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SENTENCE AND TEXT COMPREHENSION: Roles of Linguistic Structure

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■ **Abstract** Readers and listeners use linguistic structure in comprehending sentences and texts. We review research, mostly published in the past five years, that addresses the question of how they use it. We consider effects of syntactic, lexical, prosodic, morphological, semantic, and discourse structure, as well as reviewing research on how discourse context and frequency of experience, the contents of long-term memory, and the mental models being constructed by a reader or listener affect sentence and text comprehension. We point out areas of theoretical debate including depth-first versus breadth-first models of parsing and memory-based versus constructionist models of discourse comprehension, attempt to show how the empirical effects we review bear on such theoretical questions, and discuss how new lines of research, including research on languages other than English, may enrich the discussion of these questions.

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BACKGROUND: The Rises and Falls of Structural Analysis

Since the beginning of the cognitive revolution, psycholinguists have recognized that knowledge of linguistic structure allows us to construct and comprehend sentences (Miller 1962). However, they have continually argued about what role this knowledge might play in language comprehension.

The first modern psycholinguists reveled in their discovery of grammar and strove to demonstrate that linguistic structure does play a role in understanding sentences and texts (Fodor et al 1974). Although they were successful in demonstrating the relevance of linguistic structure, they were not successful in formulating coherent theories of how a processing mechanism could use the grammar to parse a sentence or to interpret it semantically. Interest shifted from asking how linguistic structure is used to asking how a reader or listener could make use of the myriad cues that language provided, resulting in the "detective theory" of sentence comprehension (Fodor et al 1974), which views language comprehension as a largely unconstrained exercise in problem solving.

In the mid-1970s, the pendulum swung back toward an emphasis on how linguistic structure is used in comprehension. The impetus was a series of theoretical proposals from linguists and computer scientists (Frazier 1979, Frazier & Fodor 1978, Kimball 1973, Marcus 1980) describing how the algorithmic use of phrase structure rules and other grammatical devices could account for a range of sentence comprehension phenomena. A similar interest in how a limited range of information constrains and guides comprehension process grew in the field of discourse processing, fueled by the development of story grammars (Mandler & Johnson 1977, Rumelhart 1975) and analyses of how readers use anaphoric reference and related reference principles to connect sentences in discourse (Haviland & Clark 1974, Kintsch & van Dijk 1978, McKoon & Ratcliff 1980).

The pendulum has since swung back. Beginning in the mid-1980s, sentence processing researchers provided myriad demonstrations that factors other than the structural geometry of sentences could influence how they are comprehended. Interactive connectionist theories of sentence comprehension became dominant, describing how a uniform processing system resolves constraints arising from frequency of use, lexical structure, plausibility, context, and the like (MacDonald et al 1994, Tanenhaus & Trueswell 1995). The current models can be seen as more explicit and principled versions of the old detective models of the 1970s. In the realm of discourse comprehension, models have also tended to lose their focus on purely linguistic structure. Some models emphasize how comprehension processes can be driven by linguistically unsophisticated processes of memory retrieval (McKoon & Ratcliff 1992, Myers & O'Brien 1998). Others focus on the end-product of the comprehension process, postulating "situation models" that

incorporate nonlinguistic as well as linguistic information (Graesser et al 1994, Zwaan 1996).

Much has been gained from these repeated shifts in fashion. We now know a great deal about what factors influence sentence and discourse comprehension. We also know that any adequate theory of sentence comprehension must address how linguistic knowledge is used to create syntactic structure and that any adequate theory of discourse comprehension must address the interplay between structural constraints and memory processes. Current theories face the challenge of having to explain how syntactic structures are created, how a reader or listener selects and interprets a single structure, and how these interpreted structures are integrated into mental models of discourse. No current theory is fully adequate. For instance, the most explicit versions of current connectionist models of parsing (McRae et al 1998, Tanenhaus et al 2000) do not address the question of where structural alternatives come from; they are simply models of choice between existing alternatives. Similarly, structurally based models are schematic at best in how they characterize interaction among different information types (see the following discussion of reanalysis processes for some relevant theoretical suggestions). In the hope of stimulating the development of more adequate theories, we concentrate on reviewing recent empirical evidence about how linguistic structure influences the comprehension of sentences and discourses, including how linguistic structure interacts with nonlinguistic knowledge. We conclude with a section that reviews current models of the use of knowledge in discourse comprehension.

SYNTACTIC STRUCTURE

Much recent research on sentence comprehension was provoked by a simple claim that a reader or listener initially constructs a single representation of a sentence based solely on grammatical principles, semantically interpreting this representation in a nearly word-by-word fashion and revising as needed (Frazier 1979, Frazier & Rayner 1982). This serial, depth-first, "garden-path" theory claimed specifically that a reader or listener parses a sentence by attaching each new word into a single syntactic structure in the quickest possible way, guided by knowledge of the phrase structure rules of the language (which are essentially templates for possible local structural configurations of words) (Frazier 1989). This "first analysis" process results in the construction of the simplest syntactic structure, measured in terms of the number of syntactic nodes (or phrase structure rule applications) needed to attach each new word into the structure (see Frazier 1987 for description of this "minimal attachment" principle). In case two or more structural analyses are equally simple, the one that attaches the new word into the more recently processed phrase will generally be preferred because this phrase will be the most active and will thus be available for attachment most quickly.

Garden-path theory makes predictions about the relative difficulty of comprehending a wide range of structurally different sentences. A sentence that requires

revision of the initial, structurally simplest analysis will generally take longer to comprehend than a sentence that does not require such revision. Many experiments have supported these predictions, showing longer reading times, longer eye fixations, and more regressive eye movements in the forms that are predicted to be difficult (see Frazier & Clifton 1996 for a review).

Several principles of garden-path theory have come under sharp attack in recent years. Some lines of criticism retain the garden-path theory's emphasis on grammatical structure but propose different decision principles. To take one example, consider the widely recognized preference to link a new phrase in parsing to the most recently processed phrase. Phillips & Gibson (1997) argued that such a recency preference is the most dominant preference in parsing. They presented evidence that sentences like 1a below are (under some experimental conditions) read more quickly than sentences like 1b. Apart from recency, all the parsing principles Phillips & Gibson consider (including structural simplicity) favor attaching the temporarily ambiguous phrase beginning "I made" as the start of the main clause of (1a) and (1b). Only recency favors attaching it as a relative clause modifying "the recipe," but this seems to be the favored analysis.

1. a. Because Rose praised the recipe I made for her birthday it was worth all the effort.
   b. Because Rose praised the recipe I made it for her birthday as a surprise.

Gibson et al (1996a) provided additional arguments for the importance of recency (cf also Stevenson 1994). They used an incremental grammaticality judgment task to show that both Spanish and English readers faced with complex noun phrases (NPs) containing a sequence like the "lamps near the paintings of the house" followed by a relative clause, prefer to have the relative clause modify the most recent NP, with progressively lesser preference for modification of the first and then the middle NP. Gibson et al claimed these data reflect competing preferences for recent attachment and for modification of a phrase that is structurally near the head of a predicate phrase (the presumed verb in a sentence containing the complex NP).

