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ABSTRACT

This research disproves the hypothesis that less-skilled comprehenders are less able to take advantage of constraints at all levels of structure. Five studies used self-paced reading, meaning probe judgment, recall, and sentence and word recognition tasks to examine the effect of supportive discourse contexts on sentence processing in skilled and average comprehenders. The results support a model in which comprehenders develop distinct sentence and discourse representations simultaneously, with limited sharing of information and processing resources. The studies suggest three conditions under which discourse information may influence on-line comprehension. To influence discourse integration, comprehenders must have produced a conceptual representation on which discourse processes can operate (the natural unit hypothesis). To influence syntactic processing, comprehenders must assign a sentence representation to the relevant discourse-based prediction (the linguistic prediction hypothesis). To influence discourse processes, the discourse information must be relevant for the emerging discourse representation (the discourse representation hypothesis). These constraints apply equally at different levels of comprehension skill. However, skilled comprehenders focus processing resources more on discourse representations, whereas average comprehenders focus resources more on sentence representations. (Five tables and six figures of data are included; contains 115 references. (Author)

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Sentence and Discourse Processes in Skilled Comprehension

David J. Townsend

Abstract

This research disproves the hypothesis that less-skilled comprehenders are less able to take advantage of constraints at all levels of structure. Five studies used self-paced reading, meaning probe judgment, recall, and sentence and word recognition tasks to examine the effect of supportive discourse contexts on sentence processing in skilled and average comprehenders. The results support a model in which comprehenders develop distinct sentence and discourse representations simultaneously, with limited sharing of information and processing resources. The studies suggest three conditions under which discourse information may influence on-line comprehension. To influence discourse integration, comprehenders must have produced a conceptual representation on which discourse processes can operate (the *natural unit hypothesis).* To influence syntactic processing, comprehenders must assign a sentence representation to the relevant discourse-based prediction (the *linguistic prediction hypothesis).* To influence discourse processes, the discourse information must be relevant for the emerging discourse representation (the *discourse representation hypothesis).* These constraints apply equally at different levels of comprehension skill. However, skilled comprehenders focus processing resources more on discourse representations, whereas average comprehenders focus resources more on sentence representations.

A central issue in research on language understanding is the relationship between discourse processes and sentence processes. I use the term "discourse processes" to refer to those processes that obtain an integrated representation of discourse by establishing cohesion across sentences in text. One type of discourse cohesion involves determining how the surrounding context influences the appropriate interpretation of a sentence, as when "Harry drove the car from Detroit" takes on a different meaning in a story about a tour of midwestern cities than in a story about deciding whether to purchase an American car or a foreign car. Discourse cohesion also requires determining semantic relations between sentences (e.g., Haberlandt and Bingham, 1984; Obrien and Myers, 1987; Schank and Abelson, 1977; Trabasso, van den Broek, and Suy, 1989) and the antecedents of referring expressions (e.g., Garnham, Oakhill, and Johnson-Laird, 1982; Gernsbacher, 1989; Haviland and Clark, 1974; Kintsch and van Dijk, 1978). The result of discourse processes is a conceptual representation of the semantic content of text in which details about sentence structure are less prominent.

I use the term "sentence processes" to refer to those processes that use details about the lexical and syntactic structure of sentences to form the semantic units of discourse representations. One result of sentence processes is the organization of words into groups that correspond to these semantic units. This aspect of sentence processes accounts in part for the oddness of sentences like *The car raced through the intersection crashed.* Sentence processes also determine the thematic roles of phrases within semantic units of discourse. For example, they determine that *manual* is the object of *read* in *Which manual did the driver read in the car?*, but *mechanic* is the object of *remind* in *Which manual did the driver remind the mechanic to read?* (cf., Tanenhaus, Carlson, and Trueswell, 1989). And they determine that *warning* is an adjective that modifies *lights* in *Warning lights signal mechanical problems*, whereas *removing* is a verb that takes *tires* as its object in *Removing the tires requires a jack* (cf., Townsend and Bever, 1982). The result of sentence processes, in principle, is a syntactically and thematically-structured representation of the lexical content of a sentence that is independent of the discourse representation.

Despite agreement that the properties of sentences differ from those of discourses, there is wide disagreement about their relationship in comprehension. There is evidence that comprehenders may not determine sentence properties independently *of* the emerging discourse representation. For example, very fast shadowers can restore mispronounced

words from connected speech at delays *of* 250 msec and still be sensitive to properties of syntactic and semantic context (Marslen-Wilson, 1975). Thus, word recognition processes have almost immediate access to sentence and discourse constraints. One interpretation *of* this result is that comprehenders map words directly onto a complete discourse representation without any independent representation of syntactic information (Marslen-Wilson and Tyler, 1987; Schank and Birnbaum, 1984; Taraban and McClelland, 1988; Tyler and Marslen-Wilson, 1977). I shall refer to this view as the *direct model* of comprehension. The following quotes illustrate some expressions of this view:

> There is no level of symbolic representation mediating between lexical representations and mental models. Instead, there are procedures and mechanisms for mapping the one onto the other; for using the information provided by what the speaker is saying to construct a representation of his intended message. (Marslen-Wilson and Tyler, 1987, p.59-60).
>
> When an abstract script is aroused, it activates memory nodes representing the script actions. Each such memory node is similar to a logogen... which accepts and accumulates activation ("evidence") from prior context and from present sensory input. Activation of the overall script brings the activation level of script actions close to the firing threshold. Hence, relatively little sensory evidence directed to an action node is required in order for it to be perceived. Also, expected stimulus patterns should be identified rapidly because their logogens have been brought near firing threshold by the context alone. (Bower, Black, and Turner, 1979, p. 206).
>
> ...the decision whether to use syntactic knowledge or conceptual knowledge is made by a single control structure, and whatever available knowledge is most useful is applied in trying to analyze and understand the input. (Schank and Birnbaum, 1984, p. 218).

In general, direct models assume that there is a single comprehension process that uses all available information and processing resources for obtaining a discourse representation directly from representations of lexical form. This assumption has the consequence that information about properties of words, sentences, and discourses are equally available throughout the comprehension process.

On the other hand, there is also evidence that sentence processes are distinct in some way from discourse processes. The complexity of ambiguous sentences even when they appear in disambiguating contexts supports the independence of sentence processes from discourse information (e.g., Bever, Garrett, and Hurtig, 1973; Ferreira and Clifton, 1986; Gorrell, 1989; Hurtig, 1978; Seidenberg, Tanenhaus, Leiman, and Bienkowski, 1982; Swinney, 1979; Townsend and Bever, 1982). For example, Rayner, Carlson, and Frazier (1983) found that fixation times on the final word were longer in *The spy saw the cop with the revolver* than in *The spy saw the cop with the binoculars*, which has a simpler syntactic structure. Such observations suggest that the process that determines whether the prepositional phrase is associated with *saw* or the *cop* does not have immediate access to information about real world plausibility. This is surprising for two reasons. Information about plausibility conceivably could simplify selection of an appropriate phrase structure. In addition, the discourse representation presumably encodes only the more plausible structure.

The resolution of this controversy about the relationship between sentence and discourse processes during comprehension depends on how quickly comprehenders access different types of representations. If comprehenders form sentence representations independently of discourse representations, but have relatively greater access to discourse representations, their behavior might give the appearance of direct mapping from words to discourse representations. Conversely, if comprehenders have relatively poor access to discourse representations, their sentence processing behavior might give the appearance of being independent of discourse constraints. Unfortunately, it has been a tricky problem to isolate access to only one type of representation. The present research explores the relationship

between sentence and discourse processes by examining one factor that clearly is related to accessibility to discourse representations -- comprehension skill. Skilled comprehenders, by definition, obtain a better understanding of discourse, though various approaches differ significantly in their explanations of how they achieve this.

The plan is to present first a specific direct model that makes explicit claims about individual differences in accessibility to sentence and discourse representations. Then I develop an alternative model, a *representational model*, in which sentence and discourse processes occur simultaneously and independently, but share some processing resources. Then I test the representational model of individual variations in comprehension skill against the direct model of comprehension and comprehension skill.

A Direct Model

Direct models maintain that, if comprehenders compute sentence properties at all, they compute them only as by-products of the discourse representation. Since these models propose no independent level of representation of sentence information, there are only two ways in which they can explain individual variability in comprehension. First, there may be individual variations in word recognition processes. If an individual is less-skilled at recognizing printed or spoken words, the mapping of words onto the discourse representation will be less effective. Assuming that word recognition skills are not at issue, as may be the case with mature comprehenders, the only other possible source of individual differences in comprehension is how readily comprehenders access relevant higher-level knowledge. If an individual does not possess the relevant knowledge, or is slow in accessing it, comprehension will suffer.

An example of a direct model that chooses the second option is the structure building framework (e.g., Gernsbacher, 1985). Like all direct models, this one explains comprehension without distinguishing sentence representations and discourse representations. According to this approach, an incoming word activates a memory cell, which in turn activates "similar" memory cells and suppresses "dissimilar" memory cells. Early words in a sentence serve as the foundation for the emerging discourse structure. Later words that are incongruous with earlier words activate different memory cells and initiate a process of building a new structure. A critical issue is what constitutes an incongruity between words, and several conditions have been identified. These conditions include a wide variety of sentence and discourse constraints:

> (a) An incongruity may occur at the beginning of a new phrase, sentence, topic, point of view, setting, or episode (Gernsbacher, 1985). The evidence for this claim comes from a variety of studies that show that reading times and monitoring times are greater at the beginnings of phrases, sentences, episodes, and texts (e.g., Aaronson and Scarborough, 1976; Cirilo and Foss, 1980; Marslen-Wilson and Tyler, 1975; Haberlandt, Berian, and Sandson, 1980). The increased times suggest that the new information at the beginning of a unit of any size requires building a new structure that is incongruous with preceding information.
>
> (b) Subordinating conjunctions like *because*, *when*, and *since*, and "adverbial leads" like *then* and *next* may also signal a new structure (Gernsbacher, in press). The evidence for this claim comes from a study that showed that the presence of *then* or *next* at the beginning of a target sentence increased time to read the sentence. The fact that these adverbial leads also decreased question-answering latencies for information in the target sentence relative to those for information in a preceding sentence suggests that adverbial leads initiate a new structure.
>
> (c) Sentences that are causally-related are relatively congruent with the preceding sentence (Gernsbacher, 1985). The evidence for this claim is that an increase in the causal relatedness between sentences decreases reading time and improves cued recall.

