Chapter 15
The Role of Lexical Representations in Language Comprehension

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It is clear from recent work in linguistics, psycholinguistics, and computational linguistics that lexical representations play a central role in the process of integrating different types of linguistic and nonlinguistic knowledge. Not only do lexical representations provide the basic bridge between sound and meaning, linking the phonological properties of word forms with clusters of syntactic and semantic attributes; they also provide the basic structural framework in terms of which an utterance can be interpreted.

The syntactic and semantic properties of words become available once the sensory input has been mapped onto representations of lexical form. Other chapters in this volume discuss the nature of form-based representations and the processes involved in making contact with them. In this chapter, I will focus on representations of semantic and syntactic content. I will begin by summarizing the process by which the content of lexical representations becomes available for the construction of higher-level representations, arguing for the parallel activation of syntactic and semantic codes, with the early selection of the contextually relevant word sense and syntactic information (Marslen-Wilson 1987; Marslen-Wilson, this volume). In the main body of the chapter I will discuss how lexical representations are used in the interpretation of an utterance, and the implications this has for the structure of the language-comprehension system.

1 The Nature of the Activation Process

An important feature of the comprehension of spoken language is that words are recognized in utterance contexts before enough of the word has been heard to ensure correct identification on the basis of the sensory input alone (Marslen-Wilson and Tyler 1980a; Tyler and Wessels 1983). To account for this finding, it has been proposed that some initial portion of the sensory input is mapped onto all those representations of lexical form
with which it is compatible. This makes available the syntactic and semantic properties of words, which can then immediately be evaluated, in parallel, against the specifications of the context (Marslen-Wilson and Welsh 1978; Marslen-Wilson 1984, 1987). This parallel evaluation process continues until a single lexical entry is selected which best matches both the context and the sensory input. The emphasis on parallelism in the lexicon is a crucial aspect of the model, since the early recognition of words in context cannot be explained without it (Marslen-Wilson 1987).

What is the evidence for this parallel activation of multiple codes and for the early selection of the contextually relevant codes? There are three types of evidence. The first is the evidence, mentioned above, that words are recognized earlier in context than they are when they appear in isolation. This robust finding is obtained by means of a variety of experimental techniques (Grosjean 1980; Marslen-Wilson and Tyler 1980a; Tyler and Wessels 1983, 1985). If words in isolation are identified at the earliest point at which there is sufficient sensory input to uniquely identify the word, then words in context must be being identified when the sensory input is still ambiguous as to the correct identity of the word. This means that the prior context in which the word is heard provides the necessary information to compensate for the ambiguous signal. This, in turn, means that information about the syntactic and semantic properties of words must become available very early in the word-recognition process; otherwise there would be no informational base upon which context could discriminate among different candidates.

The second type of evidence comes from lexical-ambiguity and gating studies. The ambiguity studies, typically using the cross-modal lexical-decision task (Swinney 1979; Onifer and Swinney 1981; Seidenberg, Tanenhaus, Leiman, and Bienkowski 1982), find that the syntactic (Seidenberg et al.) and semantic (Swinney) properties of words become available early in the processing of a word. These studies also show that context does not influence the early activation of this type of lexical information. Even when the meaning of a word or its syntactic form class is highly constrained by the context, all syntactic and semantic information is momentarily activated—even if it is contextually inappropriate.

In a different type of study—using the gating task, where subjects hear successively larger fragments of a word and are asked to say what word they think they are hearing—I also found evidence of the momentary activation of multiple lexical codes. Subjects frequently produced syntactically and semantically inappropriate words in response to the first few
fragments—corresponding to the first 50–200 msec—of a word (Tyler 1984).

These types of studies also show that context does eventually function to assist in the selection of a unique candidate. In the ambiguity studies, for example, shortly after a word has been identified, only its contextually appropriate syntactic and semantic properties are available (Seidenberg, Tanenhaus, Leiman, and Bienkowski 1982). And in gating studies (Tyler 1985), semantically and/or syntactically inappropriate words are not produced by subjects after they have heard an average of 250 msec of a word.

The third type of evidence for the parallel activation of multiple lexical codes is perhaps the most direct and compelling. This is a study in which subjects heard spoken words and made lexical decisions to visual probes presented concurrently with these words (Marslen-Wilson 1987). Earlier research by Swinney (1979) has shown that lexical decisions to visual probes are facilitated when they are semantically related to concurrently presented spoken words. Marslen-Wilson’s spoken stimuli consisted of words, such as captain and captive, that share the same initial sequence but diverge from each other at the onset of the vowel following the /t/ burst. The visual probes were semantically related to one or the other of the words. For example, ship is a semantic associate of captain and guard is an associate of captive. These visual probes were presented at two positions relative to the spoken word. The first position occurred just before the two words (captain and captive) diverged from each other. The second probe position occurred well after the point at which they diverged, toward the end of the word. Marslen-Wilson found that at the early probe position lexical decisions to both visual probes were facilitated, which suggests that the meanings of both spoken words (captain and captive) were activated. However, at the late probe position only the visual probe related to the actual word was facilitated, suggesting that by this point a single word had been selected.

