball => <ball>
the<T1> $_{obj}$ + <ball> => (the<ball>)
hit(he,O2) $_{prop}$ + (the<ball>) => [hit(he,the<ball>)]

Likewise the sentence

The pen is in the box

contains the preposition **in** and can be processed as follows:

the => the<T1> $_{obj}$
pen => <pen>
is => is{PR1}
the<T1> $_{obj}$ + <pen> => (the<pen>)
is{PR1} + in => in(O1,O2) $_{prop}$
is{PR1} + in(O1,O2) $_{prop}$ => is{in}(O1,O2) $_{prop}$
(the<pen>) + is{in}(O1,O2) $_{prop}$ => is{in}(the<pen>,O2) $_{prop}$
the => the<T2> $_{obj}$
box => <box>
the<T2> $_{obj}$ + <box> => (the<box>)
is{in}(the<pen>,O2) $_{prop}$ + (the<box>) => is{in}(the<pen>, the<box>)

The auxiliary verb **to be** may be treated as a transitive predicate. This is the most straightforward way to represent a sentence like

He is a man.

Assuming this treatment, this sentence can be processed as:

he => (he)
is => is??
a => a<T1>$_{obj}$
(he) + is?? + a<T1>$_{obj}$ => (he) + is(O1,O2) $_{prop}$ + a<T1>$_{obj}$
(he) + is(O1,O2) $_{prop}$ => is(he,O2) $_{prop}$
man => <man>
a<T1>$_{obj}$ + <man> => (a<man>)
is(he,O2) $_{prop}$ + (a<man>) => [is(he,a<man>)]

That fact that **he** and **a man** refer to the same individual is a semantic consideration that interacts with the relational structure in the full interpretation of this sentence.

It should be noted that the processing mechanism does not wait to instantiate the subject as the first argument of a predicate until after the object has been processed and instantiated into the predicate. Given the commonly accepted division of a sentence into a subject and predicate—where the predicate contains the verb and object—one might expect the instantiation of the subject to be delayed. This would accord the subject/predicate division a processing based explanation. However, I see no reason to delay instantiation of the subject into the predicate, and good reasons for not delaying the instantiation. For example, given the limited number of separate chunks which can be maintained in short term memory buffers, delaying instantiation of the subject into the predicate could result in overload of the memory buffers and loss of a cue for the subject before it can be instantiated into the predicate.

Pred(Obj,Obj,Obj)

The typical member of this class of predicate is the ditransitive verb. For such predicates, the first argument typically occurs before the predicate in the input text and the second and third arguments typically occur after it. The processing of these predicates is straightforward on the assumption that the three argument form is the preferred form. Consider

He gave me the ball

Which can be processed as follows:

he => (he)
gave => gave(O1,O2,O3) $_{\textbf{prop}}$
(he) + gave(O1,O2,O3) $_{\textbf{prop}}$ **=> gave(he,O2,O3)** $_{\textbf{prop}}$
me => (me)
gave(he,O2,O3) $_{\textbf{prop}}$ **+ (me) => gave(he,me,O3)** $_{\textbf{prop}}$
the => the<T2> $_{\textbf{obj}}$
ball => <ball>
the<T2> $_{\textbf{obj}}$ **+ <ball> => (the<ball>)**
gave(he,me,O3) $_{\textbf{prop}}$ **+ (the<ball>) => [gave(he,me,the<ball>)]**

However, most ditransitive verbs also participate in an alternative form involving the preposition **to** in which the verb and preposition jointly determine the status of the second and third object descriptions. For example, the sentence

He gave the ball to me

contains the ditransitive verb **gave** and the preposition **to** which jointly determine the status of the object descriptions **the ball** and **me**. If we provide a specialized schema of the form **|O1 gave O2 to O3|** $_{\textbf{prop}}$ to handle this sentence it can be processed as follows:

he => (he)
gave => gave(O1,O2,O3) $_{\textbf{prop}}$

(he) + gave(O1,O2,O3) $_{prop}$ **=> gave(he,O2,O3)** $_{prop}$
the => the<T2> $_{obj}$
ball => <ball>
gave(he,O2,O3) $_{prop}$ **+ to => |(he) gave O2 to O3|**$_{prop}$
the<T2> $_{obj}$ **+ <ball> => (the<ball>)**
|(he) gave O2 to O3| $_{prop}$ **+ (the<ball>) => |(he) gave (the<ball>) to O3|** $_{prop}$
me => (me)
|(he) gave (the<ball>) to O3|$_{prop}$ **+ (me) => [(he) gave (the<ball>) to (me)]**

Should this specialized schema not be available, two other alternatives exist. One is to allow **gave** to function as a transitive verb leading to a representation of the form:

[to([gave(he,the<ball>)],(me)]

where the preposition **to** is using the **pred(P1,O2)** $_{prop}$ schema. Many verbs which combine multiple arguments have reduced argument forms as is suggested for **gave**. Also, the sentence

To me, he gave the ball

where the prepositional phrase has been fronted, suggests the viability of such a treatment. Another alternative is to suggest that **gave** and **to** combine to form a complex predicate taking three arguments and leading to

[{gave}to(he,the<ball>,me]

This combination of a verb with a preposition is very common in the case of verb particles (e.g. prepositions which reflect the direction of an action as in **give up**) and may extend to other uses of prepositions. The processing of the latter form is shown below:

he => (he)
gave => gave(O1,O2,O3) $_{prop}$
(he) + gave(O1,O2,O3) $_{prop}$ **=> gave(he,O2,O3)** $_{prop}$
the => the<T2> $_{obj}$
ball => <ball>
to => to??
gave(he,O2,O3) $_{prop}$ **+ to?? => gave(he,O2,O3)** $_{prop}$ **+ {PR1}to**
gave(he,O2,O3) $_{prop}$ **+ {PR1}to => {gave}to(he,O2,O3)** $_{prop}$
the<T2> $_{obj}$ **+ <ball> => (the<ball>)**
{gave}to(he,O2,O3) $_{prop}$ **+ (the<ball>) => {gave}to(he,the<ball>,O3)** $_{prop}$
me => (me)
{gave}to(he,the<ball>,O3) $_{prop}$ **+ (me) => [{gave}to(he,the<ball>,me)]**

It should be noted that the arguments are in a different order in the ditranstive use of **gave** versus **{gave}to**. Also, the relative position of **gave** and **to** have been encoded in the **{PR1}to** schema.to reflect the typical surface order.

Pred(Prop) and Pred{Pred}

The processing of these propositional forms highlights some interesting characteristics of the processing mechanism. The typical example of a **pred(prop)** is the sentential adverb. Adverbs of this category display considerable flexibility in their location with respect to the propositional descriptions they modify. For example, the sentences

Peacefully, he left
He, peacefully, left
He left, peacefully

Are all structurally valid, despite the fact that the adverb **peacefully** occurs in three different surface positions. As will be shown below, the differing surface locations of predicates like **peacefully** do not complicate the processing mechanism, and it may be for this reason that such predicates can occur in more than one surface position. For example, the first sentence can be processed as follows:

peacefully => peacefully(P1) $_{\textbf{prop}}$
he => (he)
(he) + left => left(O1) $_{\textbf{prop}}$
(he) + left(O1) $_{\textbf{prop}}$ **=> [left(he)]**
peacefully(P1)$_{\textbf{prop}}$ **+ [left(he)] => [peacefully([left(he)])]**

When the lexical item **peacefully** is identified as a **pred(prop),** no propositional description is available in a short-term memory buffer to be instantiated as its argument, and the predicate must await the occurrence of the propositional description. When the object description **he** is processed it cannot be instantiated as the argument of **peacefully**, since it is not of the required type. When the predicate **left(O1)** is processed, the object description **he** can be instantiated into it forming a propositional description which can then be instantiated as the argument of **peacefully**.

The processing of the second sentence can proceed as follows:

he => (he)
peacefully => peacefully(P1)$_{\textbf{prop}}$
(he) + left => left(O1) $_{\textbf{prop}}$
(he) + left(O1) $_{\textbf{prop}}$ **=> [left(he)]**
peacefully(P1)$_{\textbf{prop}}$ **+ [left(he)] => [peacefully([left(he)])]**

assuming that peacefully is functioning as a sentential adverb in this sentence. The processing of this sentence is straightforward except that the predicate **left(O1)** must "look over" the predicate **peacefully(P1)** in the short-term memory buffers in order to retrieve the object description **he**. It may be that the placement of the lexical item **peacefully** between the lexical items **he** and **left** is somewhat dispreferred for this reason.

An alternative to having the predicate **left** look over **peacefully** is to suggest that **peacefully** and **left** combine to form a complex predicate. This effectively means treating **peacefully** as a predicate adverb rather than a sentential adverb. Assuming this treatment we have:

he => (he)
(he) + peacefully => peacefully{PR} $_{\textbf{pred}}$
peacefully{PR} $_{\textbf{pred}}$ **+ left => peacefully{PR}** $_{\textbf{pred}}$ **+ left(O1)** $_{\textbf{prop}}$
peacefully{PR} $_{\textbf{pred}}$ **+ left(O1)** $_{\textbf{prop}}$ **=> peacefully{left}(O1)** $_{\textbf{prop}}$
(he) + peacefully{left}(O1) $_{\textbf{prop}}$ **=> [peacefully{left}(he)]**

It is unclear if there is a difference in meaning between these two alternatives and this latter treatment simplifies the processing mechanism and is consistent with the **Main Predicate Proximity Principle** put forward in Chapter 3.