The list of conditions that "signal" new structures includes syntactic information (phrase and sentence boundaries), semantic information (e.g., episodes, settings, and causal relations), and a combination of both (conjunctions and adverbial leads). In each case, the comprehender initiates a new structure. The *processing shift hypothesis* maintains that building a new structure causes comprehenders to forget surface information (cf., Caplan, 1972; Chang, 1980; Jarvella, 1971; Johnson-Laird and Stevenson, 1970; Rodriguez, Ravelo, and Townsend, 1980; Sachs, 1967, 1974; von Eckhardt and Potter, 1985).

An alternative account of forgetting is the *integration hypothesis*. The integration hypothesis attributes loss of surface information to the integration of sentence-level details into a representation of meaning. Unlike the processing shift hypothesis, the integration hypothesis distinguishes surface information from meaning. Studies of the processing of stories with sentences that are either scrambled or normally-ordered support the processing shift hypothesis over the integration hypothesis. Since it is harder to comprehend a story when its sentences are scrambled, there is less integration of surface information into a discourse representation; therefore, the integration hypothesis predicts less forgetting of surface details. However, scrambling the sentences of a story decreases discourse constraints between sentences and therefore causes comprehenders to build more new structures, and lose more surface information. Gernsbacher (1985; Gernsbacher, Varner, and Faust, 1990) found that surface information loss was greater in scrambled stories than in normal stories, supporting the processing shift hypothesis.

According to the structure building framework, less-skilled comprehenders are less able to suppress contextually irrelevant memory cells (Gernsbacher, in press). Since these irrelevant memory cells remain active, new words that are unrelated to them will produce processing shifts. As a result, less-skilled comprehenders initiate more new structures and forget more surface information. Two pieces of evidence support the failure-to-suppress explanation of less-skilled comprehension. First, Gernsbacher et al. (1990) found that less skilled comprehenders maintain contextually-irrelevant interpretations of ambiguous words longer than more-skilled comprehenders. For example, less-skilled comprehenders retain the tendency to accept *ace* as being consistent with *He dug a hole with a spade* longer than do more skilled comprehenders. That is, less-skilled comprehenders do not take advantage of constraints within sentences. Second, compared to skilled comprehenders, scrambling the sentences of a story has smaller effects on less-skilled comprehenders' ability to recognize probe sentences that are superficially different from sentences that actually occurred in the stories (Gernsbacher, 1985). This result suggests that less-skilled comprehenders engage in processing shifts to the same extent whether sentences are scrambled or normally-ordered. That is, less-skilled comprehenders do not take advantage of the discourse constraints that exist in normal text.

The structure-building framework does not distinguish between sentence-level constraints and discourse-level constraints. As Gernsbacher, Hargreaves, and Beeman (1989) state:

> ...semantic, lexical, and verbatim information all become more accessible at the same time, and they all become less accessible at the same time. (p. 752).

The consequence of this claim is that both sentence and discourse constraints can activate memory cells, and enable faster recognition of words that correspond to the activated memory cells. Skilled comprehenders suppress memory cells that do not match sentence-level or discourse-level constraints on a word, but average comprehenders keep irrelevant memory cells activated. This reasoning suggests that less-skilled comprehenders will show *smaller* effects of both sentence-level and discourse-level constraints.

Evidence Against Direct Models

There is, however, evidence against the claim that accessing semantic, lexical, and verbatim information are equivalent. In fact, access to different levels of representation often are related *inversely:*

(a) Townsend and Ravelo (1980) found that response times to accept a picture as depicting the meaning of a clause are faster for pictures about initial clauses than for pictures about final clauses. This result was clearest for coordinate sentences like *The goat threw the ball and he pulled the wagon*, for which a picture of a goat throwing a ball was accepted faster than one of a goat pulling a wagon. Yet, response times on a word probe recognition task are faster for words in final clauses than in initial clauses (Townsend, Ottaviano, and Bever, 1979). For example, response times to say that *touched* occurred are faster than those for *scratched* in *The owl scratched the fox and he touched the monkey*. These findings indicate that tasks that tap lexical versus semantic representations interact with the position of information in sentences: lexical information is more accessible from final clauses than from initial clauses, but semantic information is more accessible from initial clauses than from final clauses. In both of these studies, however, response times depended on structural and semantic properties of clauses as well as clause position.

(b) Bever and Townsend (1979, Experiment 3) reported that word probe recognition times are faster following passive sentences than active sentences. For example, word probe recognition times are faster for *killed* following *When Sam left the house for a week, the parrot was killed by the cat* compared to *When Sam left the house for a week, the cat killed the parrot*. However, it is easier to comprehend active sentences (e.g., Forster and Olbrei, 1973, Olson and Filby, 1972; Slobin, 1966). Townsend (1983, Experiment 2) confirmed that conceptual representations are more accessible in the active versions of the materials in Bever and Townsend (1979) by showing that subjects immediately answer questions like *Who killed the parrot?* and *Who did the cat kill?* faster for active clauses than for passive clauses. Thus, tasks that assess accessibility to lexical versus semantic representations interact with the syntactic properties of sentences.

(c) Townsend and Bever (1978) found that surface details such as the location of up in *Though Pete called up his aunt each...* versus *Though Pete called his aunt up each...* influence word probe recognition more in adversative clauses (e.g., *though*) than in causal clauses (e.g., *if*). They also found that the meaning of a causal clause is more accessible on-line, compared to the meaning of an adversative clause: subjects are faster to judge that *using the telephone* is synonymous with *If Pete called up his aunt each...* than with *Though Pete called up his aunt each...* Similar results occur in monitoring for synonyms versus nonsense syllables (Townsend, Hoover, and Bever, in preparation), and in naming words that are syntactically congruent versus incongruent with preceding sentence constraints (Townsend, 1983, Experiment 3). For example, naming times for *is* are faster in *If tying shoelaces is...* than in *If diving submarines is...*, but there is no difference in naming times for *Though tying shoelaces is...* versus *Though diving submarines is...* Thus, tasks that assess accessibility to meaning versus word order, transitivity information in verbs, and lexical status of phoneme sequences all interact with discourse-level properties of clauses: when meaning is more accessible, surface properties are less accessible, and vice versa.

(d) Townsend (1983) reported a number of behavioral differences among the connectives *since, while, though, if, because, after, when, and, before, therefore, afterward, meanwhile, previously,* and *however*. These differences depend on the discourse-level meanings of connectives. For example, Townsend (1983, Experiment 3) found that lexical information from adversative clauses is more likely to prime similar lexical items in a subsequent clause, compared to lexical information from causal clauses. This was shown by the fact that word naming times for the second occurrence of *is* are faster in *Though the pilot is required to attend flight school, landing planes is...* than in *If the pilot is required to attend flight school, landing planes is...* Since *though* denies a causal relation, this result contradicts the claim causal coherence reduces surface information loss. Conversely, connectives that preserve the typical causal ordering of narratives facilitate comprehension as measured by propositional recall, reading times, question answering times, and continuation times (see also Amidon and Carey, 1972; Charon, Micko, and Thuring, 1988; Clark and Clark, 1968; Smith and McMahon, 1970). For example, average reading times per word for the second sentence of *Harry began raising snakes on the farm. Kids visited the farm everyday* are faster when it is introduced by *therefore*, which marks a conclusion or effect, than when it has no connective (Townsend, 1983, Experiment 6). But reading times

are faster for the no-connective condition than when the second sentence is introduced by *however*, which denies a causal relation between the two sentences.

(e) Loss of sentence-level information depends as well on the structural presuppositional properties of clauses (Kornfeld, 1973; Shedletsky, 1981; Townsend and Bever, 1977, 1978; Townsend et al., 1979; Tyler and Marslen-Wilson, 1978). For example, word probe recognition times generally are faster and more sensitive to word order in subordinate clauses than in main clauses. Surface information loss also depends on the extent to which language relies on fixed word order (Gergely, 1984). For example, the word order effects of Townsend and Bever (1978) do not occur in Hungarian, which has a relatively free word order, even though synonymy judgment times for causal versus adversative clauses in Hungarian differ as in English.

(f) These opposing effects of complexity on access to meaning versus form in more on-line tasks appear in longer term measures of performance as well. For example, Townsend and Saltz (1972) found that when sentences are semantically related, recall is less sensitive to phrase structure but recall of the major functional concepts (agent, action, patient) is enhanced. However, when sentences are anomalous, phrase structure has greater effects on recall, and recall of major functional concepts is reduced.

(g) Recognition of surface details is less accurate for sentences that appear later in a story, just as their recognition is less accurate in stories with scrambled rather than normally ordered sentences (Gernsbacher, 1985; Gernsbacher et al., 1990). The greater surface information loss for sentences that occur later in stories contradicts the claim that their faster reading times are due to fewer processing shifts, which should *improve* recognition of surface details.

(h) There is evidence as well for a distinction between ordered and un-ordered representations in non-linguistic information processing. For example, subjects can adjust scanning strategies for representations of sequences of digits and letters to either emphasize or de-emphasize order information (Bever and Townsend, 1979, Experiment 4). In addition, details that are less relevant for the conceptual content of a picture are not retained as well as those that are conceptually important (Mandler and Ritchey, 1977; see Anderson, 1990 for a review).

Each of these studies demonstrates a distinction between accessing information about the meaning versus form of a stimulus. The fact that conditions that reduce accessibility to one increase accessibility to the other suggests that representations of meaning and form have different roles in comprehension.

Evidence on comprehension skill also conflicts with the claims of the structure building framework. Townsend, Carrithers, and Bever (1987) gave a battery of sentence processing tests to adult skilled and average comprehenders:

(i) In one test, subjects heard narrative and expository texts that consisted of 550 words. As expected, average comprehenders performed less accurately than skilled comprehenders on subsequent comprehension questions. Surprisingly, they also performed *more* accurately than skilled comprehenders on a subsequent sentence recognition test (Townsend and Bever, 1983). For example, if a sentence like *The carrier's deck was rising and falling, rolling from side to side, and pitching from end to end,* had appeared in the text, average comprehenders were more likely to reject *The deck of the carrier was rising and falling, rolling from side to side, and pitching from end to end.* This result contradicts the claim that average comprehenders display greater surface information loss than skilled comprehenders.