This study was extended by Zwitserlood (1987) in order to examine the role of context in the activation process. The test items (captain/captive pairs) were similar to those used in the Marslen-Wilson study, but Zwitserlood presented them either in semantically biasing or neutral contexts. She found that context had no effect on the initial activation process. The meaning of both captain and captive were facilitated at the early probe positions (about 200 msec into the word), even when only one of them was contextually appropriate. At later probe positions, only the contextually relevant word was facilitated.
The weight of the experimental evidence, then, supports the claim that early in the processing of a word there is multiple activation of semantic and syntactic codes, which are evaluated in parallel against the representation of the prior context. The intersection of the accumulating sensory input and the context results in the eventual selection of the contextually appropriate lexical content. What are the implications of this early activation of lexical codes for the development of higher-level representations of an utterance?

2 How Do Lexical Representations Function in Language Processing?

If, as I have argued, the lexical processing system is structured so as to make available representations of lexical content early in the process of recognizing a word, then how and when is this information used in the development of higher-level representations?

A reasonable hypothesis to pursue is that early activation results in early use of the information that is activated. This is undoubtedly the case for form-based information. The phonological and orthographic properties of a word are used immediately to constrain the identity of the word in question (Warren and Marslen-Wilson 1986, 1987; Marslen-Wilson 1987). Is this also the case for representations of lexical content—for the syntactic and semantic attributes of words that have consequences for the construction of higher-level representations? The research that William Marslen-Wilson and I have carried out over the past 15 years suggests that it is. Much of this research has focused on the processing of verbs, although the claims we make about the function of lexical representations are not restricted to verbs. We have focused on verbs because of the important role they have in language comprehension and in current psychological and linguistic theorizing.

In linguistics, a number of theories (Gazdar 1982; Bresnan 1982; Chomsky 1965) have focused on the representation of verbs and on the structural implications of those representations for the interpretation of an utterance. These theories have moved lexical representations into a central position in determining the syntactic and semantic properties of an utterance. They closely link the subcategorization properties of a verb with its argument structure in a semantic interpretation. The argument frames associated with lexical items specify not only how these arguments might function in a purely syntactic representation of an utterance, but also how they might function in its semantic interpretation. This semantic interpretation determines how the utterance is projected onto a discourse model. The
argument frames associated with verbs have consequences for linguistic analysis and for the construction of an interpretation in the nonlinguistic, conceptual domain (Tanenhaus and Carlson, this volume).

It is thus widely accepted that the representation of each verb includes a specification of its semantic and syntactic properties, although the exact definition of these properties differs. From a psychological perspective, we want to know how these lexical representations function in on-line processing. How are they used in the process of constructing a representation of an utterance?

Research on this issue falls into two broad camps. One body of work—primarily identified with the "Amherst group" (see e.g. Clifton, Frazier, and Connine 1984; Frazier 1987; Ferreira and Clifton 1986; Rayner and Frazier 1987)—claims that, although different types of lexical information might become immediately available to the perceiver (in their case, the reader), the parser makes use of only those that are relevant to the initial syntactic representation that it builds (i.e., major category and phrasal information). Since this initial syntactic parse is computed "blind" of either the meaning of the utterance or the semantics of the word being processed, the semantic specifications of a word have consequences for syntactic processing only after its syntactic properties have been exploited.

This model makes a number of very strong predictions about the time course with which different aspects of lexical information can be projected onto higher-level representations. The one that is of most concern to us here is the prediction that the processing system will generate syntactic structures that will be incompatible with the meaning of the utterance. Almost all the evidence suggesting that the processing system makes this type of error comes from the Amherst group.

If, in contrast, the processing system is able to make use of all types of lexical information in constructing higher-level representations, then such misparses will hardly ever occur. I would argue that the entire lexical specification of a word is momentarily activated and used when the word is recognized. This information is then assessed against the demands of the utterance-and-discourse context in which the word occurs. The contextually appropriate aspects of the word's representation then function to constrain the interpretation of subsequent words. Context does not operate in a top-down fashion to determine which aspects of lexical representations should be considered; rather, it selects the contextually appropriate reading of a word after its entire lexical specification has been assessed.

Take, for example the verb claim, which has as part of its syntactic specification the fact that it can take both a sentential complement and a
noun-phrase complement. When claim is identified, this sentential complement and this NP complement (and all other lexically specified information) are activated and assessed against the prior context. If the context prefers one or another type of complement (on syntactic or semantic grounds), then only that structure will be projected from the lexicon. This structure will then be part of the representation against which subsequent words are evaluated for their contextual compatibility. Structures projected from the lexicon do not place constraints on the identity of individual words. Rather, they constrain the type of structure that can be built and, therefore, the relations between words within a phrase.