Other criticisms of garden-path theory de-emphasize its use of grammatical knowledge in creating a single structure to be interpreted, claiming instead that multiple analyses compete on the basis of a wide range of grammatical and extragrammatical information. Some influential versions of these criticisms will be considered in the next section (MacDonald et al 1994, Tanenhaus & Trueswell 1995). These attacks have not forced garden-path theorists to discard their models. Rayner et al (1983) sketched one response, that factors other than structural simplicity affect a process of reanalyzing the initially created structure, not building the initial structural analysis itself. The only legitimate way to defend such a response is to develop a serious account of reanalysis. Such development is an active focus of current research (Fodor & Ferreira 1998; cf Sturt et al 2000 for discussion of the relevance of reanalysis to models other than serial models).

Much research on reanalysis has been influenced by Fodor & Inoue's (1994) proposal that reanalysis consists in revising or repairing an already-constructed analysis rather than starting over again. Fodor & Inoue (2000) generalized the principle underlying garden-path theory to apply to reanalysis as well, terming the principle minimal everything. All choices of either initial analysis or reanalysis are made following a very general least effort principle, in which a preference for recency or local attachment weighs heavily. However, other factors may operate as well in reanalysis. For instance, Bader (1998) presented evidence from German suggesting that requiring a revision in the prosody presumably assigned to a sentence during silent reading slows reanalysis. In another approach, Sturt & Crocker (1998) developed a description theory parser in which initial structural analyses are underspecified (e.g. a new phrase is analyzed as being dominated by some existing node, rather than being immediately dominated by that node; thus, new intervening nodes can be added without revising the initial structure). In reanalysis, the parser preferentially only makes changes that require additions to the initial structure, not deletions or other changes.

Case Structure

Until quite recently, most research on syntactic structure in parsing has focused on the role of word order in English. Syntactic structure is more than word order. Current syntactic theories place substantial emphasis on morphosyntactic features, including case, number, gender, tense, and aspect. Some psycholinguistic researchers have begun to study the processing of such features (see Cairns & Teller 2000). Consider case, which is explicitly marked in many languages. The case of a noun (traditionally nominative, accusative, dative, etc) is related to its role in sentence structure (subject, object of verb, etc) and to the role it plays in the argument structure of a verb. One can ask what role case and explicit casemarking may play in parsing.

English exhibits a case system in its pronouns (where "he, she" is nominative, "her" accusative or genitive or dative, etc). Traxler & Pickering (1996) showed that this casemarking is used in parsing English. In an eyetracking study of sentences like 2, they found longer reading times on the case-disambiguated "she" than on the case-ambiguous "you," suggesting that the nominative casemarking on she forced the readers to avoid or quickly give up the normally preferred direct object interpretation of the NP after the initial verb. The following verb phrase ("would leave") was read faster following a casemarked than a noncasemarked pronoun, also suggesting that the casemarked pronoun blocked the normal garden path.

2. a. I knew you and your mother would leave the party early.
   b. I knew she and her mother would leave the party early.

The contributions that casemarking makes to parsing have been studied most intensively in German (cf Kim 1999 for research on Korean case and Yamashita 1997 for Japanese). German determiners are marked for nominative, accusative,

dative, and genitive case, but only some are unambiguously marked. Further, German permits "scrambling." The order of German NPs within a clause is quite flexible. Whereas the canonical German sentence has subject before object, other orders are possible, depending in part on pragmatic factors such as focus (Hemforth & Konieczny 2000b).

These facts, together with the fact that German clauses are generally verb-final, permit researchers to examine whether case is assigned even before a case-assigning verb. Numerous authors (see Hemforth & Konieczny 2000a) have observed a preference for subject-before-object word order (nominative before accusative case). Bader & Meng (1999) demonstrated such a preference in several different constructions, including the scrambling constructions of Sentence 3, in which the article "*die*" in the embedded clause is ambiguous between nominative and accusative. This casemarking ambiguity was resolved by the number of the final auxiliary verb. Speeded grammaticality judgments were more accurate when the sentence was singular, indicating that the NP "*die neue Lehrerin*" had initially been assigned nominative case (cf Friederici & Mecklinger 1996 for a similar conclusion based on measuring electrical potentials in the brain):

3. a. *Die Direktorin hat ersählt, dass die neue Lehrerin einige der Kollegen angerufen hat.* The director has said, that the new teacher some the colleagues phoned has. (The director said that the new teacher phoned some of the colleagues.)
   b. *Die Direktorin hat ersählt, dass die neue Lehrerin einige der Kollegen angerufen haben.* The director has said, that the new teacher some the colleagues phoned have. (The director said that some of the colleagues phoned the new teacher.)

Various accounts of the subject-before-object preference exist, including appeals to simplicity (Gorrell 2000), memory load (Schlesewsky et al 2000), and thematic role ordering preferences (Scheepers et al 2000; note that these authors conclude that thematic ordering preference only plays a secondary role). Bader et al (2000) also examined the dative case, a lexical case needing a specific lexical licenser (as opposed to nominative and accusative, generally considered structural cases). They argued that structural case is preferred over lexical case in resolving an ambiguity, and claimed that a substantial amount of syntactic structure is built before reaching the lexical head of a sentence (see the discussion of lexical projection of structure, above).

Memory Limitation and Frequency Effects

Phrase structure, word order, and casemarking do not exhaust the possible factors that might influence parsing. One factor that has long been recognized is memory limitation. The difficulty of multiply self-embedded sentences such as, "The patient who the nurse who the clinic had hired admitted met Jack" has generally been attributed to their exceeding some memory capacity (e.g. Lewis 1996, 2000; Miller

& Isard 1964). Gibson (1998) developed a version of this claim that accounts for a range of sentence complexity effects in a variety of languages, including English, Spanish, Dutch, and Japanese. The basic claim of his syntactic prediction locality theory is that there is a processing cost to predicting, holding, and integrating obligatory syntactic requirements (e.g. a subject-predicate relation) when new discourse entities are introduced, and that the maximum local cost affects comprehension difficulty and choice among ambiguous alternatives.

A final factor in some structural theories is the frequency with which structures are encountered. The most thorough exploration of frequency appears in Jurafsky 1996. Jurafsky assumed a construction grammar framework, one in which syntactic structures and lexical items are all listed (and mentally represented) in the same way, as grammatical constructions. He described a parallel-parsing algorithm that determines both access and choice of constructions in a Bayesian fashion, computing the conditional probability of each construction, given the evidence. The model eliminates relatively unlikely candidates from further consideration (accounting for garden-path effects when the unlikely candidate is required) and is biased toward favoring the more frequent candidates. Jurafsky demonstrated that his model can account for a wide variety of parsing phenomena. Although he did not provide any new evidence specifically testing predictions of his model, research on lexical category ambiguity reported by Corley & Crocker (2000, Crocker & Corley 2000) support an approach whose statistical basis is close to Jurafsky's.