(j) In a tone location task (e.g., Garrett, Fodor, and Bever, 1966), the performance of average comprehenders depended more on the location of tones with respect to clause boundaries, compared to skilled comprehenders. That is, given a sentence like *Because she is a sweet cute gi*$_1$*rl* $_2$ *boys asked her out often,* with a brief tone located at the point of one of the subscripts, all subjects were most accurate in locating tones that had occurred at point 2. However, average comprehenders showed a significantly greater difference in accuracy

between point 2 and points 1 and 3, relative to skilled comprehenders. This result suggests that average comprehenders are *more* sensitive than skilled comprehenders to constraints on sentence structure. If average comprehenders fail to suppress irrelevant memory cells, they should show smaller effects of these constraints.

(k) In the word probe task of Townsend and Bever (1978), average comprehenders responded faster than skilled comprehenders. Thus, average comprehenders have faster access to the lexical content of recently-heard sentence fragments, contrary to the claim that they show a greater loss of surface information. Furthermore, skilled comprehenders show a greater advantage for early targets compared to late targets in though-fragments, relative to if-fragments. This result suggests that skilled comprehenders' retention of surface details depends on the discourse function of the clause. Average comprehenders did not show a larger early advantage effect for *though* than for if.

(l) The studies reported in Townsend et al. (1987) suggest that surface details of sentences influence reading, listening, and memory more for less-skilled comprehenders than for skilled comprehenders. There are also demonstrations that the surface form of context sentences has greater effects on word reading times for less-skilled readers than for more skilled readers at the grade school level (Leu et al., 1986). Similarly, bilingual subjects show better sentence recognition accuracy in their weaker language than in their stronger language, but, of course, better propositional recall in their stronger language (Watanabe and Okushi, 1986). Thus, a lower level of mastery of a language leads to relatively stronger memory for form and weaker memory for meaning. In addition, research on skill in content domains such as physics demonstrates that less-skilled individuals are more influenced by surface details (e.g., Dee-Lucas and Larkin, 1988).

Each of these studies demonstrated differential access to more superficial "sentence" representations versus more conceptual "discourse" representations. However, direct models rely heavily on discourse-level constraints. Since many of the studies cited above used materials with minimal contexts -- such as single sentences or even fragments of single sentences -- they may not be a fair test of direct models. A fairer test would use texts that are rich in "thematic integrity." In other words, direct theorists might argue that the psychological distinction between meaning and form is valid only for sentences that appear out of natural contexts, when the "last resort" of processing for form becomes necessary When sentences appear in a natural context, comprehension processes may draw on semantic constraints. To be equally fair, however, it should be noted that much of the evidence for the processing shift account of comprehension skill comes from studies of sentences in isolation and scrambled stories, which also differ from natural texts. Thus, the evidence against direct models seemed to warrant the development of an account of comprehension skill that (a) distinguishes sentence and discourse representations, and (b) accounts for the apparent equivalence between sentence and discourse representations during comprehension. The next section presents a representational account of comprehension skill.

A Representational Model

The representational model has three assumptions:

(i) Sentence and discourse processes occur simultaneously.

(ii) Sentence and discourse processes occasionally share processing resources.

(iii) Sentence and discourse processes occasionally share information. There is evidence for each of these assumptions.

Marslen-Wilson's (1975; Marslen-Wilson and Tyler, 1975, 1980; Tyler and Marslen-Wilson, 1977) results on the near immediacy of access to various information sources support the assumption of parallel processing of sentence and discourse properties. There is also evidence that sentence and discourse processes share processing resources. First,

conditions that increase access to form also *decrease* access to meaning, and vice versa, as reviewed in (a)-(l) above. These results suggest that listeners divide attentional resources between ordered sentence representations and unordered discourse representations. The two representations may co-exist, but focusing on one decreases accessibility to the other. Second, Townsend and Bever (1991) found that information that constrains the emerging discourse representation inhibits monitoring for acoustic features. This result suggests that comprehenders draw resources away from acoustic representations to focus on well-formed discourse representations. The assumption that sentence and discourse processes share processing resources distinguishes the representational model from "architectural modularity," which is the proposal that sentence and discourse processes occur in separate computational spaces, with distinct neurological processes (cf., Fodor, 1983; Townsend and Bever, 1991).

The representational model assumes that sentence and discourse processes share information primarily when the two processes yield similar representations. This assumption allows for discourse context effects on comprehension processes in three situations:

(A) *Discourse context can influence comprehension processes when sentence processes have produced a representation on which discourse processes can operate.* Context may facilitate comprehension because of the integration of sentence information with the discourse representation. Townsend and Bever (1982) demonstrated that discourse information has greater effects on naming the final word of sequences like *flying planes is...* than of sequences like *flying planes are...* The word *is* in *flying planes is...* signals that the phrase *flying planes* has a verb-object structure, which is the ending for the prototypical active sentence. However, the word *are* in *flying planes are...* signals that it has the modifier-head structure of noun phrases, which are less like complete sentences (see also Mehler and Carey, 1968). This result suggests that sentence processes interact more naturally with discourse information at the end of a sentence-like sequence than at the end of a noun phrase-like sequence (see also Carroll, 1978; Hurtig, 1978; Carroll and Tanenhaus, 1978; Tanenhaus and Carroll, 1975). The *natural unit hypothesis* states that discourse context is more likely to interact with sentence processes at the ends of more complete sentence units, when sentence processes yield more complete propositional units of discourse representations (cf., Anderson and Bower, 1973; Anderson, 1974; Kintsch and van Dijk, 1978).

(B) *Discourse context can influence comprehension processes when comprehenders assign a sentence representation to conceptual knowledge.* It may be easier to understand a sentence in a richer context because conceptual information generates *sentence* representations that facilitate subsequent sentence processes. Several studies have shown that context can prime syntactic hypotheses. First, preceding syntactic context can prime syntactic categories within sentences (Wright and Garrett, 1984). Second, the syntactic form of a context sentence can prime similar syntactic forms (Frazier, Taft, Roeper, Clifton, and Ehrlich, 1984; Sheldon, 1974; West and Stanovich, 1986). This syntactic priming from a preceding sentence is greater when its discourse-level function encourages prolonged access to surface details rather than meaning (Townsend, 1983, Experiment 3). The proposal that context can prime the generation of a sentence representation follows from studies of syntactic priming in sentence production (Bock, 1986). Finally, as noted earlier, studies of comprehension skill have suggested that the form of context sentences influences less-skilled comprehenders *more than* skilled comprehenders (Leu et al., 1986). These results suggest the *linguistic prediction hypothesis:* discourse context interacts more strongly with sentence processing when comprehenders represent contextual information with a specific sentence form.

(C) *Discourse context can influence comprehension processes when comprehenders use the relevant conceptual knowledge to construct a discourse representation.* Comprehending a sentence may be easier when it appears in a natural context because the context makes it easier to obtain a *discourse* representation. Several facts support this claim. First, numerous recall studies show that discourse context facilitates the formation of an integrated discourse representation (e.g., Bransford and Johnson, 1972; Dooling and Mullett,

1973). Second, readers read sentences faster (i) when they appear later in a text rather than earlier (e.g., Cirilo and Foss, 1980), (ii) when they preserve the underlying causal organization of text rather than destroy it (e.g., Keenan, Baillet, and Brown, 1984; Townsend, 1983, Experiment 6; van den Broek, 1990), and (iii) when they match the underlying script rather than mis-match it (e.g., Bower et al., 1979). Direct theorists interpret results like these to show that higher-level constraints facilitate the perception of features at a lower level of representation. However, another interpretation for each of these results is that facilitating the formation of a discourse representation draws processing resources away from surface details to the discourse representation (Townsend and Bever, 1991). The *discourse representation hypothesis* states that increasing discourse constraints makes it easier to obtain a discourse representation.

Comprehension Skill in the Representational Model

This representational model contrasts with direct models of comprehension. Whereas direct models assume that comprehenders map words directly onto discourse representations, the representational model assumes that they map words onto a sentence representation, which they map onto a discourse representation. However, the mapping processes between different levels occur simultaneously to the most complete extent that is possible, so that representations at different levels co-exist at any given moment during comprehension. The representational model therefore suggests three possible sources of individual variations in mature comprehension skill: (i) sentence processes, (ii) discourse processes, and (iii) the allocation of processing resources to sentence processes versus discourse processes. There is evidence for each of these sources of individual variation.

One line of research has shown that some variations in comprehension skill depend on sentence processes. For example, Cromer (1970) showed that certain less-skilled comprehenders comprehend better when major phrase boundaries coincide with the ends of lines (see also Haberlandt, Graesser, and Schneider, 1989; Muncer and Bever, 1984). Apparently, the ends of lines can initiate the kinds of processes that skilled comprehenders carry out at the ends of phrases.

A large set of studies has shown that differences in comprehension skill depend on various kinds of discourse processes. First, comprehension skill depends on the ability to integrate text information with relevant background knowledge (e.g., Fincher-Kiefer, Post, Greene, and Voss, 1988; Schank, 1982; Spilich, Vesonder, Chiesi, and Voss, 1979). Second, more skilled comprehenders are better at identifying anaphoric referents (e.g., Oakhill, 1983; Oakhill and Yuill, 1986; Yuill and Oakhill, 1988). Third, they are also better at perceiving causal relations (e.g., van den Broek, 1990; Katz and Brent, 1968; Wing and Scholnick, 1980).

Another line of research on comprehension skill has emphasized limitations of processing resources and how comprehenders allocate these resources to different aspects of comprehension (Daneman and Carpenter, 1983; Daneman and Green, 1985; Hunt, Lunneborg, and Lewis, 1975; Lesgold and Perfetti, 1978; Oakhill, Yuill, and Parkin, 1988; Palmer, McLeod, Hunt, and Davidson, 1985; Yuill, Oakhill, and Parkin, 1989). Comprehenders may allocate attentional resources to meaning and form in different ways at different stages of linguistic sophistication. For example, in processing sentences with connectives like *after* and *before*, four-year-old children maintain greater access to the meaning of the initial clause in the sentence-level representation, whereas five-year-olds maintain greater access to the meaning of the initial event in the *discourse-level* representation (Townsend and Ravelo, 1980). In this case, less-advanced comprehenders organize information on the basis of the sentence-level property of the position of a clause within a sentence, but more-advanced comprehenders organize information on the basis of the discourse-level property of temporal relations. However, Townsend and Ravelo (1980) and Townsend et al. (1979) found that three-year-olds' performance on accessing the meaning versus lexical content of sentences is more like that of five-year-olds than that of four-year-olds. It seems difficult to attribute such age-related fluctuations to variations in available processing resources, which should increase throughout childhood (cf., Chi, 1976; Huttenlocher and Burke, 1976). Instead, it appears that comprehenders at different ages

adopt different strategies for allocating processing resources (see also Tyler and Marslen-Wilson, 1978). These strategies may depend on structural properties such as the main-subordinate distinction, positional properties, or discourse-level properties such as temporal relations. They may also reflect the allocation of resources to compute representations at different levels, or to attend to representations that have been computed "automatically." If we assume that less-skilled adult comprehenders "lag" behind more-skilled comprehenders developmentally, these data can help explain individual differences in mature comprehension: more-advanced comprehenders allocate resources more to discourse-level properties, whereas less-advanced comprehenders allocate resources more to sentence-level properties. This generalization contrasts with the claim from the structure building framework that decreased access to sentence representations is characteristic of less skilled comprehension.