On this view, there is no processing discontinuity in the use of different types of lexical information, since all are assessed in parallel against the context. In a number of studies, William Marslen-Wilson and I have examined the immediate processing consequences of various types of lexical syntactic information—such as subcategorization and major category information—that accept only particular lexical categories in the structures they initiate. We have also looked at the effects of two kinds of semantic information: information that is clearly lexically specified (i.e., selection restrictions such as animate, human, and abstract, which accept particular members of lexical categories in the phrase under construction) and information that cannot be directly lexically represented but rather is based on properties of lexical semantic representations (i.e., pragmatic information). The representation of a word cannot contain all the various and subtle interpretations that the word could have in different real-world contexts. Instead, we assume that the process of pragmatic inference is triggered by the activation of specific aspects of a word's meaning. When the semantic properties of a word are activated and assessed against the context, this involves more than just an assessment of intensional meaning. It also involves evaluating the pragmatic implications of that entity or event with respect to what the listener knows about how it functions in the world.

On-Line Use of Lexical Representations
What is the evidence for the claim that all these different types of information have immediate structural consequences? In a number of studies we have found no evidence that, for example, lexical semantic or pragmatic information is used much later than syntactic information to constrain the ways in which words are structurally combined. In one study (Marslen-Wilson, Brown, and Tyler 1988; Tyler 1985), we focused on verb-argument relations to ask whether both the syntactic and the semantic specifications of a verb function to immediately constrain the properties of its argument. In par-
ticular, we examined syntactic subcategory information, semantic selection restrictions, and pragmatic inference based upon the semantic specifications of the verb.

The idea behind the experiment was the following: If identification of a verb (such as sleep) includes accessing information about the kinds of arguments it selects, and if this acts as a structural constraint on the immediate processing of subsequent items, then the noun phrase the house in the sequence “He slept the house” would violate subcategorization constraints imposed by the verb. When the syntactic and semantic properties of the house are assessed (unsuccessfully) against the context, processing will be disrupted. Similarly, if either selection restrictions or the pragmatic implications of the verb place constraints on the particular words that can occur as its argument, then violating either type of constraint will also disrupt processing. So, for example, if the subject hears “The girl eats the brick”, the selection restrictions on the verb eats will accept only edible substances as its argument. Since bricks are not edible, brick violates semantic constraints on acceptable verb-argument structures, and processing will be disrupted. The same logic applies to pragmatic inference generated by lexical representations. If the pragmatic plausibility of an argument is a factor influencing the appropriateness of a particular verb-argument combination, then processing should again be disrupted when an argument is pragmatically implausible.

To test these claims, we constructed materials of the following types:

(1a) The crowd was waiting eagerly. The young man GRABBED the guitar and ...

(1b) The crowd was waiting eagerly. The young man BURIED the guitar and ...

(1c) The crowd was waiting eagerly. The young man DRANK the guitar and ...

(1d) The crowd was waiting eagerly. The young man SLEPT the guitar and ...

In condition (a) the relationship between the verb (grabbed) and object noun (guitar) is normal. In condition (b) the object noun is pragmatically implausible; however, it is not linguistically anomalous, in view of the semantics of the preceding verb and the prior context. In condition (c) the object noun violates selection restrictions (Chomsky 1965) on the prior verb (drank the guitar), in that the argument slot for drink is restricted to liquid substances. In condition (d) the noun violates strict subcategorization restrictions on the verb (slept the guitar), because sleep is intransitive and
cannot take a direct object. This means that the appropriate syntactic structure cannot be built and the semantic relations between verb and noun are not coherent. Conditions (c) and (d), then, violate constraints on permissible syntactic and semantic structural combinations of words.

To assess the effect of these various types of verb-argument violations on the process of developing an interpretation of an utterance, we had subjects perform a word-monitoring task. They were asked to press a response key as soon as they heard a target word (in this case, the word guitar) in the utterance, and their reaction times (from word onset) were recorded. The pattern of results was very clear. Subjects were significantly slowed down by all three types of violation. However, the amount by which their processing was disrupted varied according to the type of violation. The mean response time for the normal condition (a) was 241 msec. This increased by a small but significant amount in the presence of a pragmatic anomaly (268 msec), and by a larger amount in the presence of a word that violated selection restrictions (291 msec). The slowest RTs were in response to subcategorization violations (320 msec).

These results suggest that the lexical representation of a verb imposes immediate structural constraints—in the form of verb-argument frames—on the processing of the subsequent input. These constraints encompass many different aspects of a verb—its semantic as well as its syntactic specifications. The important point here is that all types of constraint affect the analysis of incoming words immediately.

Perhaps the most surprising result of this study was the immediate effect of the pragmatic implications of the verb. Response times increased significantly when the listener heard an utterance containing a pragmatically implausible verb-argument structure. This increase was smaller than for the two types of linguistic violation, reflecting the fact that pragmatic implausibility does not actually prevent the listener from developing a representation of an utterance (as subcategorization violations do), although it may increase the difficulty of doing so. What the increase in RT in the pragmatic-implausibility condition indicates is that listeners are attempting, as soon as they activate the lexical specifications of a verb, to evaluate these with respect to their model of the world on the basis of the utterances they have heard. This is evidence, then, that the argument frames associated with each verb have immediate consequences for the linguistic analysis of an utterance and for its interpretation within a nonlinguistic, conceptual domain.