Assuming the sentential adverb reading, the third sentence above can be processed as

he => (he)
(he) + left => left(O1) $_{\textbf{prop}}$
(he) + left(O1) $_{\textbf{prop}}$ **=> [left(he)]**
[left(he)] + peacefully => peacefully(P1)$_{\textbf{prop}}$
[left(he)] + peacefully(P1)$_{\textbf{prop}}$ **=> [peacefully([left(he)])]**

In the processing of this sentence, when the predicate **peacefully** is processed, there is a propositional description available in a short-term memory buffer for immediate instantiation into it.

All three of these sentences can be processed without major complication, despite the differing surface orders of the predicate **peacefully**. The second sentence does introduce some complication, but there are at least two ways to handle the interposed location of **peacefully**.

In an earlier discussion it was suggested that the predicate **slowly** is typically a predicate as opposed to propositional modifier. As such the sentence

He walked slowly

can be processed as followed:

he => (he)
(he) + walked => walked(O1) $_{\textbf{prop}}$
slowly => slowly{PR1} $_{\textbf{pred}}$
walked(O1) $_{\textbf{prop}}$ **+ slowly{PR1}** $_{\textbf{pred}}$ **=> slowly{walked}(O1)** $_{\textbf{prop}}$
(he) + slowly{walked}(O1) $_{\textbf{prop}}$ **=> [slowly{walked}(he)]**

Note that the instantiation of **he** as the argument of **walked** is delayed until after the adverb **slowly** is processed. This avoids the need for the predicate modifier **slowly** to intrude on the propositional description **[walked(he)]** which would be created if **he** were immediately instantiated into **walked**. This is another example of where delayed instantiation avoids the creation of structures that would otherwise have to be dismantled.

If the adverb **slowly** is fronted as in

Slowly, he walked

and **slowly** is treated as a predicate modifier, it is more difficult to avoid creation of an invalid structure. This may explain why fronted adverbs tend to be treated as sentential modifiers. The sentence can be processed as follows:

slowly => slowly{PR1} $_{\textbf{pred}}$
he => (he)
(he) + walked => walked(O1) $_{\textbf{prop}}$
(he) + walked(O1) $_{\textbf{prop}}$ **=> [walked(he)]**
slowly{PR1}$_{\textbf{pred}}$ **+ [walked(he)] => [slowly{walked}(he)]**

In the last step the predicate modifier **slowly** must be integrated into a complete propositional description which is atypical for the processing mechanism. An alternative last step is to convert **slowly** to a sentential adverb leading to:

slowly{PR1}$_{\textbf{pred}}$ **+ [walked(he)] => slowly(P1) + [walked(he)]**
slowly(P1)$_{\textbf{prop}}$ **+ [walked(he)] => [slowly([walked(he)])]**

Chafe (1970) argues that the fronting of adverbs like **slowly** has just this effect of converting them into sentential modifiers. One possible difference between **he walked slowly** and **slowly, he walked** is the suggestion that in the latter sentence that the act of walking was slow to start. This distinction is quite subtle. Indeed, I had overlooked it myself until it was pointed out to me (K. Paap, Oct. 1991, personal communication). While the position of the predicate **slowly** has only a subtle effect in the above sentences, the positional effect is more prominent in sentences containing multiple predicates. Consider

He stopped walking slowly
Slowly, he stopped walking.

The fronting of **slowly** results in a preferred interpretation of the second sentence which differs substantially from the first sentence. The processing of the first sentence can proceed as follows:

he => (he)
stopped => stopped??
stopped + walking => stopped{PR1} + walking(O1)

walking(O1) + slowly => walking(O1) + slowly{PR2} $_{\textbf{pred}}$
walking(O1) $_{\textbf{prop}}$ **+ slowly{PR2}** $_{\textbf{pred}}$ **=> slowly{walking}(O1)** $_{\textbf{prop}}$
stopped{PR1} + slowly{walking}(O1) $_{\textbf{prop}}$ **=>**
stopped{slowly{walking}}(O1) $_{\textbf{prop}}$
(he) + stopped{slowly{walking}}(O1) $_{\textbf{prop}}$ **=>**
[stopped{slowly{walking}}(he)]

In the resulting representation **stopped** modifies **slowly{walking}** and not just **walking**. The second sentence can be processed as:

slowly => slowly{PR1}
he => (he)
stopped => stopped??
stopped + walking => stopped{PR1} + walking(O1)
stopped{PR1} + walking(O1) $_{\textbf{prop}}$ **=> stopped{walking}(O1)** $_{\textbf{prop}}$
(he) + stopped{walking}(O1) $_{\textbf{prop}}$ **=> [stopped{walking}(he)]**
slowly{PR1} + [stopped{walking}(he)] =>
slowly(P1) $_{\textbf{prop}}$ **+ [stopped{walking}(he)]**
slowly(P1) $_{\textbf{prop}}$ **+ [stopped{walking}(he)] => [slowly([stopped{walking}(he)])]**

In this representation **slowly** modifies the propositional description **[stopped{walking}(he)]** giving a clearly different meaning.

Auxiliary verbs, modal auxiliaries and negatives are all typically predicate modifiers. Consider

He could not have been walking slowly

which can be processed as follows:

he => (he)
could => could{PR1}$_{\textbf{pred}}$
not => not{PR2}$_{\textbf{pred}}$
have => have{PR3} $_{\textbf{pred}}$
been => been{PR4}$_{\textbf{pred}}$
been{PR4}$_{\textbf{pred}}$ **+ walking => been{PR4}**$_{\textbf{pred}}$ **+ walking(O1)** $_{\textbf{prop}}$
slowly => slowly{PR5}$_{\textbf{pred}}$
walking(O1) $_{\textbf{prop}}$ **+ slowly{PR5} => slowly{walking}(O1)** $_{\textbf{prop}}$
been{PR4}$_{\textbf{pred}}$ **+ slowly{walking}(O1)** $_{\textbf{prop}}$ **=> been{slowly{walking}}(O1)** $_{\textbf{prop}}$
have{PR3 $_{\textbf{pred}}$ **+ been{slowly{walking}}(O1)** $_{\textbf{prop}}$ **=>**
have{been{slowly{walking}}}(O1) $_{\textbf{prop}}$
not{PR2}$_{\textbf{pred}}$ **+ have{been{slowly{walking}}}(O1)** $_{\textbf{prop}}$ **=>**
not{have{been{slowly{walking}}}}(O1) $_{\textbf{prop}}$
could{PR1}$_{\textbf{pred}}$ **+ not{have{been{slowly{walking}}}}(O1)** $_{\textbf{prop}}$ **=>**
could{not{have{been{slowly{walking}}}}}(O1) $_{\textbf{prop}}$
(he) + could{not{have{been{slowly{walking}}}}}(O1) $_{\textbf{prop}}$ **=>**

[could{not{have{been{slowly{walking}}}}}(he)]

The need to stack so many predicate modifiers could exceed the capacity of the short-term memory buffers. It may be that there is a mechanism for combining predicate modifiers to avoid this stacking. Assuming such a mechanism (at least for predicate modifiers that occur before the main predicate), processing can proceed as follows:

he => (he)
could => could{PR1}$_{pred}$
not => not{PR2}$_{pred}$
could{PR1}$_{pred}$ + not{PR2}$_{pred}$ => could{not{PR2}}$_{pred}$
have => have{PR3}$_{pred}$
could{not{PR2}}$_{pred}$ + have{PR3}$_{pred}$ => could{not{have{PR3}}}$_{pred}$
been => been{PR4}$_{pred}$
could{not{have{PR3}}}$_{pred}$ + been{PR4}$_{pred}$ =>
could{not{have{been{PR3}}}}$_{pred}$
could{not{have{been{PR3}}}}$_{pred}$ + walking =>
could{not{have{been{PR3}}}}$_{pred}$ + walking(O1)$_{prop}$
slowly => slowly{PR5}$_{pred}$
walking(O1)$_{prop}$ + slowly{PR5} => slowly{walking}(O1)$_{prop}$
could{not{have{been{PR3}}}}$_{pred}$ + slowly{walking}(O1)$_{prop}$ =>
could{not{have{been{slowly{walking}}}}}(O1)$_{prop}$
could{not{have{been{slowly{walking}}}}}(O1)$_{prop}$ + (he) =>
[could{not{have{been{slowly{walking}}}}}(he)]

On my preferred reading of this sentence **slowly** is within the scope of the negative **not**. That is, what is negated is **walking slowly** and not just **walking**. Had the main predicate **walking** been integrated with the negative **not** before being integrated with **slowly**, the result would be a dispreferred reading:

[slowly{could{not{have{been{walking}}}}}(he)]

Since negation is not factored out in PM as it is in the predicate calculus, negation will interact with sentential and predicate modification in interesting ways. Consider

He did not stop walking slowly
Slowly, he did not stop walking.

The latter sentence is somewhat difficult to interpret since it is not clear what it means to not stop walking in a slow manner. However, the first sentence has a clear interpretation (i.e. “it is not the case that he stopped walking slowly”) which can be represented by

[did{not{stop{slowly{walking}}}}(he)]

As a final example of the processing of sentences containing multiple predicate and propositional modifiers, consider

Unfortunately, he did not stop walking slowly.