The representational account of individual variation in discourse comprehension skill is similar to Stanovich's (1980) interactive-compensatory model of variations in word recognition skill: both attempt to integrate linguistic processes, conceptual processes, and processing resources. According to the interactive-compensatory model, highly-skilled readers recognize printed words "directly" from orthographic information, but less-skilled readers rely on phonological mediation and semantic context (see also Jorm and Share, 1983; Perfetti, Goldman, and Hogaboam, 1979). The "compensatory" use of context for word recognition involves a conscious expectation that is slow and uses processing resources that otherwise could be devoted to higher-level comprehension processes. Stanovich, Nathan, West, and Vala-Rossi (1985) invite an extension of the interactive-compensatory model beyond the word level when they state that:

> Deficiencies at a particular level of the processing hierarchy can be compensated for by a greater use of information from other levels, and this compensation takes place irrespective of the level of the deficient process (Stanovich et al., 1985, p. 1419).

The extension might go like this: Skilled adult comprehenders derive a discourse representation "directly" from linguistic information. Less-skilled comprehenders, however, rely more on syntactic mediation and the active use of semantic context to compensate for relatively inefficient processes of constructing a discourse representation from linguistic information. Thus, average comprehenders should show *greater* effects of sentence-constraints and discourse-constraints, compared to skilled comprehenders. This prediction also differs from that of the structure-building framework.

Overview

The different views on the role of sentence processes at different levels of comprehension skill seemed of such critical importance to justify examination of sentence processing in natural discourse contexts. Simple narrative texts were constructed around college students' knowledge of familiar sequences of events. This knowledge was gathered by asking college students to list events that occur in familiar situations, such as getting a flat tire or seeing an abandoned car on a highway. The subjects' lists of events formed the basis for pairs of narratives (as in Abbott, Black, and Smith, 1985; Bower et al., 1979; Graesser, Gordon, and Sawyer, 1979; Sharkey and Mitchell, 1985). The "supportive" and "neutral" members of each pair of texts contained a common critical sentence, such as *He took off the flat tire.* The subjects' lists of events nearly always mentioned the critical event for supportive texts (1), but they never mentioned it for neutral texts (2):

> (1) Harry was driving along and suddenly heard a loud bang and a flapping sound. He stopped the car and set the brake. He took the jack, a wrench, and the spare from the trunk. He loosened the bolts on the wheel. He jacked up the car and got the bolts off. Harry took off the flat tire.....
>
> (2) Harry was driving along and suddenly came upon an abandoned wreck by the road. He found nothing suspicious inside the car. He examined the damage outside

the car. The windshield was shattered. One wheel was damaged and a fender was all smashed in. Harry took off the flat tire.....

Pretesting showed that the supportiveness of the contexts influenced judgments of the plausibility of the critical sentence in the stories. Several studies with skilled versus average comprehenders, defined in terms of scores on the Verbal Scholastic Aptitude Test (VSAT), then examined the effects of sentence and discourse properties on the comprehension and memory of these critical sentences. Since the topics of the texts were likely to be familiar to all college students, it is unlikely that differences in sentence processing could depend on variations in prior knowledge. And since the length of the sentences and words was comparable to 6th grade reading texts (Fry, 1977), it is unlikely that variations in word recognition skill or available processing resources could contribute to variations in sentence processing.

Direct versus representational models make different predictions about the effect of discourse context on sentence processing. Since direct models propose that comprehenders map words directly onto the discourse representation, they predict that highly-constrained discourse contexts will eliminate the effects of sentence properties such as syntactic complexity or sentence boundaries. Since the representational model maintains that discourse information can facilitate the formation of a discourse representation, supportive contexts may reduce the effects of sentence properties, but they will not eliminate them. Furthermore, discourse information may influence comprehension under three conditions:

(A) when sentence processes have produced a discourse unit that comprehenders can integrate with discourse information -- the natural unit hypothesis

(B) when comprehenders represent discourse information with *a sentence* form -- the linguistic prediction hypothesis, or

(C) when discourse information is relevant for the emerging discourse representation -- the discourse representation hypothesis.

The two approaches to comprehension also differ in their predictions about the organization of sentence and discourse processes at different levels of skill. If sentence and discourse constraints both govern the activation of memory cells and if less-skilled comprehenders fail to suppress less constrained memory cells, the effects of both sentence constraints and discourse constraints on performance will be *smaller for* average comprehenders than for skilled comprehenders. On the other hand, if less-skilled comprehenders focus processing resources more on sentence representations than on discourse representations, they will show *greater* effects of sentence properties, compared to skilled comprehenders.

Experiment 1

In the Graf and Torrey study (1966, as cited by Anderson, 1990), subjects read texts that were formatted so that each line ended either at a phrase boundary, similar to (3a) of Figure 1, or within a phrase, similar to (4a). Each box in Figure 1 represents successive lines of text. Graf and Torrey found that recall was better with a "phrase-chunked" format like (3a). Such a result suggests that the processing of phrase structure is important for developing a memorable representation of discourse. Cromer (1970) found that less-skilled readers comprehended texts better when all lines were formatted like (3a) rather than (4a). Apparently, some variation in comprehension skill depends on processing surface properties such as phrase structure.

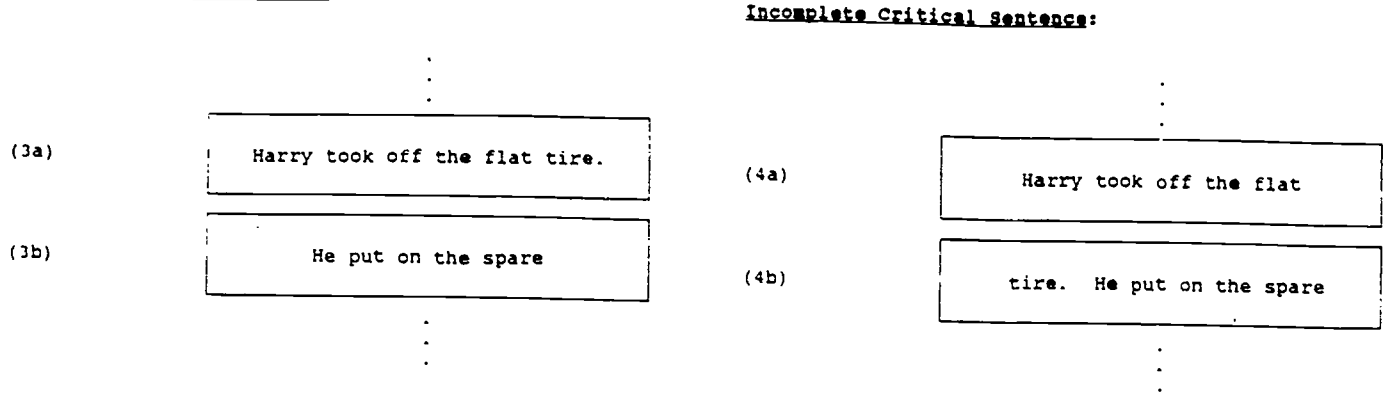

Figure 1. Text Formats for Complete and Incomplete Sentences

The first experiment modified the Graf and Torrey and Cromer procedures to present one line of text at a time to subjects in order to measure the time they spend reading each line. The lines of interest were those that presented the critical event, which the preceding context either strongly or weakly supported, as in (1) versus (2). The critical events appeared either as a "complete" sentence on a single line, as in (3a), or as an "incomplete" sentence, as in (4a). The issue is whether the presentation format influences line reading times, and, if so, whether those effects are similar for skilled and average comprehenders.

Direct models maintain that constraints from any source may activate specific hypotheses about a word, and suppress other hypotheses about it. Words that correspond to the most highly activated hypotheses are easier to perceive. I have used the term *predictability assumption* to refer to the view that the constraints on a word eliminate some hypotheses about it (Townsend and Bever, 1991). For example, because of syntactic constraints and lexical associations within the sentence, there are fewer acceptable options for the next word of *Harry took off the flat...* than there are for the next word of *Harry took off the...* The predictability assumption maintains that comprehenders will recognize *tire* faster in the former context than they recognize *flat* in the latter context. The fact that (3a) contains the most highly constrained, and hence most perceptible, word of the sentence means that the average reading time per word will be faster for (3a) than for (4a), in which the words are less-constrained. Studies that have shown that comprehenders recognize words more quickly when there is more context support this general prediction (e.g., Stanovich and West, 1979; Tulving and Gold, 1963; Marslen-Wilson and Tyler, 1980). However, direct models also propose that comprehenders will recruit discourse-level constraints -- such as (1) as compared to (2) -- in reading both (3a) and (4a). If the availability of discourse-level constraints does not depend on the existence of sentence representations, as direct models claim, these discourse constraints will reduce reading times for both complete and incomplete sentences. Thus, direct models propose additive effects of discourse-level and sentence-level constraints. Regarding comprehension skill, the structure building framework maintains that average comprehenders do not use sentence- or discourse-constraints to suppress the activation of irrelevant memory cells. Hence, both sentence-and discourse-constraints will have smaller effects on reading times for average comprehenders.