Some research we started many years ago (Tyler and Marslen-Wilson 1977) and recently revived (Marslen-Wilson and Young, unpublished) is
relevant to this issue. In our first study, we examined the effect of semantic context on the interpretation of category information. We presented subjects with syntactically ambiguous phrases, such as landing planes, which were preceded by a semantic context that biased toward either the adjectival reading (“If you walk too near the runway …”) or the verbal reading (“If you’ve been trained as a pilot …”). We found that listeners’ responses to a visual probe presented at the offset of the fragment were faster when the probe was consistent with the contextually appropriate reading of the fragment. This suggested that listeners’ syntactic interpretation of the fragments was guided by the prior semantic context.

This study was criticized by Townsend and Bever (1982), Cowart (1983), and Cowart and Cairns (1987), who pointed out that the stimuli contained a number of confounds, the most serious of which was the presence of singular and plural cataphoric pronouns in the context sentences. The contexts biasing toward the adjectival reading tended to contain plural pronouns, whereas those biasing toward the verb reading often contained singular pronouns. For example, for the ambiguous phrase cooking apples, the adjectival context was “Although THEY may be very tart …”; the verb context was “Although IT doesn’t require much work …”.

Since the test sentences were heard in isolation, these pronouns could be interpreted as referring to an entity that has yet to be mentioned. They may lead the listener to believe that either singular or plural potential referents will occur later in the sentence. This could be construed simply as a syntactic bias, without involvement of the pragmatic properties of the discourse context. It is therefore important to determine whether a discourse effect can still be observed when the pronoun effect is neutralized.

For this reason, a further study was carried out (Marslen-Wilson and Young, unpublished) using pairs of context sentences with exactly parallel structures and the same pronouns. These context sentences differed only in their pragmatic implications. For example:

(2a) If you want a cheap holiday, visiting relatives …
(2b) If you have a spare bedroom, visiting relatives …

Visiting can be interpreted either as a verb form (a gerund), in which case the sentence will have a reading in which relatives are being visited by someone, or it can be interpreted as an adjectival form modifying the noun relatives. The two cases will generate different structural implications. If visiting is interpreted as a verb, it will project onto a verb-phrase construction. If it is interpreted as an adjective, it will project onto an adverbial phrase.
My claim is that both of these possibilities are activated when the word *visiting* is recognized, and that they are assessed in parallel against the prior semantic and syntactic context. At this point the context cannot determine which reading (verb or adjective) is preferred, since both are possible. Therefore, both syntactic frames (verb phrase and adjectival phrase) are projected from *visiting*. It is only when the listener hears *relatives* and can assess its syntactic and semantic specifications against the context that a single reading can be selected. This, in turn, has structural implications for the interpretation of the subsequent input.

If the lexical specifications of *visiting relatives* are assessed in parallel against the context so that only the contextually appropriate reading generates structural constraints on the subsequent input, then processing of the subsequent word ought to be affected by the extent to which it is consistent with the contextually appropriate structure. For example, the word *are* is consistent with the verbal reading of fragment (a) but not with the adjectival reading. Therefore, it should take subjects longer to process *are* when it follows (2b) than when it follows (2a). Similarly, the word *is* is an appropriate continuation for the adjectival reading but not for the verbal one. Marslen-Wilson and Young found, just as in the original experiment, that subjects named appropriate probes significantly faster than inappropriate probes.

These results confirm that nonlinguistic context affects the assignment of a syntactic analysis, and they tell us that it does so very early. The probe word comes immediately after the end of the fragment, at the point where the ambiguity of the fragment first becomes fully established. The ambiguity of these fragments depends on hearing both words. Sequences like *visiting houses* are not ambiguous in the same way. This means that we are finding significant context effects at what is effectively the earliest point at which we can measure. This supports the claim that both the syntactic and the semantic properties of *visiting relatives* were evaluated immediately and in parallel against the context.

Finally, there is additional evidence that the pragmatic implications of a verb are immediately assessed against the existing discourse representation to constrain the analysis of the utterance being heard. In various studies (Marslen-Wilson and Tyler 1980b, 1987; Tyler and Marslen-Wilson 1982a), we presented subjects with short stories which were followed by a continuation fragment. The fragment always had the same structure: a noun phrase followed by an incomplete verb phrase. What varied was the nature of the initial noun phrase. It could be a definite description (e.g., *the man*), a proper name (e.g., Philip), or an unambiguous pronoun, or it could
take the form of a zero anaphor (i.e. it was not lexically realized). For example:

3. After the surgeon had examined the 12-year-old girl with the badly broken leg, he decided he would have to take immediate action. He'd had lots of experience with serious injuries. He knew what he had to do next.

(a) The surgeon quickly injected …
(b) He quickly injected …
(c) Quickly injecting …

Each of the fragments (a)–(c) contains an anaphoric device linking the fragment to the preceding discourse. In fragment (a) the device is a description of some individual previously mentioned. In (b) it is an unambiguous personal pronoun. In (c), an example of zero anaphora, there are no explicit lexical cues at all.