This sentence contains a sentential modifier **unfortunately** which must finally be integrated with the rest of the sentence. A shortened version of the processing is shown below:

unfortunately => unfortunately(P1) $_{\textbf{prop}}$
he did not stop walking slowly => [did{not{stop{slowly{walking}}}}(he)]
unfortunately(P1) $_{\textbf{prop}}$ **+ [did{not{stop{slowly{walking}}}}(he)] =>**
[unfortunately([did{not{stop{slowly{walking}}}}(he)])]

In Chapter 3, a similar example was discussed in support of the **Main Predicate Proximity Principle**. This principle says that the order of occurrence of predicate and propositional modifiers determines their scope relative to each other and to the main predicate—for predicates occurring on the same side of the main predicate. According to this principle, it is not possible (or is at least highly dispreferred in the unmarked case) for the predicate **not** to take on a wider scope than the predicate **did** or the predicate **unfortunately** in this example. Besides the representational arguments put forward in Chapter 3, the processing mechanism provides additional support for this principle, since the Main Predicate Proximity Principle follows from the assumption that the elements in short-term memory buffers are ordered in terms of the recency of processing. That is, since predicates closer to the main predicate and to its left (i.e. prior to it) will have been processed more recently than predicates that are further from the main predicate and to its left, their arguments will be instantiated first when those arguments become available and predicates closer to the main predicate will have smaller scope as a result. The relative scoping of predicates on differing sides of the main predicate is not determined by this principle, although it appears that predicate adverbs to the right of the main predicate tend to have smaller scope than auxiliaries, modals and negatives to the left, and sentential adverbs tend to have larger scope than these same elements regardless of the side.

We can consider the effect on meaning of the position of the word **slowly**. Consider

Slowly, he stopped walking
He slowly stopped walking
He stopped slowly walking
He stopped walking slowly.

In the first sentence, **slowly** is likely functioning as a propositional modifier since it occurs outside the propositional description **he stopped walking** leading to:

[slowly([stopped{walking}(he)])]

In the second sentence, **slowly** occurs within the subject argument and is likely functioning as a predicate modifier leading to:

[slowly{stopped{walking}}(he)]

In the third sentence, the location of **slowly** suggest two possible structures depending on which verb it modifies:

[slowly{stopped}{walking}(he)] (he stopped slowly…walking)
[stopped{slowly{walking}(he)] (he stopped…slowly walking)

In the fourth sentence, **slowly** prefers to modify **walking** leading to:

[stopped{slowly{walking}}(he)]

However, with emphasis this can be changed to

[slowly([stopped{walking}(he)])] (he stopped walking…slowly)

Pred(Prop$_{head}$,Obj)

The typical member of this category is the preposition when it is used to describe the location or time of events and actions (e.g**. in the park**, **on Tuesday**). These predicates are closely related to sentential adverbs which describe the manner of an event or action (e.g. **quickly**, **peacefully**) or to make a comment on an event or action (e.g. **unfortunately**, **regrettably**). Both of these types of predicates modify propositional descriptions, but prepositions do so by relating them to a location or time. For both types of predicates, there is considerably flexibility in the position of the predicate relative to the propositional description. However, the second argument to a preposition is firmly fixed and occurs after the preposition. This is perhaps part of the reason why prepositional phrases are frequently treated as separate constituents.

The processing of prepositions which modify propostional descriptions is complicated by their alternative use to specify the location of objects in which case they modify object descriptions. Consider

On Tuesday, he saw the man
He saw the man on Tueday
He saw the cowboy on the horse.

The processing of the first sentence proceeds as follows:

on => ??

Tuesday => (Tuesday)
nothing + on + (Tuesday) => on(P1$_{head}$,O1)$_{prop}$
on(P1$_{head}$,O1)$_{prop}$ + (Tuesday) => on(P1$_{head}$,Tuesday)$_{prop}$
he => (he)
saw => saw??
the => the<T1>$_{obj}$
(he) + saw + the<T1>$_{obj}$ => (he) + saw(O2,O3)$_{prop}$ + the<T1>$_{obj}$
(he) + saw(O2,O3)$_{prop}$ => saw(he,O3)
the<T1>$_{obj}$ + man => <man>
the<T1>$_{obj}$ + <man> => (the<man>)
saw(he,O3)$_{prop}$ + (the<man>) => [saw(he,the<man>)]
on(P1$_{head}$,(Tuesday))$_{prop}$ + [saw(he,the<man>)] =>
on([saw(he,the<man>)]$_{head}$,Tuesday)

In the processing of this sentence, the lack of an object description preceding **on** leads to the selection of the **pred(prop,obj]** schema. No propositional description is available at the time of this selection, however, an object description is available to be instantiated as the second argument of **on**. At this point in processing, the predicate **on** only needs a propositional description to be complete, and is has essentially the same relational status as an adverb. Note that this is the first instance where the processing mechanism has instantiated the second argument of a schema before the first argument. This is a consequence of the flexibility in the location of the predicate **on** relative to the propositional description it modifies. During the processing of **saw**, the occurrence of a preceding object description and subsequent object description schema leads to the selection of the transitive use of **saw** (assuming an np-object-bias for the verb **saw**). Once the arguments to **saw** are instantiated, the resulting propositional description can be instantiated as the first argument of **on**.

Since prepositions have a strong preference to be used as propositional modifiers when they occur as the first word in a sentence, the potential multiple uses of the preposition **on** does not complicate processing in this case. The same is not true when the preposition occurs after the main verb and its objects. Since there is a functional use of prepositions in which they take an object description for their first argument, any object description following the main predicate and preceding the preposition creates an ambiguity in the use of the preposition. The second sentence above is structurally ambiguous in this regard—although the use of the prepositional object **Tuesday** creates a strong preference for the propositional modification schema since times (and days) are typically associated with events and actions and not objects. Unfortunately, PM does not yet provide a mechanism for integrating this kind of semantic information into processing. "Finessing" this limitation for the moment, we have

he => (he)
saw => saw??
the => the<T1>$_{obj}$
(he) + saw + the<T1>$_{obj}$ => (he) + saw(O2,O3)$_{prop}$ + the<T1>$_{obj}$
(he) + saw(O2,O3)$_{prop}$ => saw(he,O3)

the<T1>$_{obj}$ + man => <man>
the<T1>$_{obj}$ + <man> => (the<man>)
on => ??
Tuesday => (Tuesday)
saw(he,O3)$_{prop}$ + (the<man>) + on + (Tuesday) =>
saw(he,O3)$_{prop}$ + (the<man>) + on(P1$_{head}$,O1)$_{prop}$ + (Tuesday)
saw(he,O3)$_{prop}$ + (the<man>) => [saw(he,the<man>)]
on(P1$_{head}$,O1)$_{prop}$ + [saw(he,the<man>)] =>
on([saw(he,the<man>)]$_{head}$,O1)$_{prop}$
on([saw(he,the<man>)]$_{head}$,O1)$_{prop}$ + (Tuesday) =>
[on([saw(he,the<man>)]$_{head}$,(Tuesday))]

Given the lack of a strong preference for either the predicative or functional use of the preposition **on** in the second sentence, it is probably not an effective processing strategy to select a schema for **on** before the processing of the argument following the preposition. Once that argument has been processed, the information it provides can be used to help determine the preferred use of **on**.

Finally, consider the processing of the sentence

He saw the cowboy on the horse.

In my preferred reading of this sentence, the **cowboy** is the one who is **on the horse**, although I can at least envision a reading in which **the act of seeing the cowboy** (and by extension the actor **he**) occurred **on the horse**. Once again, non-structural semantic influences are key to determining the appropriate structure for the sentence.

he => (he)
saw => saw??
the => the<T1>$_{obj}$
(he) + saw + the<T1>$_{obj}$ => (he) + saw(O2,O3)$_{prop}$ + the<T1>$_{obj}$
(he) + saw(O2,O3)$_{prop}$ => saw(he,O3)$_{prop}$
the<T1>$_{obj}$ + cowboy => <cowboy>
the<T1>$_{obj}$ + <cowboy> => (the<cowboy>)
on => on??
the => the<T2>$_{obj}$
the<T2>$_{obj}$ + horse => the<T2>$_{obj}$ + <horse>
the<T2>$_{obj}$ + <horse> => (the<horse>)
(the<cowboy>) + on?? + (the<horse>) =>
(the<cowboy>) + on(O1$_{head}$,O2)$_{obj}$ + (the<horse>)
(the<cowboy>) + on(O1$_{head}$,O2)$_{obj}$ => on(the<cowboy>$_{head}$,O2)$_{obj}$
on(the<cowboy>$_{head}$,O2)$_{obj}$ + (the<horse>) =>
(on(the<cowboy>$_{head}$,the<horse>))
saw(he,O3)$_{prop}$ + (on(the<cowboy>$_{head}$,the<horse>)) =>
[saw(he, on(the<cowboy>$_{head}$,the<horse>))]

The ambiguity in the processing of prepositional phrases is a well-known and well researched topic in computational linguistics (e.g., Schubert, 1986, 1984; Wilks, 1972; Wilks, Huang & Fass, 1985) and psycholinguistics (Ford, Bresnan & Kaplan, 1982; Frazier, 1987; Frazier & Folor, 1978; McClelland, 1987; Taraban & McClelland, 1988, 1990). Two basic positions have been put forward: (a) the autonomous syntax position in which the initial attachment of prepositional phrases is made on the basis of purely syntactic considerations, with semantic influence limited to accepting or rejecting the syntactically determined structures, and (b) the interactive position in which both syntactic and semantic factors influence the initial determination of the attachment. PM's basic assumption are consistent with the interactive position and inconsistent with the autonomous position.