However, just to illustrate the fluidity of theory development in the field of parsing, we will close this section by noting that Crocker is coauthor of a theory that explicitly denies both frequency and structural simplicity as bases of parsing decisions. Instead, Pickering et al (2000; cf also Chater et al 1998) suggested that the preferred alternative is the most informative alternative, the choice that is most easily and quickly falsified. This turns out often (possibly always) to be the structurally simplest one, not the most frequent or probable one.

LEXICAL STRUCTURE

Argument Structure, Frequency, and Plausibility Effects

The linguistic theory that guided the parsing models of the 1970s emphasized structural regularities that could be expressed by rules (e.g. phrase structure rules). Since that time, linguistic theory has moved toward formulating very general principles governing possible sentence structures and encoding much of the detailed information about sentence structure with individual lexical items. This "lexicalist" movement stimulated a new round of psycholinguistic theories emphasizing contributions individual lexical items make to parsing (e.g. MacDonald et al 1994, Tanenhaus & Trueswell 1995; cf Ford et al 1982 for an important precursor, cf MacDonald 1997 for a brief survey).

Tanenhaus and his students and colleagues (e.g. Carlson & Tanenhaus 1988; Tanenhaus et al 1990, 1993) have studied how different types of lexical information combine to guide how a sentence is understood. Their early focus was on the use of thematic roles (the semantic roles that can be played by the complements or arguments of verbs and other words) (Tanenhaus et al 1989). For instance, Boland et al (1995) used a "stops making sense" judgment task to show processing difficulty at the word "them" in sentences like 4a compared with 4b:

4. a. Which child did Mark remind them to watch ....
   b. Which movie did Mark remind them to watch ....

The "filler," "which child," is presumably assigned a thematic role like "recipient" of "remind" in 4a, in which case the pronoun "them" must trigger revision. However, no such revision is needed in the case of "which movie," which is an inappropriate recipient; further, no disruption was observed at "remind" in this case because the verb contains other possible complements that could provide a thematic role for "which movie."

Although the task used by Boland et al (1995) could be criticized for slowing reading and possibly permitting unusual judgment processes to operate, the same is not true for Trueswell et al (1994). These authors used eyetracking measures to demonstrate substantial disruption in the disambiguating region of temporarily ambiguous reduced relative clause sentences like 5a compared with unambiguous controls, and the essential absence of disruption in sentences like 5b:

5. a. The defendant examined by the lawyer turned out to be unreliable.
   b. The evidence examined by the lawyer turned out to be unreliable.

Trueswell et al (1994) proposed that the appropriateness of the initial NP as theme versus agent guided initial parsing. Their proposal conflicted with results presented by Ferreira & Clifton (1986), but they argued that not all of the Ferreira & Clifton materials had strong enough thematic biases.

Another line of evidence is found in Spivey-Knowlton & Sedivy (1995), who measured the phrase-by-phrase self-paced reading time of sentences like (6):

6. a. The salesman glanced at a/the customer with suspicion and then walked away.
   b. The salesman glanced at a/the customer with ripped jeans and then walked away.

These sentences have a temporary ambiguity in terms of where the prepositional phrase (PP) "with suspicion"/"ripped jeans" will attach. The minimal attachment principle of garden-path theory claims that the preferred attachment is to the verb "glance *at*" and thus predicts that Sentence 6b will show slower reading time at or after the noun phrase NP that ends the PP than Sentence 6a. Spivey-Knowlton & Sedivy obtained this result when the main verb of the sentence was an action verb such as smash down. However, when the main verb was a "psych" or perception verb such as glance at or hope for, and when the NP direct object of this verb is

indefinite (with "a" rather than "the"), precisely the opposite result held: Reading time was slowed during the PP in Sentence 6a compared to Sentence 6b.

One result of the investigations made by the Tanenhaus group is the formulation of the most explicit and precise models to date of how lexical (and contextual) information guides the choice between alternative syntactic analyses (McRae et al 1998, Spivey & Tanenhaus 1998, Tanenhaus et al 2000). The McRae et al and Spivey & Tanenhaus models are simple networks for choosing between pairs of analyses (e.g. relative clause versus main clause, as in Sentence 5) that permit a theorist to unambiguously compute the consequences of the assumptions he or she chooses to make. They do a good job of fitting reading time measures of sentences that are resolved in favor of the normally unpreferred analysis (e.g. the reduced relative clause analysis. However, some evidence suggests that they may not adequately fit reading time of sentences that are resolved in favor of the normally preferred (main clause) analysis (Binder et al 2000; cf Frazier 1995, Clifton 2000).

In addition to claiming that the argument structures of verbs and other words guide parsing, many interactive lexicalist theories claim that the relative frequency of these structures also affect parsing. The underlying connectionist metaphor holds that a given lexical item passes more activation to its more frequently used structures, and that frequent structures should therefore be preferred and more easily processed. Numerous demonstrations of the importance of frequency exist. Some assess frequency of usage directly, through corpus counts; others assess frequency of usage indirectly, through empirical production norms. Merlo (1994) discusses the relative merits of these procedures. MacDonald (1994) demonstrated easier comprehension of temporarily ambiguous, reduced relative clause sentences such as 7 when the ambiguous verb was more frequently used (in production norms) as a transitive verb ("pushed" in Sentence 7a) than when its more frequent use was as an intransitive ("moved" in Sentence 7b).

7. a. The rancher could see that the nervous cattle pushed into the crowded pen were afraid of the cowboys.
   b. The rancher could see that the nervous cattle moved into the crowded pen were afraid of the cowboys.

Trueswell (1996) also showed that the ease of understanding sentences like these is affected by the relative frequency with which the verb is used as a passive participle versus a simple past tense.

Examining a different structure, illustrated in Sentence 8, Trueswell et al (1993) compared verbs whose most frequent usage (in production norms) was with a direct object complement (e.g. "confirm") versus with a sentence complement (e.g. "insist").

8. a. The waiter confirmed (that) the reservation was made yesterday.
   b. The waiter insisted (that) the reservation was made yesterday.

Contrary to Ferreira & Henderson (1990), whose experiment they were following up, Trueswell et al found faster reading for sentences like 8b, where the more

frequent usage matched the actual use in the sentence, than for sentences like 8a, where it did not.