In each case, to interpret the fragment, the listener has to determine who is the agent of the action denoted by the verb and to evaluate this with respect to the preceding discourse. In (a) and (b) the agent is directly lexically specified (“the surgeon”, “He”), and can be unambiguously related to possible antecedents just on the basis of this lexical information. It is case (c) that concerns us here. The only way that agency can be assigned is on the basis of a differential pragmatic inference that matches the properties of “Quickly injecting …” to the properties of potential antecedents in the discourse. It is necessary to infer who is most likely to be injecting whom.

To measure the timing of anaphoric linkage in these three conditions, we used the naming technique described above. Subjects heard the short story together with one of the three continuation fragments. At the offset of the fragment (i.e., at the end of “injecting”) a visual probe word was presented, which the subjects had to name as rapidly as possible. In the example above, the probe would have been either HIM or HER. For each case, HER is a more appropriate continuation than HIM. The critical experimental question was whether the size of the expected preference (faster naming of the appropriate probe) would be the same in the zero-anaphor case (where the linkage depends entirely on pragmatic inference) as in the other two conditions (where there are explicit lexical markers). If the appropriateness effect is as strong in the zero-anaphor case as in the other two, then we would claim that the missing subject of the verb will have been filled in, on-line, on the basis of a process of differential pragmatic inference, triggered by the meaning of the verb in relation to the context.

We found a marked appropriateness effect in each condition, and its size did not differ significantly for different types of fragment. Moreover, the
effect remained unchanged by various additional factors—whether or not, for example, the subject of the continuation sentence was the focus of the discourse (see Karmiloff-Smith 1980). We can contrast example 3, where "the surgeon" is both the agent of the action denoted by the verb and the main focus of the story, with the following example:

4. Mary lost hope of winning the race to the ocean when she heard Andrew's footsteps approaching her from behind. The deep sand was slowing her down. She had trouble keeping her balance. Overtaking ... 

Here Mary is the focus of the discourse, although Andrew is the appropriate agent of the verb in the continuation fragment. We found that when we set up this type of conflict situation, the pragmatic implications of the verb always determined the assignment of agency. They were much stronger than the discourse focus.

What these results suggest is that the listener develops a discourse model of the story as it unfolds over time. This discourse model might or might not establish a particular protagonist as the focus of the story. When the listener hears a continuation fragment containing a zero anaphor, the lexical specifications of the verb are immediately assessed against the discourse model. Whether or not the discourse model contains a specific discourse focus, the pragmatic implications of the verb in relation to the discourse will determine which protagonist is chosen as the agent of the continuation fragment. The important point is that the agent is selected just as rapidly on the basis of pragmatic inferencing based on the semantics of the verb as on the basis of a direct anaphoric device (such as a definite noun phrase).

The view I have been developing here is supported by some recent work by Tanenhaus and Carlson (this volume). In contrast with the Amherst view that syntax is the central component in the language-processing system, Tanenhaus and Carlson stress the centrality of various non-syntactic aspects of lexical representations—in particular, the thematic roles associated with verbs. They propose that when a verb is identified, all the different senses of the verb, together with the sets of thematic roles (agent, theme, etc.) associated with each sense are made available to the processing system. Provisional assignments of thematic roles to the verb are made immediately, and this provides a mechanism for enabling the arguments of a verb to be semantically interpreted. This also means that pragmatic inference and discourse context are immediately brought into play so that they can affect the initial interpretation of the sentence.
Selective Use of Lexical Representations

On the view I have been outlining, all types of lexical information are immediately activated and exhaustively evaluated with respect to the discourse context. They all have immediate consequences for the representation that is under construction. Elsewhere (Marslen-Wilson and Tyler 1981, 1987; Tyler and Marslen-Wilson 1982b) we have argued that there is no evidence that different types of lexical information are used to construct different types of higher-level structures. Rather, all types of lexical information seem to constrain the development of a single representation.

This approach is very different from that proposed by the Amherst group. Frazier (1987), Clifton, Frazier, and Connine (1984), and Rayner, Carlson, and Frazier (1983) claim that as each word is perceived, it is incorporated into a constituent-structure representation by the syntactic parser, using only lexical category information. Other types of syntactic information that are assumed to be associated with lexical items, such as lexical preferences for particular syntactic structures, are not used for this initial parse.

There are several important facts about this parser: It can construct only one analysis at a time, it is organized so as to construct a representation that involves the fewest additional nodes in the phrase marker, and it operates under time pressure and therefore prefers to attach new items to the current phrase marker. These conditions on its structure result in the two general parsing strategies—minimal attachment and late closure—that guide the initial syntactic analysis of a sentence. These strategies are impervious to item-specific structural preferences and to lexical meaning.

In parallel with the parser's activities, a thematic processor chooses the most plausible thematic frame for each head of phrase, using discourse and real-world knowledge. Since the thematic processor knows only about the thematic roles and argument structures associated with verbs and other heads of phrases, it builds its own independent representation solely in these terms (Rayner, Carlson, and Frazier 1983).