A study by Taraban and McClelland (1988) supports the interactive determination of the status of prepositions in sentences like that above. Their study was intended to refute the autonomous syntax processing model of Frazier and Fodor (1978) and Frazier (1987). In the autonomous model, prepositional phrases are always initially attached to verb phrases (i.e. treated as predicates) and only subsequently attached to noun phrases (i.e., treated as functions) after a subsequent semantic analysis leads to the rejection of the initially syntactically based verb phrase attachment. If Frazier and Fodor are correct, then humans should be slower at processing sentences containing prepositional phrases which involve a noun phrase as opposed to a verb phrase attachment. The results of the Taraban and McClelland study show that humans tend not to take longer to process sentences in which a noun phrase attachment is preferred and apparently do not rely on a strategy of always first attempting to attach the prepositional phrase to the verb phrase. Rather, they make immediate use of semantic information in initially attaching the prepositional phrase to the verb phrase or noun phrase and do not rely on the syntactically based strategy of Frazier and Fodor. Taraban and McClelland (1988) were able to refute the results of an earlier experiment by Rayner, Carlson and Frazier (1983) which supported the autonomous position, by showing that Rayner et al. had confounded semantic influence with noun phrase vs. verb phrase attachment in their experiment. That is, semantic factors in the sentences used in the experiment supported the attachment of the prepositional phrase to the verb phrase and not the noun phrase. Rayner et al. predicted the preferred attachment of the prepositional phrase to the verb phrase in accordance with the syntactic principles of **Minimal Attachment** and **Late Closure**, and the results they obtained support these two principles. However, by simply altering the semantic influence to favor the attachment of the prepositional phrase to the preceding noun phrase, Taraban and McClelland were able to reverse the results of Rayner et al. For example, the prior semantic content leading up to the prepositional phrases in the first sentence pair below (used by Rayner et al.) leads subjects to prefer the verb phrase or minimal attachment of the prepositional phrases (despite the semantic content of the prepositional phrases themselves), whereas the prior semantic content leading up to the prepositional phrases in the second sentence pair below (used by Taraban and McClelland) leads subjects to prefer the noun phrase or non-minimal attachment of the prepositional phrase:

The spy saw the cop (with binoculars/with a revolver)

The reporter exposed corruption (in the article/in the government).

Pred(Obj,Prop)

A basic distinction is made between predicates functioning as propositional modifiers (discussed above) and predicates which take a propositional description for an argument, but are not inherently propositional modifiers (i.e. the embedded propositional description is not the head of the resulting construction). This latter category is exemplified by perceptual and cognitive verbs in which there may be an event or action that is perceived or thought about, but the perceptual or cognitive verb is still the head of the construction.

The processing of perceptual and cognitive verbs requires the introduction of additional processing considerations which stem largely from the fact that it is generally possible to perceive or cognize about both events (which are described by propositional descriptions) and objects (which are described by object descriptions). That is, these verbs can take either a propositional description or an object description for their object argument. This dual use of perceptual and cognitive verbs complicates the processing mechanism, since propositional descriptions typically begin with an object description. That is, the first element following a perceptual or cognitive is likely to be an object description whether than object description is functioning as the object argument of the perceptual or cognitive verb or as the subject argument of a subsequent propositional description. Thus, the relational status of object descriptions following perceptual and cognitive verbs will typically be ambiguous at the time it is processed.

Fortunately, English provides the complementizer **that** for use in reducing the relational ambiguity of object descriptions in this context. For example, consider

I saw the man…
I saw that the man…

In the first sentence, the status of the object description **the man** is ambiguous, whereas in the second sentence it is not.

Unfortunately, English does not require use of the complementizer **that** to mark all complements (i.e. propositional descriptions). Sentences containing complements which are not marked by a complementizer are called reduced complement sentences. Since the complementizer **that** is not used reliably to mark complements in English, it cannot, by itself, form the basis for an effective processing strategy. Even when the word **that** does occur after a perceptual or cognitive verb, it may or may not be marking a complement, since the word **that** has several relational uses. Consider

I saw that
I saw that man
I saw that man hit the ball

I saw that the man hit the ball.

In the first sentence **that** is used as an object description (pronoun). In the second and third sentences, it is used as a function (determiner). Only in the last sentence is it used as a complementizer. In PM, complementizers use the following schema:

$$\mathbf{pred}_{\mathbf{comp}}\mathbf{(prop)}_{\mathbf{prop}}$$

The processing of perceptual and cognitive verbs has been studied by numerous researchers (Ferreira & Henderson, 1990; Ford, Bresnan & Kaplan, 1982; Frazier, 1987; Frazier & Rayner, 1982; Holmes, 1987; Holmes, Stowe & Cupples, 1989; McClelland, 1987; Mitchell & Holmes, 1985; Ball, 1991). These researchers have put forward three basic positions with regard to how these verbs are processed: (a) the autonomous syntax position states that the processing mechanism is syntactically driven such that there is no influence on the initial assignment of syntactic structure from either the argument preferences of specific verbs (verb control) or semantic information more generally (Frazier, 1987), (b) the partially interactive position allows the argument preferences of specific verbs to influence the initial determination of structure, but precludes the initial influence of semantic information more generally (Holmes, 1987); and (c) the fully interactive position allows that both argument preferences and semantic information more generally may influence the initial assignment of structure (McClelland, 1987). The basic assumptions of PM are consistent with the fully interactive position, partially consistent with the partially interactive position, and inconsistent with the autonomous position.

Inherent in PM's processing mechanism is the assumption that the argument preferences of specific verbs will have immediate influence on the course of processing. In a study of the object preferences of perceptual and cognitive verbs, Holmes, Stowe and Cupples (1989) identified two groups of such verbs: (a) perceptual and cognitive verbs which strongly prefer to take an object description for the object argument (**NP bias** verbs) and (b) perceptual and cognitive verbs which strongly prefer to take a propositional description for the object argument (**clausal bias** verbs). For example, the verb **saw** prefers to take an object description for its object argument and the verb **said** prefers to take a propositional description for its object argument. Given the strong preferences of these verbs, it may be an effective processing strategy for the processing mechanism to immediately adopt these preferences during processing. Otherwise, the processing mechanism will have to wait until after the processing of the entire object description following the verb (and not just until after the processing of the next lexical item), before the status of the verb can be determined. Assuming that the processing mechanism immediately adopts the preferences of the verbs with a strong preference, the sentence

He said the movie was good

can be processed as follows:

he => (he)

(he) + said => said(O1,P1) $_{prop}$
(he) + said(O1,P1) $_{prop}$ => said(he,P1) $_{prop}$
the => the<T1> $_{obj}$
the<T1> $_{obj}$ + movie => <movie>
was => was{PR1} $_{pred}$
the<T1> $_{obj}$ + <movie> => (the<movie>)
was{PR1} $_{pred}$ + good => was{PR1} $_{pred}$ + good(O2) $_{prop}$
was{PR1} $_{pred}$ + good(O2) $_{prop}$ => was{good}(O2) $_{prop}$
(the<movie>) + was{good}(O2) $_{prop}$ => [was{good}(the<movie>)]
said(he,P1) $_{prop}$ + [was{good}(the<movie>)] =>
[said(he,[was{good}(the<movie>)])]

On the other hand, the sentence

He saw the movie

can be processed as

he => (he)
saw => saw??
the => the<T1> $_{obj}$
(he) + saw + the<T1> $_{obj}$ => (he) + saw(O2,O3) $_{prop}$ + the<T1>$_{obj}$
(he) + saw(O2,O3) $_{prop}$ => saw(he,O3) $_{prop}$
the<T1> $_{obj}$ + movie => <movie>
the<T1> $_{obj}$ + <movie> => (the<movie>)
saw(he,O3) $_{prop}$ + (the<movie>) => [saw(he,the<movie>)]

The processing of both these sentences is straightforward so long as the object arguments fulfill the preferences of the verbs. However, when the object arguments fail to do so, problems result. Consider

He said the pledge

which can be processed as follows:

he => (he)
(he) + said => said(O1,P1) $_{prop}$
(he) + said(O1,P1) $_{prop}$ => said(he,P1) $_{prop}$
the => the<T1> $_{obj}$
the<T1> $_{obj}$ + pledge => <pledge>
the<T1> $_{obj}$ + <pledge> => (the<pledge>)
said(he,P1) $_{prop}$ + (the<pledge>) + end-of-sentence =>
said(he,O2) $_{prop}$ + (the<pledge>) =>
[said(he,the<pledge>)]

At the end of the processing of this sentence, there is no propositional description to be instantiated as the object argument of **said** and the preference of this predicate for a propositional description must be given up in favor of an object description. It may be that the conversion process is not particularly expensive in this case since it does not require deconstruction of the existing representation.