MacDonald et al (1994) provide a variety of reasons why frequency should play a major role in parsing. Others have provided arguments against its centrality. One argument is that the effect of frequency is not always obtained. Kennison (2000) failed to observe any sign of a frequency effect in an experiment similar to that of Trueswell et al 1993, using materials that were very tightly controlled for plausibility. A second argument is that preferences for some constructions flatly go against frequency considerations, as shown by Gibson et al (1996b) and Gibson & Schütze (1999) for conjoined NPs. A third argument against a pure frequency account is that no existing frequency account has given a motivated reason for the level at which frequency is counted (cf Mitchell et al 1995). Gibson et al (1996b) examined a range of "grain sizes" for the NP conjunction construction they studied and demonstrated that none showed that frequency determined parsing preferences.

Finally, some research exists that strongly suggests readers initially analyze ambiguous phrases in a manner that ignores frequency of usage, even though frequency may play a role in recovering from the initial misanalysis. Pickering & Traxler (1998) used eyetracking measures to demonstrate disruption essentially immediately upon reading "magazine" in sentences like "As the woman sailed the magazine about fishing amused all the reporters." They suggested that this means that "the magazine" is initially analyzed as the direct object of "sailed" and that its implausibility as a direct object slows reading. Pickering et al (2000) observed the same effect in sentences with verbs like "hinted" that are much more frequently used with sentence complements than with direct objects. They argued that this showed that the direct object analysis was constructed in spite of its low frequency (cf Garnsey et al 1997).

If sheer frequency, however measured, is incomplete as the basis of a full theory of parsing, results like those of MacDonald (1994) and Trueswell (1996) still suggest that it plays some role. Furthermore, any shortcomings of a simple frequency account do not invalidate the more general lexicalist position. Some researchers have advocated a position in which the existence but not the frequency of lexical structures guides parsing. Ferreira & McClure (1997) show that the disruption of reading normally observed when a postverbal NP turns out to be the subject of a complement sentence is essentially eliminated when the verb is a reciprocal verb such as "kissed" and the matrix subject is plural, as in Sentence 9a (compared with nonreciprocal verbs such as in Sentence 9b and other controls):

9. a. After Jose and the bride kissed the party began in earnest.
   b. After Jose and the bride signaled the party began in earnest.

Ferreira & McClure argue that a reader avoids taking "the party" as object of "kissed" not because kiss is infrequently used as a transitive verb (it is not), but because its plural subject has already saturated its argument structure.

Is Sentence Structure Projected from Lexical Heads?

Some parsing theories that emphasize lexical guidance propose that all sentence structure is projected from the lexical heads of phrases (e.g. MacDonald et al 1994, Pritchett 1992). This claim is not a necessary part of a lexicalist model, so long as the grammatical principles in the model go beyond projection from lexical heads (see Crocker 1995 for a model that permits projection from functional as well as lexical heads). Furthermore, the claim must be wrong. It would make readers and listeners of all the languages in the world where a head comes at the very end of a phrase (about half of existing languages) have to wait until the end of a sentence before beginning to understand it (see Bader & Lasser 1994, and Frazier 1995 for further discussion).

Experimental evidence exists that points the way toward a lexicalist model that is not limited to creating structure by head projection. Konieczny et al (1997) presented eyetracking data for German sentences that they argue support a "parameterized head attachment principle." They showed that whereas PPs are preferentially taken to modify a verb as opposed to a noun in sentences with subject-verb-object-PP order, they preferentially modify the noun in verb-final constructions (subject-object-PP-verb). They argued that this finding contradicts the predictions of minimal attachment and supports a principle according to which a new constituent is attached to a phrase whose head (preferably a verbal head) has already been encountered, if possible. However, the (serial, depth-first) architecture of the model Konieczny et al (1997) proposed permits parsing to proceed without waiting for a head; it simply favors attachment to a head if one exists.

The Konieczny et al experiment is an instance of a refreshing new wave of sentence comprehension research done on languages other than English. This research exploits properties of these languages to test theories and to explore possible new information sources that can influence parsing. German is a language in which verbs must generally appear in the final position of a clause (except in root clauses with simple tense), allowing a researcher to ask what structure is created before the head of the sentence (the verb) is read or heard. Hemforth & Konieczny (2000a) provide a collection of investigations of German sentence processing, including (but not limited to) experimental studies of head-final constructions. Additional evidence from strongly head-final languages, including Korean and Japanese (plus other East Asian languages), appears in Mazuka & Nagai (1995) and in Chen & Zhou (1999). Much of this research (e.g. Kamide & Mitchell 1999, Koh 1997) strongly suggests that readers analyze NPs as arguments of a sentence well before they read the verb that ends the sentence.

PROSODIC STRUCTURE

The reader will have noted that most research discussed to this point examined reading, not listening. This reflects a characteristic of the field that is regrettable, given that any specialized language faculties people may have surely were shaped

by the need to comprehend spoken language, and given that the prosody (the rhythm and melody) of spoken language carries information that could potentially guide parsing (Cutler & Clifton 2000).

Fortunately, the situation is changing, and more and more research is being conducted on auditory sentence comprehension (see Warren 1996, Nicol 1996). Current research has gone beyond demonstrating that prosody can disambiguate ambiguous sentences (Lehiste 1973) and examines the roles that prosody plays in parsing. Linguistic analyses of prosody and the prosody-syntax interface (e.g. Selkirk 1984, 1995) indicate that prosody has a structure of its own, constrained, but not determined by, syntactic structure. Psycholinguistic research asks how this prosodic structure is identified (cf Beckman 1996) and how it constrains the parsing and interpretation of sentences.

In contrast to earlier research, most of which focused on what types of ambiguities can be resolved prosodically (e.g. Nespor & Vogel 1986), Kjelgaard & Speer (1999) asked whether appropriate prosody can overcome the effects of structural or lexical biases and block garden paths (see Marslen-Wilson et al 1992, for a precursor). Kjelgaard & Speer examined temporary late-closure ambiguities like those in Sentence 10:

10. a. When Madonna sings the song is a hit.
    b. When Madonna sings the song it's a hit.

In the written language, the phrase "the song" is taken as the direct object of "sings," leading to disruption in reading the end of Sentence 10a. Kjelgaard & Speer recorded sentences like these in two disambiguating prosodies (one with the boundary of an intonational phrase after the verb "sings," appropriate for early closure, and one with the boundary of an intonational phrase after the NP "the song," appropriate for late closure). They showed that an appropriate prosody eliminated comprehension difficulty and that an inappropriate (cross-spliced) prosody increased it, relative to a baseline condition with prosody appropriate to either interpretation. The results indicated that prosody can eliminate structural garden-pathing, leading Kjelgaard & Speer to argue that prosody is used at a very early stage in parsing.