The representational model provides a somewhat different set of predictions. According to this model, comprehension involves integrating sentence information into a coherent discourse representation. This integration occurs more naturally at the ends of complete units of discourse -- roughly, sentences. Integrating sentence and discourse information,

therefore, will be harder for incomplete sentences like (4a) than for complete sentences like (3a). In order to integrate (4a) with preceding information, readers must devote some resources to inferring a complete sentence representation. Hence, average reading times per word will be longer for incomplete sentences than for complete sentences. This prediction corresponds to that of direct models. However, the two models differ in their predictions about the effect of supportive contexts on reading incomplete sentences. The representational model maintains that sentence processes produce sentence representations on which discourse processes can operate, and that discourse constraints can facilitate the formation of a discourse representation. Since it is harder for sentence processes to obtain a sentence representation for incomplete sentences, it will be harder for discourse processes to integrate a sentence representation with discourse constraints. Therefore, the representational model predicts that the effects of discourse constraints will be *smaller* for incomplete sentences than for complete sentences. This prediction contrasts with the claim from direct theories that discourse constraints are equally available throughout comprehension. The prediction of the representational model about comprehension skill also differs from that of direct models. Since less-skilled comprehenders focus resources more on the sentence-level whereas skilled comprehenders focus resources more on the discourse level, the effects of format should be greater for average comprehenders than for skilled comprehenders (cf., Cromer, 1970).

Method

Materials. Texts were based on college students' knowledge of stereotypical sequences of common events. The procedure for generating texts was similar to that of Bower et al. (1979). Thirty-two college students at Montclair State College listed in sequence 10 events that typically occur in 30 common situations like *changing a flat tire, visiting a doctor, eating in a restaurant,* and so on. From their responses, 8 "supportive" stories like (1) were constructed in which there was a critical event that was mentioned by 90% or more of the subjects. There were also eight "neutral" stories like (2) that contained a critical event from one of the supportive stories; none of the students mentioned this critical event in their list of events for the neutral scenario. However, the critical event was plausible in the neutral context, as in (2). The critical sentences appeared as the third through sixth sentence in the eight pairs of stories, and position was matched within pairs. The number of lines preceding the critical sentence was 7.5 for both supportive and neutral contexts. Table 1 lists other properties of the supportive and neutral passages.

Table 1

PROPERTIES OF THE PASSAGES

	Supportive	Neutral
Mean Number of Sentences in Passage	13.0	13.0
Mean Number of Sentences Preceding Critical Clause	4.5	4.5
Fry Readability Index	6.0	6.0
Rated Essentialness of Critical Clause	3.8	2.3***

***$p < .0001$

Pretests. Two pretests were conducted to determine whether the procedure for generating materials was effective. One group of 158 subjects read sets of eight of the sixteen generated passages. There were two lists of passages, each with four supportive contexts and four neutral contexts. The two lists differed in which context was paired with each critical event. The subjects' task was to rate how essential the critical event was in the text as a whole.

These ratings confirmed that critical events were more essential in the supportive stories than in the neutral stories, $F(1,157) = 66.4$, $p < .001$.

To determine whether presenting critical sentences as incomplete sentences disrupted judgments of contextual supportiveness, an independent group of 32 subjects read the contexts line by line as in Figure 1. The screen that presented the complete versus incomplete critical sentence also instructed subjects to rate on a scale from 1 to 7 how predictable the information on that screen was, based on the preceding context. Subjects entered their rating before continuing to the next screen. Ratings of predictability were 4.29 in neutral contexts and 5.57 in supportive contexts, $F(1, 31) = 17.2$, $p < .01$. Context did not interact with completeness, $F < 1$. Thus, differences in the predictability of supportive versus neutral contexts were similar for complete and incomplete sentences.

Procedure. Subjects read stories like (1) and (2) one line at a time on a computer screen. The subject's key-press removed the previous line, presented the next line, and recorded the viewing time. The subject's task was to write a title for each text after reading it. All lines were formatted so that they ended at a sentence boundary, or just before the last word of a sentence. In the former case, the line began with the first word of the sentence and ended with its last word. In the latter case, the final word of the sentence appeared on the next line together with at least part of the following sentence as in (4b). These line formats were pseudo-randomly arranged throughout each text so that the number of complete lines and the average number of words per line were matched within pairs of contexts. There were never more than three successive lines with a format of a particular type. Supportiveness and completeness were counterbalanced so that each item appeared in each combination of supportiveness and completeness across four lists. Since combinations of variables on items were randomly assigned to subjects, statistical tests that treat subjects and items as random variables are identical (Clark, 1973, p. 348), and only F statistics are reported.

Subjects. Thirty-two undergraduate students from Montclair State College and Columbia University participated for pay. Half were classified as "skilled comprehenders," based on having VSAT scores between 540 and 700; their mean VSAT was 612. Half of the subjects were classified as "average comprehenders;" their VSAT scores were between 400 and 520, with a mean of 432. These VSAT ranges were used to define skilled versus average comprehenders in all of the studies that are reported here.

Results and Discussion

To compare reading times for complete and incomplete sentences, line reading times were converted into a measure of average reading time per word. One long response time was replaced with the value corresponding to that subject's mean plus two standard deviations. Overall, skilled comprehenders read at a rate of 287 msec per word while average comprehenders read at a rate of 444 msec per word, $F(1, 30) = 10.2$, $p < .01$. The results for context and completeness appear in Table 2. Overall, reading times were 84 msec per word faster for complete sentences than for incomplete sentences, $F(1, 30) = 6.1$, $p < .01$. This result was predicted by both the direct model and the representational model. However, the completeness effect was 108 msec for average comprehenders (a 22% difference) and 39 msec for skilled comprehenders (a 13% difference), $F(1, 30) = 8.1$, $p < .01$, confirming Cromer's (1970) memory results.

Table 2

MEAN READING TIMES PER WORD (MSEC) IN CRITICAL LINES

	Incomplete	Complete
Neutral Context	401	373
Supportive Context	402	285
Facilitation	-1	88

Discourse context interacted with sentence completeness. The discourse facilitation effect was greater for complete sentences than for incomplete sentences, $F(1, 30) = 4.5$, $p < .05$. This result indicates that integration of sentence information with discourse information occurs more naturally at the end of a sentence, and conflicts with the view that the use of discourse constraints does not depend on a level of sentence representation.

The amount of discourse facilitation in reading times for the two types of comprehenders appears in Figure 2. To facilitate comparisons across subject groups and experiments, the percentage that supportive contexts improve performance relative to neutral contexts appears in this and in later figures. Overall, average comprehenders showed more facilitation from supportive contexts than skilled comprehenders: supportive contexts reduced reading times by 12% for average comprehenders versus 9% for skilled comprehenders. This result contradicts the hypothesis that average comprehenders do not utilize discourse constraints as effectively as skilled comprehenders. Both types of comprehenders showed greater context effects for complete sentences than for incomplete sentences, as predicted by the representational model. The discourse context effect in incomplete sentences differed for skilled and average comprehenders, $F(1, 30) = 3.8$, $p < .05$, but the context effect for skilled comprehenders on incomplete sentences was not significant, $F < 1$.

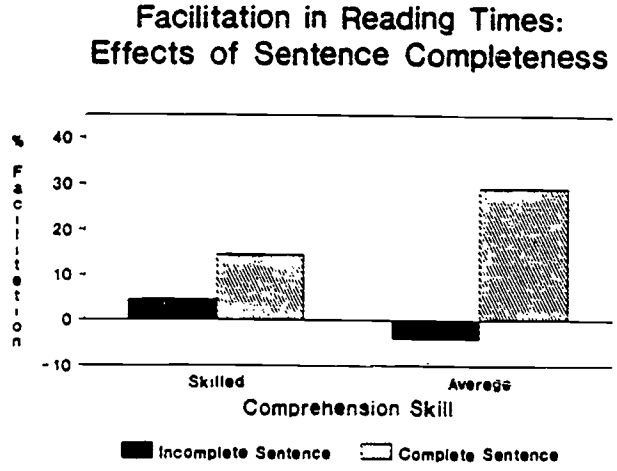

Figure 2. Contextual Facilitation in Line Reading Times for Skilled and Average Comprehenders on Complete and Incomplete Sentences

These results do not support direct models. The view that sentence and discourse information are equally available during comprehension predicted that comprehenders will use discourse constraints equally before a sentence boundary and at a sentence boundary. This prediction clearly was not supported. Since predictability ratings showed that incomplete sentences were rated as more essential in supportive contexts than in neutral contexts, the interaction cannot be explained in terms of greater discourse constraints on the last word of the sentence than for the remaining words of the sentence. In addition, the location of line boundaries with respect to sentence boundaries influenced average comprehenders more than skilled comprehenders, even though the structure-building framework implies that sentence constraints will have smaller effects for average comprehenders.

However, skilled comprehenders did show greater discourse facilitation in incomplete sentences compared to average comprehenders. This result suggests that skilled comprehenders may use conceptual information from context to facilitate decisions about sentence properties *before* the completion of a sentence. If so, this violates the assumption of the representational model that discourse representations do not directly influence sentence processes, and supports a fail-to-suppress explanation of variations in

comprehension skill. Even though skilled comprehenders' supportiveness effect for incomplete sentences was not significant, the trend may suggest a real effect to which the reading time measure is relatively insensitive. If this were a real effect, the representational model could account for it in two ways. Skilled comprehenders may use discourse information to anticipate particular sentence forms which interact with sentence processes -- the linguistic prediction hypothesis. Alternatively, skilled comprehenders may use discourse constraints to construct a discourse representation, which may render sentence processing irrelevant: the comprehender shifts processing resources away from sentence processes to the results of discourse processes -- the discourse representation hypothesis. Further experiments examined these two possibilities.

Experiment 2

There are many demonstrations that discourse context can facilitate comprehension (e.g., Bower et al., 1979; Bransford and Johnson, 1972; Dooling and Mullet, 1973). These demonstrations frequently are interpreted to show that discourse information facilitates decisions about lower level properties such as syntactic structure. The representational model allows for two other interpretations. One is that comprehenders use discourse context to form discourse representations. A second interpretation is that expectations about forthcoming events that comprehenders have assigned a sentence representation may interact with subsequent sentence processing. The second experiment tested the linguistic prediction hypothesis, that the representation of expected events as an unordered discourse-level representation versus an ordered sentence-level representation affects the nature of discourse context effects on sentence processing.