On the other hand when the preferences of a NP bias verb are violated, more processing resources may be required to construct an appropriate representation if the object description is immediately instantiated into the NP bias verb. Consider

He saw the boy was sad.

which can be processed as follows:

he => (he)
saw => saw??
the => the<T1> $_{obj}$
(he) + saw + the<T1> $_{obj}$ **=> (he) + saw(O2,O3)** $_{prop}$ **+ the<T1>** $_{obj}$
(he) + saw(O2,O3) $_{prop}$ **=> saw(he,O3)** $_{prop}$
the<T1> $_{obj}$ **+ boy => <boy>**
the<T1> $_{obj}$ **+ <boy> => (the<boy>)**
saw(he,O3) $_{prop}$ **+ (the<boy>) => [saw(he,the<boy>)]**
was => was{PR1}
was{PR1} $_{pred}$ **+ sad => was{PR1}** $_{pred}$ **+ sad(O4)** $_{prop}$ **=> was{sad}(O4)** $_{prop}$
[saw(he,the<boy>)] + was{sad}(O4) $_{prop}$ **=>**
saw(he,O3) $_{prop}$ **+ (the<boy>) + was{sad}(O4)** $_{prop}$
(the<boy>) + was{sad}(O4) $_{prop}$ **=> [was{sad}(the<boy>)]**
saw(he,O3) $_{prop}$ **+ [was{sad}(the<boy>)] =>**
saw(he,P1) $_{prop}$ **+ [was{sad}(the<boy>)]**
saw(he,P1) $_{prop}$ **+ [was{sad}(the<boy>)] =>**
[saw(he,[was{sad}(the<boy>)])]

Given the amount of reprocessing required to construct the appropriate representation, it may not be an effective processing strategy to immediately instantiate an object description as the object argument of an NP-bias verb, despite the preference of NP-bias verbs for object descriptions. However, the experimental evidence suggests that the instantiation is not delayed. The experiments of Holmes, Stowe and Cupples (1989) and Ball (1991) show that subjects are strongly "**garden pathed**" by such sentences during the processing of the auxiliary verb in the embedded propositional description. It is of interest to note that there is some evidence (Holmes, 1987) which shows that skilled readers are less susceptible to garden pathing in such sentences than are less skilled (but not poor) readers. In general, it may be a characteristic of skilled readers that they know when to delay the creation of structures which may subsequently require deconstruction, whereas, less skilled readers are more likely to be lead up the garden path.

Pred(Prop$_{head}$,Prop$_{head}$) and Pred{Pred$_{head}$,Pred$_{head}$}

The typical example of a predicate of this class is the conjunction. However, conjunctions also have numerous other uses and this collection of different uses complicates their processing considerably. For example, consider the sentence

I hit him and he cried

which can be process as follows:

I => (I)
(I) + hit => hit(O1,O2) $_{prop}$
(I) + hit(O1,O2) $_{prop}$ **=> hit(I,O2)** $_{prop}$
him => (him)
hit(I,O2) $_{prop}$ **+ (him) => [hit(I,him)]**
[hit(I,him)] + and => and(P1,P2) $_{prop}$
[hit(I,him)] + and(P1,P2) $_{prop}$ **=> and([hit(I,him)],P2)** $_{prop}$
he => (he)
(he) + cried => (he) + cried(O3) $_{prop}$
(he) + cried(O3) $_{prop}$ **=> [cried(he)]**
and([hit(I,him)],P2) $_{prop}$ **+ [cried(he)] => [and([hit(I,him)],[cried(he)])]**

The occurrence of a propositional description preceding the conjunction **and** leads to the preference for the **pred(prop,prop)** schema. Of course, if the sentence where

I hit him and his buddy

this schema would not apply and it might be better to delay schema selection until after the occurrence of **he** (in the preceding example) which signals the start of a propositional description given its subjective case marking. As such, it may not be an effective processing strategy to select a particular relational form for a conjunction at the time it is processed. Rather, the selection of a relational form is likely to be conditioned by the subsequent text. Assuming this, the sentence can be processed as follows:

I => (I)
(I) + hit => hit(O1,O2) $_{prop}$
(I) + hit(O1,O2) $_{prop}$ **=> hit(I,O2)** $_{prop}$
him => (him)$_{obj\text{-}case}$
and => and??
he => (he)$_{subj\text{-}case}$
(him) $_{obj\text{-}case}$ **+ and?? + (he)** $_{subj\text{-}case}$ **=> and??**
hit(I,O2) $_{prop}$ **+ (him) => [hit(I,him)]**
[hit(I,him)] + and?? + (he) $_{subj\text{-}case}$ **=> [hit(I,him)] + and(P1,P2) + (he)** $_{subj\text{-}case}$
[hit(I,him)] + and(P1,P2) $_{prop}$ **=> and([hit(I,him)],P2)** $_{prop}$
(he) + cried => (he) + cried(O3) $_{prop}$
(he) + cried(O3) $_{prop}$ **=> [cried(he)]**

and([hit(I,him)],P2) $_{\textbf{prop}}$ **+ [cried(he)] => [and([hit(I,him)],[cried(he)])]**

It is important to note that a fairly subtle syntactic feature (i.e. case marking on pronouns) is used to help determine the appropriate schema for the conjunction in this sentence. Had pronouns not occurred in this sentence, some other mechanism for schema selection would be required. In specific sentences, such subtle syntactic features may be used to help in determining meaning, however, in general they redundantly encode information and need not be considered. On the other hand, semantic influences are likely to be needed to resolve the relational status of conjunctions in the general case.

Just how much context is required to resolve the relational status of conjunctions is highlighted by the following sentences:

I like ice cream and pie
I like ice cream and my brother
I like ice cream and my brother likes pie

In the worst case, the entire sentence may be required. In the first sentence, the semantic similarity of **ice cream** and **pie** suggests the conjunction of these object descriptions. In the second sentence, the semantic distance between **ice cream** and **my brother** should delay their conjunction until the end of the sentence where structural considerations take over and dictate their conjunction. In the third sentence, the correlation between the two propositional descriptions strongly suggests their conjunction, especially when the second instance of **likes** occurs.

As a basic processing strategy, it is assumed that the conjunction typically looks to the preceding input to determine what it is conjoining. It is an open research question under what circumstances the preceding input is chunked together before determining the schema for the conjunction. In the examples above, chunking before schema selection produces a propositional description. If chunking does not occur then an object description precedes the conjunction. Of course other types may precede the conjunction as in

I like the red shoes and socks
I like the red and white shirt

suggesting that chunking may not be the default behavior.

As an example of the use of conjunctions to conjoin two predicates consider

He hit and kicked the wall

which can be processed as follows:

he => (he)
(he) + hit => (he) + hit(O1,O2) $_{\textbf{prop}}$

(he) + hit(O1,O2) $_{\textbf{prop}}$ **=> hit(he,O2)** $_{\textbf{prop}}$
and => and??
hit(he,O2) $_{\textbf{prop}}$ **+ and?? + kicked =>**
hit(he,O2) $_{\textbf{prop}}$ **+ and{PR1,PR2}** $_{\textbf{pred}}$ **+ kicked(O3,O4)** $_{\textbf{prop}}$
hit(he,O2) $_{\textbf{prop}}$ **+ and{PR1,PR2}** $_{\textbf{pred}}$ **+ kicked(O3,O4)** $_{\textbf{prop}}$ **=>**
and{hit,kicked}(he,O4} $_{\textbf{prop}}$
the => the<T1> $_{\textbf{obj}}$
the<T1> $_{\textbf{obj}}$ **+ ball => the<T1>** $_{\textbf{obj}}$ **+ <ball>**
the<T1> $_{\textbf{obj}}$ **+ <ball> => (the<ball>)**
and{hit,kicked}(he,O4} $_{\textbf{prop}}$ **+ (the<ball>) =>**
[and{hit,kicked}(he, the<ball>}]

In order to conjoin the two schemas **hit(he,O2)** $_{\textbf{prop}}$ and **kicked(O3,O4)** $_{\textbf{prop}}$ their arguments must be unified leading to **and{hit,kicked}(he,O4}** $_{\textbf{prop}}$. How does this unification occur when the conjoined predicates have differing argument structures? Consider,

He cried and gave me a hug.

An alternative is to allow the predicates to maintain their individual schemas, using coreference to represent the shared argument. Allowing this, the sentence above is represented by

[and([cried(he $_{i}$**)],[gave(e**$_{i}$**,me,a<hug>)])]**

where $\mathbf{e_i}$ is coreferential with **he** $_{i}$. Of course, in this case the conjunction is conjoining propositional descriptions and not predicates.

The following sentence could also be represented as a conjunction of propositional descriptions where it is the object argument that is shared:

He hit and I kicked the wall
[and([hit(he, e$_{i}$**)],[kicked(I,the<wall>**$_{i}$**]]**

Sentences whose representations include empty elements are essentially elliptical. Such elliptical constructions abound in conjoined contexts since there are two constructions from which the overall pattern can be determined. Consider the sentence

I go where I want.

A suggestion for the processing of this sentence is shown below:

I => (I)
(I) + go => go(O1) $_{\textbf{prop}}$
(I) + go(O1) $_{\textbf{prop}}$ **=> [go(I)]**
where => where??