Not all researchers hold this position. For instance, Pynte & Prieur (1996) suggested that the effect of prosody may simply be to speed recovery from a garden path. However, others claim that prosody determines the initial structuring of an auditory sentence (e.g. Schafer 1997, Schafer & Speer 1997). Schafer (1997) proposed a "prosodic visibility hypothesis" that suggested that listeners may form a "prosodic package" of material within a single prosodic phrase. Material within a prosodic package is more visible than material outside it, making attachment to the current phrase easy. She predicted that attaching the PP "with a mean look" to the NP "the rider" in Sentence 11 would be preferred in Sentence 11b relative to the other conditions because in Sentence 11b only the NP-attachment site is inside the current prosodic package (brackets indicate phonological phrases):

11. a. [The bus driver angered the rider] [with a mean look].
    b. [The bus driver angered] [the rider with a mean look].
    c. [The bus driver angered the rider with a mean look].
    d. [The bus driver] [angered] [the rider] [with a mean look].

Schafer also predicted that Sentence 11d would be intermediate between Sentences 11b and 11a,c because the rider should be more visible than angered in Sentence 11d but not in the others. Data from a listening study confirmed these predictions.

Schafer et al (2000) showed that these types of prosodic effects could be seen in spontaneously produced speech. They devised a board game in which two people communicate using a constrained set of sentence forms (including ones like those in Sentence 11). The players proved to use prosodies that effectively disambiguated their utterances and that had phonological properties similar to those manipulated in Schafer's earlier work.

Schafer argued against a "local cue" analysis of prosody, and argued that the interpretation of a prosodic boundary depends on the global prosodic representation of the sentence. In order for this to be a substantive claim, it is necessary to propose a specific scheme for representing prosody. Fortunately, a promising scheme, called "ToBI" (for tones and break indices), has developed out of the work of J Pierrehumbert (see Beckman 1996 or Shattuck-Huffnagel & Turk 1996 for tutorial introductions). Just as the formal descriptions of syntax devised in the 1950s and 1960s permitted the development of a psycholinguistics that seriously investigated the use of syntactic structure, the existence of a formal description of prosody will allow researchers to describe their auditory language materials and should stimulate new hypotheses about the role prosody might play in parsing.

SEMANTIC STRUCTURE

Most research on parsing has focused on the creation or recovery of syntactic structure. It is a truism that building syntactic structure is not the final goal of parsing, comprehension is. Logically, a process of semantic interpretation must bridge the gap between a syntactic form and a proposition that can become part of a discourse representation. Some recent research examines aspects of this process, including the processing of causality, tense, aspect, and quantifiers.

One example of such research is that done by Stevenson & Merlo (1997), who reopened the old question of why sentences like "The horse raced past the barn fell" are so terribly hard to understand. They suggest that it is not enough to note, as MacDonald (1994) did, that the transitivity preference of a verb affects difficulty. They proposed instead that the verbs (particularly manner of motion verbs) that lead to major garden-path effects are the ones that acquire a complex causal structure when they are used transitively: not only must an unexpressed causal agent be posited, but also the superficial subject "the horse" (the underlying object of "race") is assigned a role as agent. Verbs like "melt," which do not have this

two-agent complication when they are taken to be transitive, do not lead to nearly as much garden-pathing (cf "The butter melted in the microwave was lumpy").

Another instance of research at the syntax/semantic interface is that done by Piñango et al (1999). These researchers presented a visual lexical decision task immediately after the word "time" while a listener was hearing sentences like (12a) and (12b) (this probe position is marked by ^). They found evidence of slower reaction times, indicating greater processing load, in Sentence (12a) than in Sentence (12b).

12. a. The man kicked the little bundle of fur for a long time ^ to see if it was alive.
    b. The man examined the little bundle of fur for a long time ^ to see if it was alive.

The verb "examine" denotes a temporally unbounded activity, compatible with for *a* "long time." The verb "kick" on the other hand is telic, with an intrinsic beginning and end, and must be aspectually coerced (or typeshifted) to a verb that refers to a repeated activity. Presumably, the action of aspectual coercion is forced by the need to comprehend "for a long time," and requires processing capacity.

A third instance of research at the syntax/semantics interface was done by Frazier (1999). Among other topics, Frazier discussed the scope ambiguity of Sentence 13 (from Kurtzman & MacDonald 1993):

13. a. Every kid climbed a tree.
    b. A kid climbed every tree.

Although Sentence 13a could have either one or multiple trees (and Sentence 13b one or multiple kids), readers seem to prefer interpretations where the first quantifier takes logical scope over the second (e.g. in Sentence 13a, every kid could have his or her own tree). Frazier argued that this reflects a deeper fact, namely that scope interpretation takes place at Logical Form, where the quantifiers could appear in either order (giving rise to the ambiguity). She proposed a "minimal lowering hypothesis" to the effect that the language comprehension system moves phrases from their (high) position in the surface structure to other (lower) positions in Logical Form only if necessary. Frazier demonstrated how this principle accounts for a variety of observations, including the apparent fact that in the discourse, "Five ships appeared on the horizon. Three ships sank," the three ships are most often taken to be three of the five original ones, not three different ships.

EFFECTS OF CONTEXT ON SENTENCE PROCESSING

Meaning and syntax can interface in a different way. The situational or discourse context in which a sentence appears must affect how it is interpreted and may affect how it is parsed. The research examining how discourse affects parsing has largely been limited to one type of possible contextual influence, how the existence of one versus more than one possible discourse antecedent for a simple noun affects

the analysis of a phrase that might modify the noun (Altmann 1988, Altmann & Steedman 1988, Altmann et al 1994).

The motivation for this research came from Crain & Steedman (1985), who proposed that garden paths arise because of semantic selection principles. A reader or listener's syntactic knowledge makes available, in parallel, the possible interpretations of a phrase or sentence, and semantic principles guide the selection of one of these interpretations. Crain & Steedman assumed that analyzing a phrase as a modifier of a definite NP presupposes the existence of contrasting potential referents, and claimed that in isolation a modifier interpretation is semantically unpreferred because the reader/listener lacks the presupposed referents. If context provided these referents, then normal garden path preferences would disappear (see Clifton & Ferreira 1989, Steedman & Altmann 1989 for discussion).

Existing data do allow some fairly solid conclusions (Altmann 1988, Altmann & Steedman 1988, Altmann et al 1994, Britt 1994, Ferreira & Clifton 1986, Mitchell & Corley 1994, Murray & Liversedge 1994; see Mitchell 1994 for a summary). First, if a discourse contains two possible antecedents for an unmodified definite NP, the failure of the NP to refer will disrupt processing. Interpretation in this case seems to be nearly immediate. Second, if the out-of-context preference for the nonmodifier resolution of an ambiguity is weak (e.g. for a PP that is an optional argument of a verb), a context that supports the modifier resolution can greatly reduce or eliminate evidence for a garden path when the normally unpreferred analysis is selected. This may mean that context guided the initial analysis, but could simply reflect a much-facilitated revision. Third, while referential context can substantially reduce strong garden-path effects (involving, e.g. obligatory arguments of verbs, reduced relative clauses, or adverbs that could modify recent versus distant verbs), it cannot eliminate them.