Moreover, neither processor can directly affect the operations of the other. The only communication between them is initiated by the parser, which is allowed to submit its analysis to the thematic processor. If the thematic processor doesn't like the proposed structure, it can ask the parser to reanalyze the sequence, but it cannot suggest alternate analyses. This model is, in many respects, a direct descendant of Bever's (1970) language-processing model, which also has parallel but independent representations constructed by autonomous subcomponents of the language-comprehension system.
On the Amherst account, all the syntactic information within a lexical entry becomes available when a word is identified, but only the information that is relevant for the syntactic representation the parser prefers to construct is used immediately. To illustrate how this model works, consider the following example of the parsing strategy of late closure:

(5a) Even before the truck stopped the driver was getting nervous.
(5b) Even before the police stopped the driver was getting nervous.

According to the Amherst group, the parser pursues its strategy of late closure, irrespective of any structural preferences that might be associated with the verb stopped and irrespective of the pragmatic context (i.e., the fact that in (5a) trucks are less likely to stop something than to be being stopped). This means that readers will treat (5a) and (5b) alike. They will delay closing off the subordinate clause as long as possible, and will assume that the NP following the verb is its object, rather than closing off the subordinate clause early and taking the NP as the subject of the main clause.

At the same time, the thematic processor will be constructing its own representation based on the thematic frames associated with the verb. In (5a), this will result in a different interpretation of the sentence from the one the syntactic parser is constructing, because of the thematic relationship between truck and stopped. When the parser submits its analysis to the thematic processor, a mismatch will be detected. It is at this point that readers will realize that their initial parse of the sentence is incorrect, and the parser will have to reinterpret the sentence.

The second parsing principle, minimal attachment, can be illustrated with the following example:

(6) The spy saw the cop with the revolver.

When the parser encounters this type of sentence, it follows the principle of postulating the fewest additional nodes and incorrectly attaches the PP “with the revolver” to the verb phrase “saw”. For the sentence to make sense, the parser should attach the PP to the NP “the cop”. The thematic processor, however, constructs the correct interpretation. Thus, the syntactic parse and the thematic representation conflict, and the parser has to attempt a second analysis of the sentence.

An important aspect of the Amherst claim is that these structural biases affect the first parse through a sentence, whereas lexical preferences and pragmatic context come into play only at a later stage of the interpretation process. To test this claim it is necessary to use tasks that probe the representation the perceiver constructs as it is being constructed rather than
at some later point in time. "On-line" tasks are assumed to probe the initial representation of a sentence (Marslen-Wilson and Tyler 1980a; Tyler and Marslen-Wilson 1982b). These are tasks in which the subject's response is closely tied in time to relevant aspects of the sentence. If we want to know whether, for example, verb preferences affect the initial parse, then we have to probe immediately after the verb has been encountered. Probing at some later point in the sentence runs the risk that the response will be influenced by processes that occurred after the first structure was assigned. It is, therefore, critical to use an appropriate experimental task when attempting to address issues concerning when particular types of analysis are carried out. Unfortunately, this has often not been done in parsing research. A few studies have employed some type of on-line task (e.g. Clifton, Frazier, and Connine 1984; Ferreira and Clifton 1986), but many have not (e.g. Crain and Steedman 1985; Mitchell 1987). This has added to the difficulty of interpreting the often contradictory experimental results (e.g. Stowe, in press; Ferreira and Clifton 1986).

The model developed by the Amherst group has been tested in a number of studies, most of which have been carried out by Frazier, Rayner, Clifton, and colleagues, who claim solid empirical support for their model. However, this and related research has not been completely convincing, because it has tended to confl ate a number of issues that need to be treated separately. The Amherst claim is that there are purely structural biases corresponding to the parsing principles of minimal attachment and late closure. What must be established is whether these biases ignore the specific syntactic and semantic preferences of a verb, whether they are affected by the meanings of the other words in the sentence, and whether they ignore the pragmatic context of the sentence. To show that there are parsing preferences that are independent of any other source of information, we need to examine separately the effects of all these: lexical preferences, parsing principles, and pragmatic context. This has not been done systematically.

**Verb Preferences**

The issue of whether the initial syntactic parse of a sentence is developed solely on the basis of parsing principles, without taking into account specific lexical preferences, has barely been investigated. Frazier's (1987) position is that lexical preferences associated with particular verbs do not guide the initial parse (although they may be used later), but she presents no data to support her claim. The closest she came to testing this hypothesis was in a study (Rayner and Frazier 1987) in which the experimental sentences were divided into two groups—those with and those without
lexical preferences associated with the verb—on the basis of the experimenters’ intuitions rather than any objective criteria. Rayner and Frazier found that readers parsed the sentences according to the principle of minimal attachment, irrespective of lexical preferences. This is not, however, a very compelling test of the role of lexical preferences, in view of the lack of any objective assessment of preferences prior to the experiment.

A few other studies have examined the role of lexical preferences in parsing. For example, Ford, Bresnan, and Kaplan (1982) and Clifton et al. (1984) show that lexical information about preferred subcategorization frames is used very rapidly during reading, and Holmes (1987) and Mitchell and Holmes (1985) find that readers make use of the structural biases of complement verbs in assigning structure to a sentence. However, Frazier (1987) claims that these studies do not show unequivocally that lexical preferences guide the initial decisions of the parser as opposed to providing some type of later filtering mechanism, because of limitations in the tasks and materials used in the various studies. It should be clear from the above brief description of research on the role of lexical preferences in initial parsing decisions that this still remains an open issue.