I => (I)
[go(I)] + where?? + (I) => [go(I)] + where(P1,P2) $_{\textbf{prop}}$ **+ (I)**
[go(I)] + where(P1,P2) $_{\textbf{prop}}$ **=> where([go(I)],P2)** $_{\textbf{prop}}$
where([go(I)],P2) $_{\textbf{prop}}$ **+ (I) + want =>**
where([go(I)],P2) $_{\textbf{prop}}$ **+ (I) + want(O2,P3)** $_{\textbf{prop}}$
where([go(I)],P2) $_{\textbf{prop}}$ **+ (I) + want(O2,P3)** $_{\textbf{prop}}$ **=>**
where([go(I)],P2) $_{\textbf{prop}}$ **+ want(I,P3)** $_{\textbf{prop}}$
where([go(I)],P2) $_{\textbf{prop}}$ **+ want(I,P3)** $_{\textbf{prop}}$ **=>**
where([go(I)$_{\textbf{i}}$**],P2)** $_{\textbf{prop}}$ **+ [want(I,e** $_{\textbf{i}}$**)]**
where([go(I)$_{\textbf{i}}$**],P2)** $_{\textbf{prop}}$ **+ [want(I,e** $_{\textbf{i}}$**)] => [where([go(I)**$_{\textbf{i}}$**], [want(I,e** $_{\textbf{i}}$**)])]**

In this example an entire propositional description **I go** has been elided from the second propositional description **I want**…Further, the form the elided propositional description would take if it had occurred—**to go**—is different from the form in the first propositional description.

The processing of highly elliptical conjoined constructions is likely to involve the use of either specific schemas for dealing with such constructions or special rules which allow for the recovery of elided elements. That processing may also involve a consideration of semantic influence more generally, or may involve the intrusion of higher level cognitive capabilities on what is ordinarily a fairly automatic processing mechanism. For example, consider the sentence

John likes Sue and Joe, Mary.

The processing of this sentence requires identification and recovery of the elided predicate. Since relational elements are the driving force of the processing mechanism, recovery of elided relational elements is likely to require the use of processing resources external to the basic processing mechanism. The processing of this sentence probably requires the recognition of the symmetry between the text to the left and right of the conjunction **and**, and the use of that symmetry to recover the elided predicate. This sentence might be processed as follows:

John => (John)
(John) + likes => (John) + likes(O1,O2) $_{\textbf{prop}}$
(John) + likes(O1,O2) $_{\textbf{prop}}$ **=> likes(John,O2)** $_{\textbf{prop}}$
Sue => (Sue)
likes(John,O2) $_{\textbf{prop}}$ **+ (Sue) => [likes(John,Sue)]**
and => and??
Joe => (Joe)
[likes(John,Sue)] + and?? + (Joe) =>
[likes(John,Sue)] + and(P1,P2) $_{\textbf{prop}}$ **+ (Joe)**
[likes(John,Sue)] + and(P1,P2) => and([likes(John,Sue)],P2) $_{\textbf{prop}}$
Mary => (Mary)
and([likes(John,Sue)],P2) $_{\textbf{prop}}$ **+ (Joe) + (Mary) =>**

and([likes $_i$(John,Sue)],P2) $_{prop}$ + e $_i$ (O3,O4) $_{prop}$ + (Joe) + (Mary)
and([likes $_i$(John,Sue)],P2) $_{prop}$ + e $_i$ (O3,O4) $_{prop}$ + (Joe) + (Mary) =>
and([likes $_i$(John,Sue)],P2) $_{prop}$ + e $_i$ (Joe,O4) $_{prop}$ + (Mary) =>
and([likes $_i$(John,Sue)],P2) $_{prop}$ + [e $_i$(Joe,Mary)]
and([likes $_i$(John,Sue)],P2) $_{prop}$ + [e $_i$(Joe,Mary)] =>
[and([likes $_i$(John,Sue)], [e $_i$(Joe,Mary)])]

It is less than clear just what additional processing resources are needed in the construction of the final representation for this sentence.

An equally difficult example of ellipsis is the sentence

He likes candy better than you do

which might be processed as follows:

he => (he)
(he) + likes => (he) + likes(O1,O2) $_{prop}$
(he) + likes(O1,O2) $_{prop}$ => likes(he,O2) $_{prop}$
candy => <candy>
likes(he,O2) $_{prop}$ + <candy> => likes(he,O2) $_{prop}$ + (candy)
likes(he,O2) $_{prop}$ + (candy) => [likes(he,candy)]
better => better??
better + than => better_than??
[likes(he,candy)] + better_than?? =>
[likes(he,candy)] + better_than(P1,P2) $_{prop}$
[likes(he,candy)] + better_than(P1,P2) $_{prop}$ =>
better_than([likes(he,candy)],P2) $_{prop}$
you => (you)
do => do{PR1}
better_than([likes(he,candy)],P2) $_{prop}$ + (you) + do{PR1} =>
better_than([likes$_i$(he,candy)],P2) $_{prop}$ + (you) +do{e$_i$}(O3,O4) $_{prop}$
better_than([likes$_i$(he,candy)],P2) $_{prop}$ + (you) +do{e$_i$}(O3,O4) $_{prop}$ =>
better_than([likes$_i$(he,candy)],P2) $_{prop}$ + do{e$_i$}(you,O4) $_{prop}$
better_than([likes$_i$(he,candy)],P2) $_{prop}$ +do{e$_i$}(you,O4) $_{prop}$ =>
better_than([likes$_i$(he,candy$_k$)],P2) $_{prop}$ + [do{e$_i$}(you,e$_k$)]
better_than([likes$_i$(he,candy$_k$)],P2) $_{prop}$ + [do{e$_i$}(you,e$_k$)] =>
[better_than([likes$_i$(he,candy$_k$)],[do{e$_i$}(you,e$_k$)])]

The processing of this sentence is complicated by the fact that in the second propositional description both the predicate and the object argument are elided. In place of the elided predicate the pro-verb **do** occurs. The processing of such elliptically conjoined propositional descriptions is the most difficult to be considered in this chapter.

Pred(Obj,Obj,Prop)

The typical members of this category are verbs which may be used to describe the transfer of information about an event, action or state from one person to another. For example, the sentence

He told me he likes you

contains the verb **told** which is used to convey the propositional description **he likes you** to the person referred to by the pronoun **me**. This sentence can be processed as follows:

he => (he)
(he) + told => told(O1,O2,P1) $_{\textbf{prop}}$
(he) + told(O1,O2,P1) $_{\textbf{prop}}$ **=> told(he,O2,P1)** $_{\textbf{prop}}$
me => (me)
told(he,O2,P1) $_{\textbf{prop}}$ **+ (me) => told(he,me,P1)** $_{\textbf{prop}}$
he => (he)
(he) + likes => (he) + likes(O3,O4) $_{\textbf{prop}}$
(he) + likes(O3,O4) $_{\textbf{prop}}$ **=> likes(he,O4)** $_{\textbf{prop}}$
you => (you)
likes(he,O4) $_{\textbf{prop}}$ **+ (you) => [likes(he,you)]**
told(he,me,P1) $_{\textbf{prop}}$ **+ [likes(he,you)] => [told(he,me,[likes(he,you)])]**

The processing of this sentence is straightforward on the assumption that the verb **told** prefers the **pred(obj,obj,prop)** schema. However, such verbs can also be used to convey information about objects rather than propositions. In this use, they employ the **pred(obj,obj,obj)** schema. Consider

He told her the story

Assuming a preference for a propositional description as the third argument, this sentence can be processed as follows:

he => (he)
(he) + told => told(O1,O2,P1) $_{\textbf{prop}}$
(he) + told(O1,O2,P1) $_{\textbf{prop}}$ **=> told(he,O2,P1)** $_{\textbf{prop}}$
her => (her)
told(he,O2,P1) $_{\textbf{prop}}$ **+ (her) => told(he,her,P1)** $_{\textbf{prop}}$
the => the<T1>
the<T1> + story => the<T1> + <story>
the<T1> + <story> => (the<story>)
told(he,her,P1) $_{\textbf{prop}}$ **+ (the<story>) + end-of-sentence =>**
told(he,her,O3) $_{\textbf{prop}}$ **+ (the<story>) =>**
[told(he,her,the<story>)]

In the processing of this sentence, when the end of the sentence is reached there is no propositional description available for instantiation as the third argument. The processing mechanism must convert the preference for a propositional description into an object description. As was suggested in the section dealing with the processing of reduced complement sentences, this conversion process is assumed to be relatively inexpensive, since it does not require deconstruction of an existing representation.

By way of contrast, if **told** preferred the **told(O1,O2,O3)** schema, then the processing mechanism could run into problems in the processing of sentences which failed to conform to the preference. For example, assuming the preference for a third object description, the sentence

He told me the story was sad

could be processed as follows:

he => (he)
(he) + told => told(O1,O2,P1) $_{\textbf{prop}}$
(he) + told(O1,O2,O3) $_{\textbf{prop}}$ **=> told(he,O2,O3)** $_{\textbf{prop}}$
me => (me)
told(he,O2,O3) $_{\textbf{prop}}$ **+ (me) => told(he,me,O3)** $_{\textbf{prop}}$
the => the<T1>
the<T1> + story => the<T1> + <story>
the<T1> + <story> => (the<story>)
told(he,me,O3) $_{\textbf{prop}}$ **+ (the<story>) =>**
[told(he,me,the<story>)]
was => was{PR1} $_{\textbf{pred}}$
was{PR1} $_{\textbf{pred}}$ **+ sad => was{PR1}** $_{\textbf{pred}}$ **+ sad(O4)** $_{\textbf{prop}}$
was{PR1} $_{\textbf{pred}}$ **+ sad(O4)** $_{\textbf{prop}}$ **=> was{sad}(O4)** $_{\textbf{prop}}$
[told(he,me,the<story>)] + was{sad}(O4) $_{\textbf{prop}}$ **=>**
told(he,me,P1) $_{\textbf{prop}}$ **+ (the<story>) + was{sad}(O4)** $_{\textbf{prop}}$ **=>**
told(he,me,P1) $_{\textbf{prop}}$ **+ [was{sad}(the<story>)] =>**
[told(he,me, [was{sad}(the<story>)])]

At the processing of the adjective **sad**, there is no object description to be instantiated as its argument. In order to make an object description available, the propositional description preceding **sad** must be deconstructed. As a result of this deconstruction, the mistaken instantiation of the object description **the<story>** into the predicate **told(he,me,O3)** is assumed to be computationally expensive. This is another example of what have been described as "garden path" sentences. The experimental evidence suggests that disruption of processing occurs at the auxiliary verb **was** rather than the adjective **sad**. Since **was** is a predicate modifier, it is unclear in relational terms why disruption should occur at this point.