It appears that garden paths do not simply result from a failure to satisfy semantic presuppositions. Structural factors are involved, perhaps in interaction with contextual factors, perhaps in a separate and modular fashion. A few studies of sentence processing in contexts other than one versus two antecedent referential contexts show some promise of shedding light on the relation between structural and semantic processing. Altmann et al (1998) used direct or indirect questions in discourse to vary the appropriateness of NP modification. Their contexts queried (e.g.) "When will Fiona implement the plan she proposed?" and then answered it with "She'll implement the plan she proposed last week." This answer is infelicitous; "last week" should have been the answer to the when question, which focused a modifier of the matrix verb implement. However, it is forced by its tense to modify the most recent verb, "proposed." Under certain conditions, Altmann et al observed that this infelicity eliminated the normal "late closure" preference for the adverb to modify the most recent verb, and in conjunction with other factors even seemed to reverse it.

Another apparently successful attempt to use context to eliminate a normally strong garden path is found in Trueswell & Tanenhaus (1991, 1992). They found that contexts that described a future event (e.g. "...tomorrow...a proctor will notice

one of the students cheating") largely eliminated the normal main clause preference for a following reduced relative clause like "The student spotted by the proctor..."

A promising new line of research creates a nonlinguistic context and sees how its contents influence the comprehension of words and sentences about it. Tanenhaus and his colleagues (e.g. Allopenna et al 1998, Eberhard et al 1995, Sedivy et al 1999, Tanenhaus et al 1995) extended a technique introduced by Cooper (1974) to study a person's eye movements while following verbal instructions about an array of objects. The speed of word identification seems to be affected by the set of possible referents; thus, the speed with which a person's eyes move to the candle when told to pick up the candle, is slowed by the presence of another object whose name begins with /kaen/. The contrasts that exist in an array affect the interpretation of adjectival modifiers; thus, fixation on a tall glass given an instruction to "touch the tall glass" is speeded when the array contains a contrasting short glass. The existence of two same-named referents in the array (e.g. two cups) that contrast in some attribute apparently facilitates interpretation of a PP as a postnominal modifier (e.g. the cup "on the napkin"), eliminating the out-of-context preference for the PP to be taken as the argument of a verb.

Only a few published examples of this research exist, and it may turn out that some of the apparently most interesting effects depend on as-yet-unexplored details of the procedure used (e.g. the possibility that the participant can use the properties of the array to anticipate the linguistic form that will be used). However, interesting extensions of the work are already appearing. For instance, Altmann & Kamide (1999) used it to examine how quickly referential interpretation takes place. Their subjects observed a scene on a video display and judged whether an auditory sentence could apply to the scene. Eye movements to a relevant target item were speeded when the verb in the sentence was stereotypically appropriate to the target item (e.g. participants looked more quickly at a picture of a cake when the sentence was "The boy will eat the cake" than when it was "The boy will move the cake"). Keysar et al (2000) used the technique to see whether listeners respect mutual knowledge in comprehending a speaker's utterances. Do they tend to look at a possible referent that they as listener can see although they know the speaker can't see it and wouldn't say anything about it? Keysar et al's answer is basically yes, mutual knowledge does not fully override other sentence comprehension preferences (cf Hanna et al 1997).

ANAPHORA AND LOCAL COHERENCE

The extent to which a sentence is coherent in its local context affects how it is processed. A major source of local coherence is co-reference relations between an anaphoric phrase in the current sentence and its antecedent in a preceding sentence. Research on anaphoric reference has focused on three general questions: how the form of the anaphoric phrase influences processing, what factors influence the

availability of various entities as antecedents, and what factors determine the ease of matching anaphor to antecedent.

Form of Anaphoric Phrase

Gordon, Grosz, and colleagues (Gordon et al 1993, Grosz et al 1995) have addressed these questions through centering theory. Under the assumptions of the theory, each noninitial utterance of a discourse has two kinds of centers, a backward-looking center (Cb) by which it is linked to the previous utterance and one or more forward–looking centers (Cfs), one of which will become the Cb for the next utterance. One critical prediction of centering theory is that a Cb must appear as a pronoun in order to signal its role in creating coherence.

The repeated-name penalty supports this claim. Reading times for sentences in discourse are longer when the Cb in the current utterance appears as a repeated name rather than as a pronoun (Gordon et al 1993). Structural factors influence interpretation of an entity in the current sentence as the Cb. For example, by varying the voice of the verb (passive versus active), Gordon & Chan (1995) found a repeated name penalty for entities appearing in subject position, regardless of whether they were also the agent of the verb, suggesting that grammatical structure of the current utterance rather than thematic structure governs identification of Cb.

Almor (1999) reinterpreted the repeated name penalty within a broader view of various types of anaphoric phrases including nonrepeated names. He claimed that anaphoric phrases can be characterized along a continuum of "informational load," which reflects how much information the anaphor conveys about its antecedent. In general, when an antecedent is relatively unavailable, a high informational load anaphor like a repeated name is required for successful coreference. In contrast, when an antecedent is relatively available (e.g. in focus in the preceding sentence), a high informational load anaphor is inappropriate and slows processing, producing a repeated name penalty.

Availability of Potential Antecedents

Several factors influence the relative availability of the entities mentioned in the preceding sentence as antecedents. Consistent with centering theory, structural factors such as syntactic role and serial position in the sentence influence anaphor availability (availability of the Cfs). Gordon and his colleagues (Gordon et al 1993, Gordon & Scearce 1995) found that pronouns are comprehended more quickly when their antecedents are the grammatical subject or the first-mentioned entity of the preceding sentence. These structural factors played a role in comprehension even in sentences where preceding semantic information disambiguated the pronoun (Gordon & Scearce 1995).

In contrast to the focus on structural factors, Stevenson et al (1994) found an influence of thematic role on the availability of antecedents from the preceding sentence. In a sentence continuation task, participants tended to continue with the goal in goal-source sentences, with the patient in agent-patient sentences, and

with the stimulus in experience-stimulus sentences. For example, in source-goal sentences like Sentence 14 participants tended to begin

14. a. John took the book from Phil.
    b. Phil gave the book to John.

with John (the goal) in their continuation regardless of whether John was mentioned first or second in the sentence. Stevenson et al claimed that the preferred continuation entities are represented as part of the consequences of the preceding event and consequences are in focus. Whereas grammatical position of the entity had no effect on the content of continuations, grammatical position did influence the form of the anaphoric phrase used. When the antecedent was the subject of the sentence, a pronoun was used as the anaphor; when the antecedent was not the first-mentioned entity in the sentence, the tendency was to use a repeated name. This suggests that thematic role in the mental model influences which entities are initially in focus and available as antecedents, and structural constraints influence the actual form of the anaphor.

Sanford et al (1996) and Paterson et al (1998) investigated the effect of quantifiers on focus. A positive quantifier ("a few" in Sentence 15a) seemed to create a focus on the set of items being referred to in the quantified phrase, facilitating a subsequent anaphoric reference to that reference set. In contrast, a negative quantifier ("few" in Sentence 15b) permitted the MPs who did not attend to be in focus.