Subjects read the texts with the critical event in either active or passive form: *Harry took off the flat tire* versus *The flat tire was taken off by Harry*. The subjects' focus on sentence or discourse representations of anticipated events was manipulated by having them read text either one clause at a time or one word at a time. Since readers need not process words within clauses sequentially in the whole-clause format, they should be able to adopt more semantic processing strategies, and therefore, to focus more on discourse representations of text. The representational model allows for two mechanisms for discourse context to influence comprehension in the clause format. First, the discourse representation may 'prime' the subject, verb, and object concepts in the critical sentence, but in an unordered discourse representation. Hence, subjects can use the discourse representation of a predicted event to neutralize the fact that its passive expression is not in the active syntactic order. Second, a focus on discourse representations may draw resources away from sentence processing, reducing the effect of the processing complexity of passive sentences. In either case, supportive contexts should reduce reading times more for passives than for actives.

However, when subjects read word-by-word, words disappear as they read through the sentence. As a result, there are increased demands on assigning a structure to each word in sequence and building up an *ordered* representation. This increased focus on an ordered sentence representation should draw resources away from a discourse representation. Therefore, the effects of increased discourse constraints will be smaller for word-by-word presentation than for clause-by-clause presentation. Furthermore, if word-by-word presentation does favor the representation of anticipated events in an ordered sentence form, the interactions between discourse context and sentence structure should differ for word-by-word versus clause-by-clause presentation. In English, the more common order of expressing concepts is 'agent, patient'. Therefore, increased discourse constraints in word-by-word presentation should lead to representations of anticipated events in the 'agent, patient' order. As a result, reading times should be faster for active sentences than for passive sentences, which present concepts in the 'patient-agent' order. Since the primed order of concepts mismatches the order of concepts in passive sentences, increased discourse constraints may even *increase* word-by-word reading times for passive sentences. And since average comprehenders are more likely to focus on sentence representations, they will more likely represent anticipated events in a sentence-level representation. Since skilled comprehenders focus more on discourse representations, they will more likely represent anticipated events in an (unordered) conceptual form. This leads to the prediction that

supportive contexts will inhibit average comprehenders' processing of passive sentences, relative to skilled comprehenders.[1]

In contrast to the representational model, direct models propose that comprehenders map words onto a discourse representation without computing an independent sentence-level representation. Therefore, supportive contexts will eliminate the processing complexity of the passive form. Since these models also suggest that discourse information and sentence information are equally available as comprehenders process successive words, they predict that the effects of sentence constraints and discourse constraints will be similar in clause-by-clause and word-by-word formats. Lastly, if average comprehenders do not use semantic and syntactic constraints as effectively as skilled comprehenders, they will show smaller effects of both supportive contexts and syntactic complexity, compared to skilled comprehenders.

Method

Materials. The materials from Experiment 1 were modified so that the critical clause appeared in either active or passive form. The critical clauses contained an inanimate logical object (e.g., *tire)* and a verb that required an animate logical subject (e.g., *removed).* Supportive and neutral contexts did not differ in mean number of explicit references to the logical subject of the critical clause in the entire preceding context (4.0 and 3.8 respectively) or in the immediately preceding sentence (0.8 and 1.0 respectively). The mean number of references to the logical object of the critical clause in the supportive and neutral contexts was also similar in the entire preceding context (0.4 and 0.3 respectively) and in the immediately preceding sentence (0.0 in both cases). The critical clauses were introduced by *when.* Each subject received one story with each combination of syntactic form (active versus passive) and supportiveness (supportive versus neutral). Across lists, the eight critical events appeared with each combination of syntactic form and supportiveness. Four filler stories provided variation in the syntactic form of critical sentences.

Procedure. One group of subjects read the stories clause-by-clause on a computer screen; another group read them word-by-word. The subjects' task was to construct a two-sentence summary for each story. When the subject finished reading a segment of text, s/he pressed a key that recorded the time spent on the segment, removed it from the screen, and displayed the next one. Subjects read instructions for the experiment with the same reading format that they received for the experimental texts.

Subjects. The subjects were 64 undergraduates from Montclair State College and Columbia University selected as in Experiment 1. As before, VSAT scores were used to categorize subjects as skilled versus average comprehenders. There were 32 subjects in each skill group.

Results and Discussion

Reading times for critical clauses were converted into a measure of reading times per word. In the clause format, 3.1% of the response times for critical clauses were greater than 900 msec per word; these were replaced with a value of 900. In the word format, 5.2% of the response times for critical clauses were greater than 1100 msec per word, and were replaced with a value of 1100. Table 3 shows the mean reading times per word. The mean response times were 342 msec per word in the clause format, and 470 msec per word in the word format, F (1, 60) = 16.6, $p < .01$. Skilled comprehenders read faster than average comprehenders, F (1, 60) = 13.9, $p < .001$. Subjects read active sentences more quickly than passives, F (1, 60) = 10.3, $p < .01$, and they read sentences in supportive contexts more quickly than sentences in neutral contexts, F (1, 60) = 6.8, $p < .05$. As shown in Table 3, subjects read passives more slowly than actives in both supportive contexts and neutral contexts. This shows that comprehenders do not use discourse constraints to eliminate sentence processing, contrary to the prediction of direct models.

Table 3

MEAN READING TIMES PER WORD (MSEC) IN CRITICAL SENTENCES

	Clause Format		Word Format	
	Active	Passive	Active	Passive
Neutral Context	322	436	465	477
Supportive Context	294	316	439	497
Facilitation	28	120	26	-20

Discourse context influenced reading times for active and passive sentences differently depending on the presentation format, as shown on the bottom line of Table 3. For the clause format, supportive contexts reduced reading times more for passives than for actives, $F(1, 60) = 9.8$, $p < .01$. For the word format, they reduced reading times more for actives than for passives, $F(1, 60) = 4.9$, $p < .05$. In fact, the numerical effect of supportive contexts on word-by-word reading of passives was to *increase* reading time.

Figures 3A (clause format) and 3B (word format) show that supportive contexts reduced reading times proportionately more for skilled comprehenders than for average comprehenders, $F(1, 60) = 16.9$, $p < .01$. The interaction between syntactic form, supportiveness and format was virtually identical for the two groups of subjects, except that supportiveness effects were uniformly smaller for average comprehenders than for skilled comprehenders. This had the surprising consequence that in the word format, average comprehenders read passives more *slowly* in supportive contexts than in neutral contexts. The opposite effects of context in the two formats confirms the linguistic prediction hypothesis -- conceptually supportive contexts can prime information at both the discourse and sentence levels of representation. Primed information at the sentence level is available only in an ordered form, and this representation may actually impede sentence processing. The fact that the conceptual priming of discourse versus sentence representations of events has opposite effects on sentence processing, of course, means that these representations function in different ways during comprehension.

An alternative explanation of the slower word-by-word reading times for passive sentences is that the passive morphology (e.g., *was taken off by*) raises the average reading times per word. However, further analysis showed that in the word format supportive contexts increased reading times for the initial noun phrase of passive clauses, which precedes any passive morphology. Reading times for the initial noun phrase were 63 msec per word slower in supportive contexts, $F(1, 60) = 14.5$, $p < .01$. For the final noun phrase, they were 39 msec per word in supportive contexts, $F(1, 60) = 6.4$, $p < .01$. In contrast, the only effect of supportiveness on reading active sentences was a 53 msec per word reduction in reading times for the final noun phrase, $F(1, 60) = 7.5$, $p < .01$. The inhibition of the initial noun phrase in passive clauses eliminates the interpretation that increased reading times for passives are due to longer reading times for passive morphology.

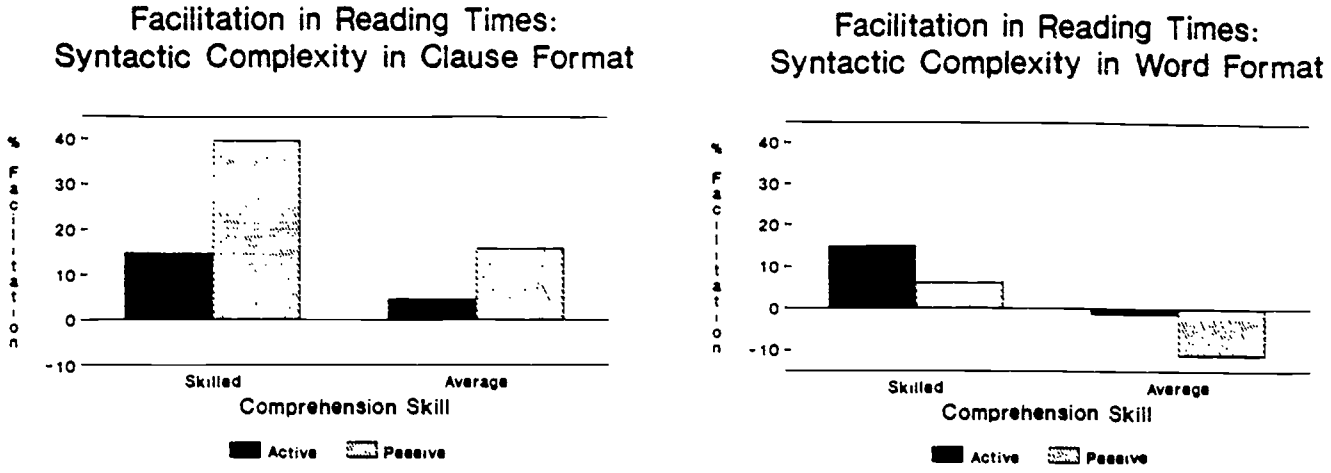

Figure 3. Contextual Facilitation in Clause (A) and Word (B) Reading Times for Skilled and Average Comprehenders on Active and Passive Sentences

The increased reading times for initial noun phrases also refutes a *discourse function hypothesis* of the longer reading times for passive sentences in supportive contexts. This hypothesis is based on the view that discourse context licenses particular syntactic forms (e.g. Davison and Lutz, 1985; Herriot, 1969; Olson and Filby, 1972). The discourse function hypothesis predicts that reading times are faster when the initial noun phrase of the critical sentence matches the topic of discourse. For example, the topic of supportive contexts (e.g., "the flat tire") is the surface subject of the passive form of the critical sentence, but it is the surface object of the active form. The topic of neutral contexts (e.g., "Harry"), however, is the surface object in the passive construction and the surface subject in the active. The topic here is defined in terms of conceptual-cuing from preceding context, not in terms of explicit references, which were controlled in the materials. Thus, the discourse function hypothesis predicts that reading times for the initial noun phrase of passive sentences will be faster in supportive contexts, but reading times for the initial noun phrase of active sentences will be faster in neutral contexts. As noted, however, supportive contexts increased reading times for the initial noun phrase of passives, and they had no effect on reading times for the initial noun phrase of actives. Thus, the word reading time results do not support a discourse function explanation for the slower reading times for passives in supportive contexts.