In this particular example, it is the highly schematic pattern of "someone telling someone a story" that leads to the preference for the **pred(obj,obj,obj)** schema. Given this, it may still be that the preferred schema was **pred(obj,obj,prop)** until the occurrence of the highly schematic object description **the story**:

told(he,me,P1) $_{\textbf{prop}}$ **+ (the<story>) => told(he,me,O3)** $_{\textbf{prop}}$ **+ (the<story>)**
told(he,me,O3) $_{\textbf{prop}}$ **+ (the<story>) => [told(he,me,the<story>)]**

Perhaps the occurrence of the auxiliary verb **was** which cannot take a propositional description for an argument is enough to disrupt the processing mechanism at this point.

In general, for predicates which can take either a propositional description or an object description for an argument, the preference for a propositional description leads to less additional computation when an object description occurs than does the reverse.

Not all sentences containing predicates of this type contain complete propositional descriptions. The subject argument of the embedded propositional description is typically elided when it is co-referential with the object argument of the main predicate. For example, in the sentence

I told him to go

The subject of the propositional description **to go** is elided since it is co-referential with the object argument **him**. This sentence can be processed as follows:

I => (I)
(I) + told => told(O1,O2,P1) $_{\textbf{prop}}$
(I) + told(O1,O2,P1) $_{\textbf{prop}}$ **=> told(I,O2,P1)** $_{\textbf{prop}}$
him => (him)
told(I,O2,P1) $_{\textbf{prop}}$ **+ (him) => told(I,him,P1)** $_{\textbf{prop}}$
to => to??
to?? + go => to{PR1} $_{\textbf{pred}}$ **+ go(O3)** $_{\textbf{prop}}$
to{PR1} $_{\textbf{pred}}$ **+ go(O3)** $_{\textbf{prop}}$ **=> to{go}(O3)** $_{\textbf{prop}}$
told(I,him,P1) $_{\textbf{prop}}$ **+ to{go}(O3)** $_{\textbf{prop}}$ **=> told(I,him**$_{\textbf{i}}$**,P1)** $_{\textbf{prop}}$ **+ [to{go}(e**$_{\textbf{i}}$**)]**
told(I,him$_{\textbf{i}}$**,P1)** $_{\textbf{prop}}$ **+ [to{go}(e**$_{\textbf{i}}$**)] => [told(I,him**$_{\textbf{i}}$**, [to{go}(e**$_{\textbf{i}}$**)])]**

In the processing of this sentence, the determination of the status of the highly ambiguous word **to** is delayed until after the next lexical item is processed. Once the predicate **go** is processed, **to** is determined to be an infinitive marker that combines with **go** to form a complex predicate. Next, the argument to **to{go}(O3)** is determined to be co-referential with the object argument of the predicate **told(I,him,P1)**. Finally, the propositional description **[to{go}(e**$_{\textbf{i}}$**)]** is instantiated as the third argument of **told**.

Chapter 7: Summary

PM is a computational psycholinguistic model of written language (English) comprehension. It consists of a propositional system of representation and a processing mechanism for constructing propositional descriptions directly from input text. There is no separate process for the construction of syntactic representations, and no distinctly syntactic representations exist. In PM there is no distinction between syntactic and semantic processing, or between syntactic and semantic representations. Nor is there a clear distinction between grammar and lexicon.

Propositional descriptions are linguistic representations. They contain no nonlinguistic entities. Propositional descriptions are associated with nonlinguistic representations which are constructed in parallel with propositional descriptions during processing. Nonlinguistic representations are perceptually based abstractions of nonlinguistic input and they represent nonlinguistic aspects of structure and meaning. Propositional descriptions are perceptually based abstractions of linguistic input and they represent linguistic aspects of structure and meaning. We may (loosely) say that nonlinguistic representations function as the referents of associated propositional descriptions. But it is understood that nonlinguistic representations are mental representations, and reference to a nonlinguistic representation is not reference to the real world.

Humans have a very general ability to recognize the similarities and to abstract away from the differences between particular experiences. Humans make use of this ability in the creation of mental representations corresponding to their experience. Based on this ability and experience of language, humans construct representations which capture knowledge of language. Such representations vary in their level of abstraction, some capturing very general knowledge of language, and other capturing knowledge of specific linguistic constructions. Once constructed, these mental representations or schemas are available for use in subsequent language processing, with more specific and concrete schemas providing more predictive power than less specific and more abstract schemas. The nine basic propositional and four basic predicate modification forms introduced in Chapter 3 correspond to fairly abstract schemas which capture information about the basic predicate/argument structure of English.

PM's processing mechanism operates on the input text from left to right, activating learned schemas which correspond to individual lexical items or larger chunks of text, as it goes along. These schemas in turn establish expectations which both determine the possible structures and drive the processing mechanism. In PM there is effectively no overall grammar and no top down control mechanism—just the local preferences of individual lexical items and larger linguistic units which must be integrated together in the construction of a coherent representation for a piece of text.

The Theoretical and Historical Basis of PM

From a linguistic perspective, PM's representational and processing commitments are most closely allied with the following linguistic approaches:

- Cognitive Linguistics (Fillmore & Kay, 1987; Johnson, 1987; Lakoff, 1988, 1987; Langacker, 1987, 1986), especially Langacker (1987)
- Case Grammar (Fillmore, 1977a, 1977b, 1971, 1968; Nilsen, 1973; Somers, 1987)
- Valency Grammar (Heringer, 1985; Somers, 1987)
- Functional Grammar (Dik, 1987b; Givon, 1989, 1984; Halliday, 1984)
- Traditional Grammar (Jackson, 1990; Jespersen, 1984, 1965; Quirk, Greenbaum, Leech & Svartvik, 1985, 1982).

Within the framework of Transformational Grammar (Chomsky, 1965, 1957; Radford, 1981), Jackendoff (1983, 1978) has been influential, although in general the basic assumptions of PM are not compatible with those of Transformational Grammar. The basic assumptions of PM are more compatible with those of Government and Binding Theory (Chomsky, 1995, 1988, 1982a, 1982b, 1981; Sells, 1985) than Transformational Grammar, and the advent of Government and Binding Theory is seen as an improvement over its predecessor. Government and Binding Theory is also in some ways more compatible with PM than are Lexical Functional Grammar (Bresnan, 1982, 1978; Sells, 1985) and Generalized Phrase Structure Grammar (Gazdar, Klein, Pullum & Sag, 1985; Sells, 1985). Lexical Functional Grammar and Generalized Phrase Structure Grammar retain some of the features of Transformational Grammar (e.g., phrase structure rules) that have been eliminated in Government and Binding Theory.

From a psychological perspective, PM is most compatible with psychological approaches which focus on propositional systems of representation and process and which espouse unified theories of cognition:

- ACT-R (Anderson & LeBiere, 1998; Anderson, 1993, 1983, 1976)
- Construction-Integration Model (Kintsch, 1998, 1988, 1977, 1974; Kintsch & van Dijk, 1978)
- Miller, 1978; Miller & Johnson-Laird, 1976
- Mental Models (Johnson-Laird, 1983)
- Clark & Clark 1977 ; Clark & Haviland, 1977 ; Haviland & Clark, 1974
- CAPS (Just & Carpenter, 1987)

The research of Miller and Johnson-Laird (1976) and Miller (1978) has been especially influential on the development of PM's system of representation. The discourse processing models put forward by Kintsch and van Dijk (1978) and Clark and Haviland (1977) have influenced the development of PM's processing mechanism. The psychologically based models of Anderson (1983, 1976; Anderson & LeBiere 1998), Just and Carpenter (1987), and Kintsch (1998, 1988, 1977, 1974; Kintsch & van Dijk 1978) are the most comprehension treatments of both representation and process available. The

most glaring omission in the research of Kintsch is the lack of a processing mechanism for constructing propositional representations from input texts. PM provides just such a mechanism.

From the perspective of Artificial Intelligence, PM is most indebted to the following:

- Preference Semantics (Wilks 1979, 1975a, 1975b, 1973, 1972)
- Conceptual Dependency Theory (Lytinen, 1986; Schank, 1975, 1972; Schank & Abelson, 1977; Wilensky, 1986)
- Conceptual Structures (Sowa, 1984).
- Winograd 1983, 1972.

Wilks' Preference Semantics set the stage for the development of PM. Schank's Conceptual Dependency theory has provided numerous useful insights, although, the exclusive use of extremely abstract schemas that it espouses is not considered a reasonable model of language comprehension. Winograd's thesis and program (1972) is an impressive achievement and his shift towards a more cognitive orientation (1983) precipitated a similar shift in the development of PM.