15. a. A few of the MPs attended the meeting.
    b. Few of the MPs attended the meeting.

Matching Antecedent to Anaphor

Chambers & Smyth (1998) found that structural parallelism plays a role in coherence relations between sentences. Their readers tended to interpret a pronoun in a sentence as co-referential with an entity in a parallel structural position in the preceding sentence. In contrast to the predictions of centering theory, a pronoun in direct object position is most readily interpreted as coreferential with the entity in direct object position in the preceding sentence. Furthermore, they found a repeated name penalty for an entity that was coreferential with an entity in a parallel position in the preceding sentence. Critically, this occurred for entities in nonsubject position as well as subject position and occurred even when a pronoun in subject position provided the standard Cb predicted by centering theory. This research suggests that other structural constraints are operating in the ranking of Cfs and that a sentence may have more than one Cb when it has multiple entities, each of which is coreferential with entities in parallel position in the preceding sentence.

A number of recent studies investigated the effect of another purely structural characteristic of pronouns, grammatical gender independent of meaning, by using languages other than English. Garnham et al (1995) looked at reading times

for sentences in both Spanish and French containing a target pronoun with grammatical gender (e.g. *lo* versus *la* in Spanish and *il* versus *elle* in French). The advantage of using these languages is that these pronouns are appropriately used to refer to entities with grammatical gender but no semantic gender (e.g. the feminine pronoun *la* can refer to a table, which is grammatically feminine but has no semantic gender). Garnham et al (1995) found effects of grammatical gender on the comprehension of pronouns whose antecedents had no semantic gender. Cacciari et al (1997) found similar effects in Italian using epicenes, a class of words whose grammatical gender does not always match the semantic gender of their referents (e.g. in Italian *la vittima* (the victim) is grammatically female, but it can refer to a male individual).

MEMORY AND KNOWLEDGE IN DISCOURSE COMPREHENSION

Early models of discourse comprehension focused on the process of establishing links between sentences that were relatively close in the discourse (Haviland & Clark 1974, Kintsch & van Dijk 1978). It was assumed that information in long-term memory (LTM) (either world knowledge or the portion of the text representation that resides in LTM) was retrieved through an effortful and time-consuming search only when there was a local coherence break in which no local connection could be established. More recent work, however, has established that some critical LTM information is retrieved in the absence of local coherence breaks and seems to be retrieved effortlessly. Two current models, the memory-based models and constructionist models, address the question of how to characterize this process.

Memory-Based Models

During the 1980s researchers in sentence processing developed the concept of modularity, in which fast, highly-specialized processors did the initial work in activating word meaning and determining syntactic structure for a sentence. These processors were fast because they were "dumb." They took as input only a small set of the data available to them and ignored other potentially useful information. For example, the lexical access processor ignored prior context and the syntactic processor ignored meaning.

A similar approach has recently been taken in the memory-based models of discourse processing. In these models, beginning with Kintsch's (1988) construction-integration model and McKoon & Ratcliff's (1992) minimalist model, and extending to current memory-based models (McKoon et al 1996, Myers & O'Brien 1998), activation of related information from LTM is assumed to be a passive, automatic process that occurs continually during comprehension. All concepts currently in short-term memory serve as cues that broadcast a signal in parallel to the contents

of LTM. Information in LTM is activated through a passive resonance process, with level of activation for a given item determined by overlap in semantic features and strength (but not type) of association between activated item and cue.

This model is able to account for a number of findings in the literature where lengthened reading times are observed for sentences that are locally coherent but that conflict with information presented in a distant sentence earlier in the text. For example, Albrecht & O'Brien (1993) asked participants to read long passages in which the main character Mary was introduced as a strict vegetarian. After 6 filler sentences, the reader encountered the target sentence in which Mary ordered a cheeseburger and fries. This sentence was locally coherent with the preceding sentence, but reading times for this sentence were longer than in a neutral version of the paragraph that gave no preliminary information about Mary's eating habits. A memory-based model accounts for this result by claiming that the concept of vegetarian was re-activated through a resonance process initiated by the word "cheeseburger." This allowed the reader to detect the inconsistency in the text.

Evidence that this resonance process has the dumb characteristic of earlier modular processors was provided in follow-up studies (O'Brien et al 1998), in which similar results were obtained even when the concept of vegetarian was linked to Mary through a statement that made it clear that she was not a vegetarian (e.g. participants read that Mary had once been a vegetarian but wasn't any more). Findings such as these support the claim that the initial resonance process is a dumb process that is insensitive to the precise nature of the syntactic and semantic relationships among the relevant concepts.

Memory-based processing has also been used to account for readers' ability to comprehend "unheralded pronouns" whose antecedents do not appear in the immediately preceding discourse context (Greene et al 1994, McKoon et al 1996). For example, in one paragraph, Jane and Gloria discuss Jane's invitation to dinner at her cousin's (the target individual). While Jane goes off to her cousin's, the text remains with Gloria at home. Finally, a reunion sentence brings Gloria and Jane back together, and Gloria asks Jane, "Did she play you old disco records?" The pronoun "she" (referring to the cousin, who has not been mentioned since the introduction) is unheralded. Results from a probe recognition task indicated that the concept "cousin" increased in availability immediately after the reunion sentence (before the pronoun referring to the cousin was encountered). This result can be accounted for by a resonance process in which "cousin" is re-activated by the reunion sentence. Thus, it is not the unheralded pronoun itself that does the work of retrieving its distant antecedent. Rather, it is the reunion sentence that does the work through memory-based processing.

Constructionist Models

An alternative to the memory-based view is the constructionist view of text comprehension (Graesser et al 1994). According to this view, text comprehension involves a more active and intelligent "search after meaning." Comprehension of

narrative text is assumed to involve building a representation of the causal relations among events in the text, where events are classified by types (e.g. goals, reactions, actions) reminiscent of the categories proposed in the original story grammars. Within this representation a character's goals have special status because an as-yet-unsatisfied goal can provide a causal antecedent for many events in the narrative, including events quite distant from the initial goal statement. Evidence for the critical status of unsatisfied goals was established by Suh & Trabasso (1993). In their texts, a character's initial goal was either immediately satisfied or was not. For example, Jimmy wanted a new bicycle (goal). In the goal-satisfied version, Jimmy's mother immediately bought him a bicycle; in the goal-unsatisfied version, she did not. Several sentences later Jimmy has earned a large amount of money and heads for a department store where, in the case of the goal-unsatisfied version of the story, one might infer that he was intending to buy a bicycle (finally satisfying his distant goal). Suh & Trabasso provided evidence that this is indeed what readers inferred. In particular, they found that the bicycle goal was much more available after the sentence in which Jimmy headed for the department store in the goal-unsatisfied version of the text than in the goal-satisfied version.