So far, I have only discussed the structural preferences some verbs may have. There is also the question of whether the thematic preferences some verbs have (for animate agents, for example) affect the initial parse. Ferreira and Clifton (1986) explored this issue by contrasting sentences containing reduced or unreduced relative clauses, where the verb required an animate agent in some cases but not in others. They found that the animacy of the agent did not affect the reader's first parse of the sentence, which was always based on a minimal attachment strategy. But what they failed to do in this study was to determine whether the verbs they used had syntactic preferences in addition to their assumed (and untested) semantic preferences. It is a mistake to look in detail at the role of any one factor without also controlling for the potential effects of others.

Noun Preferences
It is insufficient just to examine the role of verb preferences (both semantic and syntactic) in parsing decisions. We also need to know whether the meaning of the various NPs around the verb affects the operations of the parser. There is very little research on this aspect of sentence interpretation. Stowe's (in press) recent study is relevant here. She asked whether readers could use thematic information (in the form of the animacy or inanimacy of subject NPs) in assigning a syntactic analysis to a sentence. She used sentences of the type I discussed earlier:
(7a) Even before the police stopped the driver was getting nervous.

(7b) Even before the truck stopped the driver was getting nervous.

According to the principle of late closure, readers should assume that the NP (the driver) following the verb (stopped) is its object, rather than closing off the subordinate clause and assuming that the NP is the subject of the main clause. This should lead to a garden path in (7a). This strategy should be followed regardless of the animacy of the subject of the subordinate clause. However, Stowe found that when the subject was inanimate and therefore unlikely to be the agent of the action denoted by the verb, as in (7b), readers tended to close after the verb. In the presence of an animate subject, as in (7a), the verb was taken as transitive, which led to a garden path in the main clause. Thus, Stowe found that animacy affects the initial syntactic interpretation of the sentence. Clearly, the relationship between lexical preferences (both syntactic and semantic) and syntactic parsing decisions is an important issue in parsing, and much more research is needed to clarify it.

**Pragmatic Context**

The role of the meaning and syntactic preferences of individual words must be established independently of the issue of whether the parser is influenced by the pragmatic context of an utterance—an issue that has been investigated numerous times and in different ways. The results from Amherst suggest that the first structure attempted by the parser is not affected by any aspect of the pragmatic context (Ferreira and Clifton 1986; Rayner, Carlson, and Frazier 1983). However, as Taraban and McClelland (1987) point out, in these studies weak pragmatic constraints tend to be pitted against strong syntactic ones, so that it is not surprising that syntactic principles should win. In support of this point, other studies have explicitly manipulated various aspects of the pragmatic context—presuppositional information (Crain and Steedman 1985; Altmann and Steedman 1987) and lexical semantics (Stowe, in press)—and have found that they all affect the syntactic representation which is constructed.

Frazier (1987) tends to dismiss such results on the grounds that either the materials used in an experiment do not contain the appropriate linguistic structures to test the theory (Tyler and Marslen-Wilson 1977) or the tasks used do not probe the initial representation which the parser develops (Crain and Steedman 1985; Stowe, in press; Altmann 1987; Mitchell and Holmes 1987). Since Frazier claims that pragmatic context has an effect only after the parser submits its analysis to the thematic processor, she predicts that there will be an effect of pragmatic context—but only in
tasks that tap late stages of processing. She claims that most of the studies that purport to show an effect of pragmatic context on syntactic structure use tasks (such as whole-sentence reading times) that tap late stages of processing.

However, recent results reported by Altmann and Steedman (in press) are hard to refute on these grounds. They presented subjects with sentences containing either complement clauses (such as “The psychologist told the woman that he was worried about her marital problems”) or relative clauses (such as “The psychologist told the woman that he was worried about to visit him again”). These were preceded by a semantic context that induced either the complement reading or the relative-clause reading. On the Amherst model, subjects should always attempt the complement reading first (minimal attachment), and therefore should be garden-pathed in the sentences where the correct reading is the relative-clause reading. However, if pragmatic context is used immediately to guide the initial parse, subjects should not be garden-pathed. Altmann and Steedman found that when the pragmatic context biased against the minimal-attachment reading, it was the syntactic structure that was consistent with the pragmatic context which was developed first. Since they used a word-by-word reading task, their results cannot be dismissed on the grounds that the task does not tap the early stages of processing.

Moreover, the Amherst group’s own research on this topic suffers from a serious methodological flaw: They have never systematically evaluated the strength of the semantic biases in their materials. Ferreira and Clifton (1986) and Rayner et al. (1983) construct sentences which they assume provide semantic/pragmatic biases against the minimal-attachment reading—for example (from Rayner et al. 1983),

(8) The spy saw the cop with a revolver but the cop didn’t see him.