A third interpretation is the discourse representation hypothesis -- that increased discourse constraints draw processing resources toward the discourse representation and away from the sentence representation. This shift of processing resources would have the consequence that syntactic complexity has smaller effects on reading times in supportive contexts than in neutral contexts. In the clause format, this prediction was confirmed. However, in the word format, syntactic complexity had greater effects in supportive contexts than in neutral contexts. This interaction suggests that if the discourse representation hypothesis is correct, word-by-word presentation can reduce its effects. Further experiments examined this hypothesis in more detail.

Experiment 3

An important part of the discourse representation of text is the semantic relations between propositions, such as what causes what (e.g., Graesser, Hemphill, and Brainerd, 1989; Haberlandt and Bingham, 1984; Keenan et al., 1984; Obrien and Myers, 1987; Schank and Abelson, 1977; Townsend, 1983; Trabasso, van den Broek, and Suy, 1989; van den Broek, 1990). Comprehenders may use prior knowledge to infer these semantic relations.

They may also use various linguistic cues to the causal and temporal structure of text. The existence of these cues allows us to examine the relations between sentence processes and discourse processes rather easily.

Cues like *if* and *because* signal that the following proposition is a causal event.2 Temporal cues like *after* signal possible causal events because they signal explicitly that the following proposition is temporally prior to some other proposition, which is a necessary condition for a causal role (e.g., Townsend, 1983; van den Broek, 1990). Adversative cues such as *although* and *but*, on the other hand, deny that an expected outcome actually occurred (see Blakemore, 1989; Dakin, 1970; Halliday and Hasan, 1976; Lakoff, 1971). For example, *Although he operated the jack, the car did not rise* denies that operating the jack in this case caused the car to rise, and *Although he took the flat tire off of the axle, he couldn't put on the spare* denies that taking off the flat tire enabled him to put on the spare. On the other hand, *Although he took the flat tire off of the axle, he couldn't find a puncture* denies that taking off the flat enabled him to find a puncture. In each of these cases, *although* denies not an event, but an anticipated causal relation between events. A complete discourse interpretation of an *although* clause requires a representation of this anticipated but denied causal relation. The examples above suggest that comprehenders can infer the anticipated causal relation that is denied by *although* from the main clause of the sentence. That is, the speaker's anticipated causal relation for *Although he took the flat tire off of the axle* differs depending on whether the main clause is *he couldn't put on the spare* versus *he couldn't find a puncture*. In general, the discourse interpretation of an *although* clause requires determining what event the speaker expected to follow from the event in the *although* clause. *Although* and *because* differ in complexity more at the discourse level than at the sentence level.

The different meanings of adversative and causal cues initiate differences in the focus of processing resources on semantic versus syntactic information: causal cues focus resources more on semantic information, while adversative cues focus resources more on syntactic information (Townsend and Bever, 1978; Townsend, 1983). This was demonstrated by the fact that comprehenders make judgments about meaning faster near the end of if-clauses than near the end of though-clauses. On the other hand, the position of a target word has greater effects on word probe recognition performance for *though-clauses* than for if-clauses. This difference supports the view that comprehenders readily integrate a causal clause like *Because Harry took the flat tire off of the axle...* into a discourse representation of text, but that their discourse representation of an adversative clause like *Although Harry took the flat tire off of the axle...* requires knowing information that is not available at the time of hearing the clause. In the absence of this necessary information, comprehenders cannot integrate of the sentence representation with a complete discourse representation. Consequently, comprehenders have greater access to the sentence representation of *although* clauses.

Three experimental results confirm this interpretation. First, a main-subordinate ordering reverses these differences in access to the meaning versus form of clauses with different discourse roles (Townsend and Bever, 1978). For *although* sentences, an initial main clause presents information that comprehenders can use to infer the expected effect. Since comprehenders can link the sentence representation of an *although* clause to its discourse representation as they read it, they show decreased accessibility to form but increased accessibility to meaning. For *because* sentences with an initial main clause, the events appear in an effect-cause order, which mismatches the preferred cause-effect organization of discourse representations. In this case, it is harder to link a sentence representation with the discourse representation, and it is easier to access the form of a final *because* clause, but harder to access its meaning.

Second, subjects recall *although* sentences better when they had appeared in a main-subordinate order rather than a subordinate-main order. These effects of clause order are reversed for *because* sentences (Charon et al., 1988; Townsend, 1983, Experiment 5; see also Clark and Clark, 1968).

Third, a context sentence has different effects on comprehending *although* versus *because* sentences. In Townsend (1983, Experiment 8), subjects read a context sentence followed by a two-clause sentence that contained either *although or because*. The context sentence paraphrased either the main clause or the subordinate clause. The subjects' task was to generate a sentence that plausibly could continue the text. For *although* sentences, continuation times were faster when the context paraphrased the main clause, but for *because* sentences they were faster when it paraphrased the subordinate clause. This result suggests that a paraphrase of the main clause of an *although* sentence (i.e., the unexpected effect) provides comprehenders with information that facilitates forming a discourse representation for *although*. But a paraphrase of the subordinate clause a *because* sentence (i.e., the causal event) facilitates placing the events into a cause-effect organization. Lehman (1990) replicated these effects of linguistic context on reading and recalling information from *although* versus *because* clauses.

The present experiment determined whether comprehenders use conceptual information from context to draw the inferences that are needed for the discourse interpretation of adversative clauses. Suppose that college students know about various scenarios, or "tracks," that occur when they get a flat tire, and that discourse may activate different scenarios (cf., Schank and Abelson, 1977). For example, by mentioning the presence of a spare tire in the trunk, (1) activates the REPLACE-FLAT track of the CHANGE-A-TIRE script, rather than, say the FIX-FLAT track or CALL-ROAD-SERVICE track. In this case, comprehenders may anticipate that after Harry removes the flat tire he will install the spare. If this information is available at the time of reading the adversative *Although Harry took the flat tire off of the axle*, comprehenders can focus processing resources on the discourse representation. If it is not available, of course, comprehenders will postpone integrating the sentence representation of the adversative clause until the necessary information becomes available, that is, until they read the following main clause. Since the conceptual knowledge that supportive contexts provides is more relevant for the discourse representation of *although* than that of *because*, supportiveness effects should be greater for *although*.

To test the discourse representation hypothesis, subjects read texts like (1) and (2) clause-by-clause. Either *although* or *because* introduced the critical clause. After reading all of the texts, subjects received a surprise memory test to examine their retention of sentence information and meaning. Direct models predict similar effects of discourse context on reading times and memory for *although* versus *because* clauses, since comprehenders map words directly onto a discourse representation. Notice that since both *although* and *because* are "new structure" cues, and the events in both *although* and *because* clauses are causally related to preceding information, the structure building framework predicts that they will produce similar amounts of surface information loss. Furthermore, if average comprehenders engage in more processing shifts, they will show smaller effects of supportive contexts than skilled comprehenders, and more loss of surface information on a subsequent memory test. On the other hand, since the discourse representation hypothesis predicts that supportive contexts can provide knowledge of the expected causal relation that *although* denies, supportiveness should facilitate reading and memory for *although* clauses more than for *because* clauses. These effects should be greater for skilled comprehenders, who focus resources more on discourse representations.

Method

Materials. Sixteen texts from Experiments 1 and 2 were modified slightly. Either *although* or *because* introduced the critical clauses, which appeared only in active form. The clause that followed the critical clause was reworded depending on the connective that introduced it. This was necessary in order to make the sentence coherent.

Procedure. Subjects read eight stories one clause at a time on a computer screen. Their purpose in reading was to be able to write a two sentence summary of the story at the end of each story. During presentation of the passages, exactly one clause appeared on the screen at any given moment. Subjects moved through the stories by pressing a key on the keyboard; each key-press removed the previous clause, displayed the next clause, and recorded the time

from the last key-press. Half of the stories presented critical sentences in supportive contexts, and half in neutral contexts. Connective was crossed with type of context.

After reading all stories, the subjects received a surprise memory test. One group was given a recall test in which they wrote down the stories as accurately as possible. Three judges independently rated the protocols for how accurately subjects recalled the gist of the critical event. The judges' ratings were correlated .74, .81, and .83. A second group of subjects checked off from a list of eight sentences those that they thought had occurred in the stories, and they rated on a scale from one to four how confident they were of each decision. For each subject, half of the test sentences were identical to critical sentences, and half involved a change in syntactic form that did not affect the meaning, as in *Harry took the flat tire off of the axle* versus *Harry took off the flat tire from the axle.* Two lists of test sentences differed by reversing identity versus syntactic change for each target sentence. Performance on the recognition test was converted to an 8-point scale, from correct and very confident to incorrect but very confident.

Subjects. Forty-eight right-handed, native English speaking undergraduates from Montclair State College and Columbia University participated. Half were designated "average comprehenders" and half "skilled comprehenders," as in Experiments 1 and 2. Eight of each skilled group received the recall test, and sixteen of each group received the sentence recognition test.

Results and Discussion

Clause Reading Times. The mean reading time for critical clauses was 332 msec per word. Skilled comprehenders read the critical clauses faster than average comprehenders by 51 msec per word, F (1, 33) = 5.04, $p < .01$. Overall, reading times were 20 msec per word faster in supportive contexts than in neutral contexts, F (1, 33) = 4.45, $p < .05$. Reading times were 27 msec per word faster for *although* clauses than for *because* clauses, F (1, 33) = 4.15, $p < .05$.

If average comprehenders engage in more processing shifts, they should be *less* likely to take advantage of familiarity with the topic of the text in processing the critical sentences. However, Figure 4 shows that supportiveness effects were greater overall for average comprehenders than for skilled comprehenders, F (1, 33) = 8.06, $p < .01$. Figure 4 also shows an obvious interaction between supportiveness, connective, and skill. Skilled comprehenders showed greater effects of supportiveness for *although* than for *because*, F (1, 33) = 6.25, $p < .05$. This result supports the hypothesis that skilled comprehenders use discourse information to form a discourse representation.