This kind of result would seem to be evidence against a dumb memory-based process like the resonance process. In both the goal-satisfied and goal-unsatisfied version of the stories there is the same featural overlap and distance between the original goal sentence ("Jimmy wanted to have a new bike") and the critical sentence ("He went to a department store"). In this analysis, the resonance process operating at the critical sentence should activate the goal equally in the goal-satisfied versus goal-unsatisfied version. However, Lutz & Radvansky (1997) observed that in the goal-unsatisfied version of the story, the goal is more likely to be linked to later sentences in the text than in the goal-satisfied version. Because it is more interconnected with other concepts in the text that the target sentence may activate, the unsatisfied goal is more likely to be activated by the target sentence than the satisfied goal.

Albrecht & Myers (1995) illustrated the importance of this interconnectivity. In one example paragraph Mary had to make an airline reservation by midnight (goal). The target sentence occurs later in the text: "She was tired and decided to go to bed." Albrecht & Myers found that this sentence was not sufficient to reactivate the unsatisfied goal when it was distant in the text. In a modification of the text, the authors introduced a critical concept that provided the interconnection. After the initial goal statement, Mary sits down on her leather couch to look up the phone number in the telephone book (in the unsatisfied goal version, she is interrupted before she calls the airline). Mentioning the leather couch again immediately before Mary decides to go to bed was sufficient to reactivate the goal even when the goal was distant. Notice that the leather couch is arbitrarily associated with the airline reservation goal rather than being related through the kind of causal connection that is important in constructionist models. The fact that this arbitrary connection was sufficient to trigger activation of an unsatisfied goal lends support

to claims of memory-based models that the resonance process is insensitive to type of connection.

Although these models are frequently seen as being in opposition to each other, it is not clear that they have to be. Myers & O'Brien (1998) presented the resonance process as the first stage of the comprehension process. A later stage of processing (unspecified in their theory) makes use of the information activated in the resonance stage. This later stage might be sensitive to the type of propositions activated (e.g. unsatisfied versus satisfied goals) and to the relations among the critical concepts (e.g. Mary is or is not a vegetarian). Indeed, Rizzella & O'Brien (1996) suggested that the resonance process might be conceptualized as the first stage in a constructionist model.

Mental Models

Another traditional focus has been on characterizing the mental representation that is created through the comprehension process. During the "local coherence" phase of research on discourse processing, the focus was on the construction of a textbase that preserved the propositions of the individual sentences with their connections (through argument overlap) with other propositions in the text. As processing research has come to focus on the creation of links between distant sentences in the text, research on discourse representation has come to focus on a new representation, variously labeled a situation model (van Dijk & Kintsch 1983) or a mental model (Johnson-Laird 1983). In contrast to a propositional textbase, a mental model is a representation of what the text is about rather than of the text itself. This representation includes information relevant to the constructionist model of comprehension (i.e. causal relations among events, protagonists' goals) as well as spatial and temporal information relevant to the text. Although it has a constructionist flavor, the mental model view has supporters on both sides of the memory-based versus constructionist model debate (e.g. O'Brien & Albrecht 1992, Zwaan et al 1995a).

Much of the research that initially motivated the constructionist model of comprehension provided evidence that readers represent causal relations among events. In addition, several studies provided evidence for the preservation of spatial information. In an early study, Glenberg, Meyer and Lindem (1987) found that a target concept (e.g. a sweatshirt) that remained physically close to the protagonist (the protagonist put on the sweatshirt and then jogged around the track) remained more available during comprehension than the same concept when it was physically distant from the protagonist (the protagonist took off the sweatshirt and then jogged around the track). Furthermore, O'Brien & Albrecht (1992) found that readers keep track of the spatial location of protagonists in narrative, taking longer to comprehend a sentence that conflicted with an earlier sentence about protagonist location.

Recently, Zwaan (1996) investigated the claim that temporal relationships among events are reflected in the reader's mental model. Drawing upon work

of Dowty (1986), he outlined the "strong iconicity assumption," in which readers assume that (*a*) events took place in the order in which they are mentioned in a text and (*b*) successively mentioned events are contiguous in time. Time adverbials can overturn these default assumptions, but the cost is processing time. Evidence for the first iconicity assumption already existed; Mandler (1986) and Ohtsuka & Brewer (1992) found that reading time for sentences increased when the chronological order of events in the sentences does not match the order of their occurrence. So Zwaan (1996) focused on testing the contiguity assumption, creating texts in which a second target event did or did not occur immediately after a first target event (see also Anderson et al 1983). For example, in a text about the opening of Maurice's new art gallery, Maurice is shaking hands and beaming, and in the next sentence he turned very pale. However, this second event is introduced by one of three time adverbials: "a moment later" or "an hour later" or "a day later". The first adverbial preserves the contiguity assumption and the other two violate it. Zwaan demonstrated that reading times for the second event were longer when the two events were not contiguous in time, supporting the contiguity assumption.

Zwaan et al (1995a) have proposed the event-indexing model, a specific version of a mental or situation model. Under the assumptions of this model the reader keeps track of the current situation or state of the textual world at each sentence. Five indices of the current situation are coded: spatial location, time, protagonist, cause, and goals. If an incoming event differs from the preceding event on one or more of these indices (e.g. it conveys a change in time or location or an event that is causally unrelated to the immediately preceding events), then the current situation model must be updated to reflect this change. This leads to two predictions. First, a sentence that elicits this updating will take longer to read than a sentence that does not. Second, the distance between events in the mental model will be determined by number of shared situational indices. Zwaan et al (1995b) provided evidence for the first prediction in a study in which they found that reading times for sentences in naturalistic texts were positively correlated with the number of indices that needed updating for the sentence. Zwaan et al (1995a) provided evidence for the second claim by demonstrating that in a verb-clustering task, readers' judgments of which verbs from a text "belonged together" reflected the number of shared situational indices among the verbs.

The event-indexing model provides a new answer to an old question. One of the insights in the original Kintsch and van Dijk (1978) model was that the critical linking processes in discourse comprehension are carried out on the contents of working memory. This raised the question of what already-comprehended information would have the privilege of being held in working memory as the reader went on to read the next sentence. A variety of answers to this question have been proposed over the years. Zwaan et al (1995a) continue this tradition by proposing a new answer: what is held over is the current situation (who, where, when, cause, and goal).

A FINAL WORD

One must go beyond linguistic structure to understand fully how sentences and texts are understood. Still, our examination of the recent literature on sentence and text comprehension convinces us that there is much to be learned by continuing to study the various roles that linguistic structure play in the process. We have had to overlook a great many interesting topics, including the use of evoked brain potentials to study sentence processing, immediacy in language comprehension, the comprehension of sentences with long-distance dependencies, and the role of discourse context in word recognition, to name only a few. We can only hope that our presentation of the material we were able to discuss has convinced the reader that our belief in the value of studying structural factors in comprehension is not misplaced.

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