Rayner et al. assume (but never establish empirically) that the semantics of the prepositional phrase (with a revolver) requires that it be attached to the noun phrase (the cop), therefore creating a bias toward the non-minimal-attachment reading. In spite of this assumed bias, they still found evidence of garden-pathing, indicating that the initial parse of the sentence had not been affected by pragmatic plausibility (although pragmatic plausibility did have an effect later).

These results have recently been challenged by Taraban and McClelland (1987), who argue that, since the materials used by Rayner et al. had not been pretested, there is no way of knowing whether they contained a bias toward the minimal-attachment reading in the sequence up to the preposi-
tional phrase (*a revolver*). To check this, they asked subjects to read sentences like (8) above, up to and including the preposition at the beginning of the critical VP, as in (9).

(9) The spy saw the cop with ...

Subjects were asked to generate a completion for the incomplete sentence. They then saw the completed sentence and rated how well it matched their expectations. Subjects rated VP completions (minimal attachment) significantly closer to their expectations than NP completions. In other words, the context preceding the prepositional phrase biased toward minimal attachment. What we cannot be sure about is the nature of the biases. Taraban and McClelland did not try to determine to what extent they resulted from verb preferences or from such variables as the meaning of the subject or object noun phrases.

Taraban and McClelland then constructed a new set of materials which had not been included in the original Rayner et al. experiment. These materials generated an NP (non-minimal attachment) completion, and subjects subsequently rated these sentences as closer to their NP expectations. Finally, these two sets of items (one set containing a VP bias and the other containing an NP bias) were used in a word-by-word reading-time task. Subjects were significantly faster at reading the sentences where the bias was consistent with the continuation. That is, they were faster to read sentences that were biased either toward minimal attachment or to NP attachment, as long as the prepositional phrase was consistent with this bias. This study demonstrates the subtle interplay among the various sources of information within a sentence and suggests that they all contribute to the initial interpretation.

An additional problem with the study by Rayner et al. (1983) is that the materials were not pretested to ensure that pragmatic factors were actually strong enough to override putative syntactic biases. When experimental materials are pretested to ensure that they do indeed provide appropriately strong pragmatic constraints, then they clearly affect the initial structural interpretation of an utterance (Tyler and Marslen-Wilson 1977; Marslen-Wilson and Young, unpublished). Similarly, in the anaphora studies discussed earlier (Tyler and Marslen-Wilson 1982a; Marslen-Wilson and Tyler 1987), we objectively established the strength of contextual constraints and found that they could determine the assignment of predicate-argument relations in logical form. Recall that the pragmatic implications of a verb, in relation to the discourse context, were sufficient to assign agency to the subject of the continuation sentence (see example 4). Such
influence would be explicitly excluded by the Amherst group. Context (in the form of the thematic parser) can tell the syntactic parser whether the representation it has constructed is compatible with the context, but it can never directly tell the parser what the content of its analyses should be.

A slightly different aspect of the anaphora data supports my position. When we generated stories in which the verb exerted no pragmatic biases (as in example 10 below), then discourse focus alone could effectively and rapidly determine the assignment of agency.

(10) As Bill was buying popcorn at the movies, he saw an old girlfriend get in line for a ticket. He had arrived at the movies especially early. He wanted to be sure of getting a good seat. *Waving at ...*

Here the pragmatics of the verb are neutral, and designed to be equally compatible with both potential antecedents, but the discourse sets up Bill as its focus. These results showed that discourse focus on its own could also control the on-line interpretation of utterance fragments—and to the same extent as the pragmatic implications of the verb and definite noun phrases. Once again, we see agency being assigned under conditions where the parser could have no basis for doing so purely on linguistic grounds. It is only in the representation of the discourse that any basis exists for choosing one actor or another as the subject of the verb in the continuation fragment.

**Conclusion**

I would argue that these various results suggest that the research of the Amherst group does not conclusively establish that syntactic parsing is independent either of semantic bias or of the semantic and syntactic specifications associated with individual words. Since these factors have been conflated in most studies, further research is needed to evaluate their role in syntactic parsing. Indeed, there is considerable evidence from a variety of sources that the interpretations of the syntactic implications of verb are immediately constrained by the semantic context in which it occurs.

The view I have developed here suggests that representations of lexical content become available early in the process of recognizing a word, and certainly well before all of the word has been heard. These representations are evaluated, in parallel, against the demands of the context, and those that fit contextual specifications then form part of the higher-level representation against which upcoming words are assessed. The on-line processing data I have presented suggest that this holds for all types of lexical represen-
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tation (both semantic and syntactic). There was no evidence from these studies that only specific types of syntactic information are used immediately in the process of interpreting an utterance.

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Notes

1. It is sometimes difficult to see what kind of data the Amherst group would take as evidence of lexical preferences affecting parsing decisions. For example, Clifton et al. (1984) found an effect of lexical preferences using a task that is generally considered to reflect immediate processing (lexical decision). Nevertheless, the authors proposed alternate explanations rather than taking this as evidence of lexical preferences affecting initial parsing decisions.

2. These results are in direct conflict with those of Ferreira and Clifton (1986), and there is no obvious way of resolving the discrepancy at present (Stowe, in press). This is always a problem when materials and tasks vary so much between experiments.

References