The Soap Box

PM is a model of language processing with incorporates and extends current understanding about language processing from three separate disciplines: linguistics, psychology, Artificial Intelligence. In doing so, it takes seriously the following comment by Winograd (1977, pp. 85-6):

> Current research tends to lie in clusters along…separate lines. There is little work which combines the linguist's sophistication in recognizing the complexity of the data with the computer system builder's concern with the properties of the system as a whole, and the psychologist's demand that the resulting analysis be verifiable through experiments. If we are ever to really understand natural discourse, we have to develop methodologies which span these approaches, providing both scope and rigor in their theories.

At the same time, I have adopted psycholinguistics as the central subdiscipline for this work. Psycholinguistics is frequently referred to as the subdiscipline in which language processing (in humans) is studied (e.g., Carroll, 1986; Tanenhaus, 1988). It is also often distinguished from linguistics proper as concerned with performance, whereas linguistics is concerned with competence. However, many linguists study performance as well as competence, and the reality is that the distinction is more methodological than theoretical. Psycholinguists tend to make extensive use of the experimental method to study language behavior, and discount linguistic models and theories which are not supported by empirical evidence. Linguists tend to discount the ecological validity of controlled experimentation and rely instead on introspection and observation of language behavior

in situ. Psycholinguists have also been somewhat more willing to adopt (adapt) the models, theories and techniques of Artificial Intelligence, whereas linguists have tended to make use of more formal theories of computation.

It might be argued that PM is an extremely mushy and unscientific model or theory. PM makes no strong commitment to the existence of specific levels of representation, nor to the specific form such representations must take. PM allows for the existence of alternative representations and processing mechanisms which are not mutually exclusive, introducing considerable redundancy into the model. PM has problems of falsifiability, is not particularly parsimonious, may not be efficient, and might not be considered elegant. PM is not especially concerned with the philosophical foundations of language nor with issues of computational power. The discussion of many important philosophical and computational issues has intentionally been avoided. PM is essentially an attempt to describe a system of representation and a processing mechanism which can model a reasonable range of observable phenomena regarding written language (English) comprehension in humans, providing enough detail to make computer implementation of part of that model feasible and making certain testable predictions. However, it is not true that PM has been developed in (total) ignorance of philosophical and computational issues. Rather, such issues, while important, are not considered part of the model. Elegant theoretical arguments, logically presented and (perhaps even) consistent, but based on incorrect or faulty axioms provide an aura of truth they do not deserve. We need to spend more time trying to get the axioms right. This can only be accomplished by actually modeling data and building working systems. The skeptic's position is theoretically unassailable. He just happens to be wrong. In sum, abiding by principles of parsimony, simplicity, efficiency, computability, falsifiability and the like may make for good science or good philosophy, but it need not make for good models.

Likewise, the elevation of basic computational techniques to the level of theory occurs far too often. For example, unification is an interesting computational technique, but it hardly deserves the theoretical status it has been accorded in many computational linguistic models of language processing (witness the name Functional Unification Grammar). At the 28th Annual Meeting of the Association for Computational Linguistics, as many as half of the presented papers involved some discussion of the theoretical and computational implications of unification. While an earlier implementation of PM relied on the Prolog programming language and unification, programming languages and computational techniques are viewed as implementation tools (Ball, 1985b), not theoretical constructs. I believe the intensive research on the use of efficient parsing algorithms to parse natural language is similarly misguided in that its primary motivation is technical (e.g. Tomita, 1985). Further, the attempt to force natural language into the mold of the predicate calculus (frequently justified on the basis that the predicate calculus is the best representational system we have available) is lacking in empirical justification (Johnson-Laird, 1983; Allwood, Anderson, & Dahl, 1977). And the taking of the computer metaphor of the mind too seriously happens far too regularly (Pylyshyn, 1984). In my own research, I have not been immune to the temptation to let current techniques drive that research (Ball, 1985c). Indeed, the development of new computational techniques is an interesting area of research in its own right. However,

computational techniques and computer programs are not theories (Simon, 1990) in any strong sense. Basing models and theories on current computational techniques gives them an ephemeral existence. Such models and theories become irrelevant when the specific computational technique falls out of favor. The short half-life and rapid turnover of computationally and technically fashionable models and theories leads to a degree of cynicism with regard to the basic validity of such models and theories. On the other hand, computational techniques can provide some insight into an understanding of what a realistic model of language processing would need to be like. Further, the attempt to program up a model or theory of language processing is a highly sobering experience, revealing inconsistency and confusion in the model and forcing the explicit consideration of details not normally incorporated into such models and theories. Indeed, the dividing line between theory and implementation is not nearly as clear-cut as the preceding discussion suggests (witness the dispute over whether or not connectionist models are primarily concerned with implementation details), and the criticism vented above should perhaps be tempered by this realization.

PM attempts to chart a middle ground between theoretically driven research based on unsupported axioms, technically driven research based on the latest and greatest technical innovation, and empirical research which has limited theoretical basis. It is concerned with the development of a model of language processing which is theoretically motivated, without being overly tied to highly theoretical notions and issues, technically informed, without being unduly driven by prevailing techniques, and empirically based, without being atheoretical and merely redescribing the data.

The Representation of Propositional and Object Descriptions

From a relational perspective, it is argued that the clause structure of written English has two basic elements:

- Propositional Descriptions
- Object Descriptions

Propositional descriptions represent the predicate-argument structure of clauses. They consist of a predicate, the head of the propositional description, and zero (in reduced argument constructions) to three arguments. The predicate consists of a main predicate which is typically a verb, adjective or preposition, associated predicate modifiers and perhaps a distinguished predicate specifier (i.e. the first element of the predicate). The arguments to a predicate are of two types: object descriptions and embedded propositional descriptions. Embedded propositional descriptions give propositional descriptions a recursive potential.

Object descriptions represent the function-term structure of noun phrases. They consist of a term which is the head of the object description, optional functional modifiers and an optional functional specifier. This term is typically a noun, although lexical items which are typically other parts of speech (e.g. adjective, present participle) may also be used as

terms. This term may be modified by one or more functions which correspond to presupposed relations that are associated with the term. Functions may themselves be modified by function modifiers (e.g. adverbs). Finally, an optional function specifier which explicitly establishes the referential nature of the object description may occur.

Nine basic propositional forms and four basic predicate modification forms have been put forward and discussed in this manuscript. These basic forms constitute a set of schemas for establishing the basic relational structure of propositional descriptions without consideration of low level grammatical details. It is claimed that these form are generally adequate for the representation of propositional structure in written English.

A collection of functional forms for establishing the structure of object descriptions has also been presented. It is claimed that the collection of forms is generally adequate for the representation of the relational structure of object descriptions. The propositional forms and functional forms are parallel in several respects. They both contain relational elements that determine overall structure, however, the main predicate in a propositional form is the head of the form, whereas functions in object forms are always modifiers of the head term.

Despite the fact that PM's propositional and object representations are described in relational terms, PM representations are actually very consistent with the more detailed grammatical and functional treatments of Jespersen (1984, 1965) and Quirk, Greenbaum, Leech and Svartvik (1985, 1972). This consistency makes it possible to extend PM to handle grammatical details which are not currently modeled. For example, the more detailed representational system developed in Jespersen (1984) can be added to PM with only minor reworking. Further, the mapping from parts of speech and grammatical categories to PM's propositional categories is straightforward enough to consider the use of on-line dictionaries to bootstrap the development of functional language processing systems.

The Processing of Propositional and Object Descriptions

The processing mechanism operates on an input text from left to right, identifying relational and non-relational elements and using the relational elements as a basis for determining how to integrate the lexical items into a coherent relational structure. The processing mechanism is heavily dependent on the occurrence of relational elements that set up expectations for the prior or subsequent occurrence of the arguments to the relational elements. These expectations drive the processing mechanism and determine the possible structures. Thus, the processing mechanism is driven by the relational expectations of relational lexical items and is in this sense very much a bottom-up processing mechanism. In PM, function words (e.g. determiners) and prepositions are treated as relational lexical items and they are important to the processing mechanism. For example, the occurrence of a determiner establishes the context of an object description, whereas the occurrence of an auxiliary verb establishes the context of a propositional description. Likewise, the occurrence of a preposition marks the end of the

previous propositional or object description and sets up an expectation for the occurrence of a subsequent object description. Thus, these often ignored sentence constituents are important markers for the processing mechanism. That they are short words in English is a reflection of the efficient encoding of these often occurring constituents, and not an indication of their minor importance for understanding. Their omission in contexts like newspaper headlines, often leads to difficulty in determining the meaning of those headlines.

The processing mechanism make use of effective strategies during the processing of input texts. For lexical items which evoke strong preferences to be used in specific ways, those preferences can be immediately realized based solely on the prior context. For lexical items which evince multiple different uses, subsequent context may also be necessary to determine which use is relevant in the given context. The processing mechanism does not make extensive use of backtracking, but to the extent that it does, that backtracking essentially involves jumping back to the beginning of some chunk of text and is not like the formalized backtracking of a computational system like Prolog.

Semantic information that is not currently modeled in PM is assumed to play an important role in resolving certain types of ambiguities (e.g. prepositional phrase attachment, resolution of verb object argument preferences). This is an open area of research, but Latent Semantic Analysis (LSA) techniques (Landauer & Dumais, 1997; Kintsch, 1998) offer prospects for providing the kind of low level associations between lexical items needed to resolve such amibiguities. On the other hand, adequate mechanisms for the processing of corresponding nonlinguistic representations are not yet available and this remains a gap in PM. Nonetheless, it is assumed that a reasonable level of performance in language understanding can be achieved with available techniques.

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