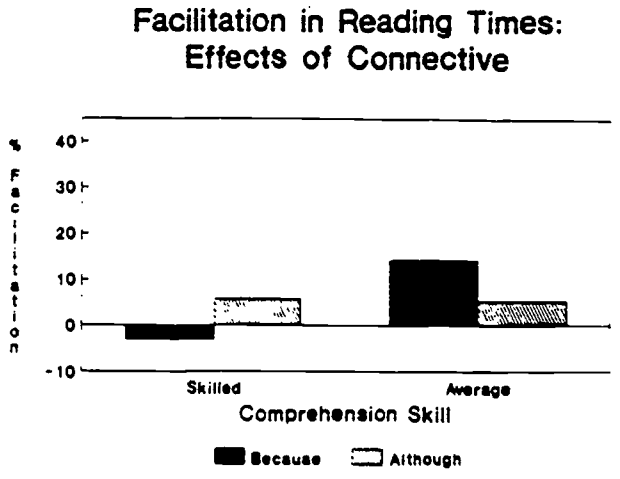

Figure 4. Contextual Facilitation in Clause Reading Times for Skilled and Average Comprehenders on *Because* and *Although* Clauses

Notice that if this experiment had used only *although* sentences in supportive versus neutral contexts with skilled comprehenders, the interpretation of the results may have been very different. The results of such an experiment might have been taken as support for a direct model: If we invoked the predictability assumption, we would interpret the faster reading times in supportive contexts to show that increased discourse constraints reduce the processing complexity of sentence-level properties. However, the fact that sentences that differ in their discourse-level representation produced very different results forces a conclusion that is quite different. Since discourse constraints clearly interact with cues to the discourse representation and the comprehension skill of the subject, discourse information may not affect the formation of a sentence representation. This point is worth emphasizing because research on the organization of sentence and discourse processes rarely considers the possibility that these factors could influence access to sentence versus discourse representations.

One interpretation of the finding that average comprehenders did not show greater effects of supportiveness for *although* than for *because* is that they have less knowledge about their meanings. While this possibility cannot be ruled out, developmental studies have shown that school children perform correctly on adversatives at a 68-85% rate by the 5th or 6th grade (Katz and Brent, 1968; Wing and Scholnick, 1980). It seems unlikely that college-age average comprehenders have comprehension skills that are less developed than those of 5th or 6th grade school children.

Memory. When the critical event had appeared in a supportive context, accuracy of recall of its propositional content was 70%, compared to 62% for neutral contexts, F (1, 14) = 9.18, $p < .01$. This result replicates previous studies on the role of script supportiveness in recall (e.g., Bower et al., 1979). Skilled and average comprehenders did not differ in overall level of propositional recall, $F < 1$, suggesting that they did not differ in their comprehension of the critical sentence. The supportiveness effect was significant for average comprehenders, F (1, 14) = 8.58, $p < .05$, but not for skilled comprehenders, F (1, 14) = 2.04, $p > .10$. Supportiveness improved recall of meaning for *although* clauses, F (1, 14) = 5.94, $p < .05$, but not for *because* clauses, $F < 1$, as predicted by the discourse representation hypothesis.

On the sentence recognition test, average comprehenders performed *better* than skilled comprehenders: skilled comprehenders were correct on 60% of the items while average comprehenders were accurate on 66%, F (1, 28) = 3.92, $p < .05$. This result contradicts the view that average comprehenders show more surface information loss than skilled comprehenders. Accuracy was greater for sentences that had appeared in neutral contexts (67%) rather than supportive contexts (59%), F (1, 28) = 4.42, $p < .05$. This supportiveness effect was significant only for average comprehenders, F (1, 28) = 7.11, $p < .05$; in fact, skilled comprehenders showed a nonsignificant 9% advantage for supportive contexts, F (1, 28) = 1.73, $p > .10$. There were no interactions with connective, though recognition performance was more accurate for *because* (75%) than for *although* (52%), F (1, 28) = 4.76, $p < .05$. This last result does support the claim of the structure building framework that non-causal events induce loss of surface information.

Overall, the bulk of the evidence favors the discourse representation hypothesis over the processing shift hypothesis. First, for reading times, only skilled comprehenders showed greater facilitation from supportive contexts for *although* clauses than for *because* clauses. This result suggests that skilled comprehenders use discourse constraints to facilitate the formation of a discourse representation. Second, supportiveness had greater overall effects on reading times for average comprehenders than for skilled comprehenders. Third, for recall of meaning, supportiveness improved recall of *although* clauses more than *because* clauses. However, skill interacted with supportiveness and connective only in the sentence recognition task, not in propositional recall. Fourth, script supportiveness had opposite effects on recall of meaning versus recognition of formal changes in sentences. The fact that the supportiveness variable has opposite effects on memory for meaning versus form is a good sign that sentence and discourse representations are distinct. Fifth, average comprehenders were more accurate than skilled comprehenders on the sentence recognition test. However, the fact that the only effect of connective on sentence recognition was greater accuracy for *because* clauses than for *although* clauses contradicts the discourse

representation hypothesis, which predicts interactions of connective, supportiveness, and skill. Subsequent analysis of the materials revealed a possible confounding factor: Note that a clause like *Harry took off the flat tire from the axle* allows the completion of a proposition after *tire*. This property of the materials confounds the predictions of the discourse representation hypothesis and the natural unit hypothesis, which predicts that integration of a sentence representation into a discourse representation may occur upon reading *tire* (see Carroll, 1978; Hurtig, 1978 Carroll and Tanenhaus, 1978; Mehler and Carey, 1968; Tanenhaus and Carroll, 1975; Townsend and Bever, 1982).

Table 4

MEAN READING TIMES PER WORD (MSEC) FOR CRITICAL LINES

	Skilled		Unskilled	
	Incomplete	Complete	Incomplete	Complete
Although	418	556	535	435
Because	533	455	481	487

Experiment 4

The next two experiments tested alternative interpretations of the results of Experiment 3 by improving the materials and by using different tasks. In Experiment 4, subjects made judgments about the meaning of the critical clause just before it ended (as in Gergely, 1984; Townsend and Bever, 1978; Townsend, 1983). Subjects listened to the stories but the tape recorder stopped just before the last word of the critical clause, as in (5).

(5) ...Although he took off the punctured...

At that point, a phrase like *removing a flat* appeared on a screen in front of the subject. In the critical cases, the phrase probe paraphrased the meaning of the interrupted clause. Response times provide a measure of the listener's accessibility to meaning at the point of the interruption. This task, therefore, can examine more directly than sentence reading times how contextual supports and connectives interact to focus processing resources on meaning. At the same time, the task can assess the generality of the clause reading time results of Experiment 3 by examining listening comprehension. It was anticipated that there would be similar results for reading and listening (cf., Carr, 1981; Jackson and McClelland, 1979; Sticht, 1972).

A direct model of comprehension predicts that comprehenders will access meaning faster in supportive contexts regardless of which linguistic cue is present. Furthermore, the effects of discourse constraints will be smaller for average comprehenders than for skilled comprehenders, since average comprehenders are less likely to use constraints to suppress irrelevant structures. The representational model maintains that comprehenders use conceptual information primarily for integrating sentence information into a discourse representation, and so supportiveness will interact with linguistic cues to the discourse representation. In particular, supportive contexts will provide comprehenders with knowledge about what the speaker expected to follow from an adversative clause, thereby enabling them to obtain a complete discourse representation more readily. Since this information is not available in neutral contexts, comprehenders must postpone interpretation of the adversative clause. Hence, supportiveness effects will be large for adversative clauses. But since the discourse interpretation of a causal clause is less dependent on context, supportiveness effects will be small for causal clauses. In addition, the representational model maintains that increased comprehension skill involves

increased sensitivity to discourse representations. If so, these interactions between supportiveness and connective will be larger for skilled than for average comprehenders.

Method

Subjects listened to recordings of 26 stories. Critical clauses were interrupted just before the last word of the clause by a 50 msec tone; 300 msec later, subjects heard a 2-4 word verb-object phrase (e.g., *removing a flat*). Their task was to say as quickly as possible whether or not the phrase was similar in meaning to what had just been said, and to provide a two-sentence summary for the story, which they wrote after hearing the remainder of the story. Subjects heard eight critical stories like (1) and (2), for which the correct answer on the phrase probe task was 'yes.' Connective and supportiveness varied factorially across the eight critical stories. Eighteen filler stories balanced for correct answer on the phrase probe task, main versus subordinate structure of the tested clause, and sentence-initial versus sentence-final position of the tested clause. The subjects were 32 undergraduates at Montclair State College. Sixteen "skilled comprehenders" had VSAT scores in the 550-700 range, and sixteen "average comprehenders" had VSAT scores in the 400-520 range, as in Experiments 1-3.

Results and Discussion

Errors occurred on 10% of the critical trials; response times for these trials were replaced with the corresponding cell mean for correct trials. The mean overall response time was 2,360 msec. Overall, skilled comprehenders responded 110 msec faster than average comprehenders, $F(1, 33) = 12.2$, $p < .01$, and response times were 150 msec faster in supportive contexts than in neutral contexts, $F(1, 33) = 6.24$, $p < .01$. Figure 5 shows that average comprehenders responded faster in supportive contexts than in neutral contexts for both connectives, whereas skilled comprehenders showed the supportiveness effect only for *although*. The interaction between supportiveness, connective, and skill was significant, $F(1, 33) = 4.48$, $p < .05$.

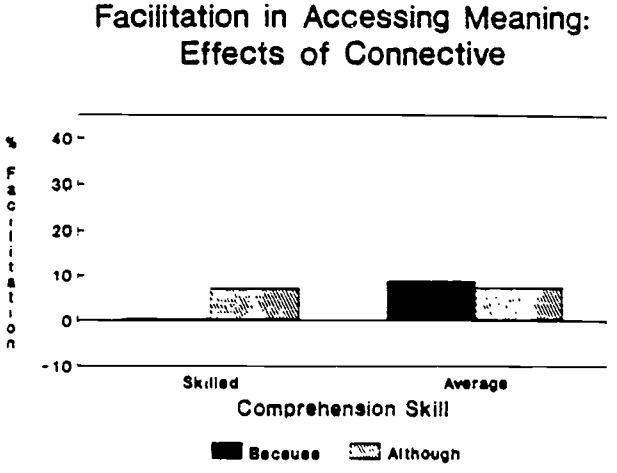

Figure 5. Contextual Facilitation in Synonomy Judgment Times for Skilled and Average Comprehenders on *Because* and *Although* Clauses

These results are consistent with the clause reading time results of Experiment 3. While response times were faster overall in supportive contexts than in neutral contexts, for skilled comprehenders this context effect occurred only for *although* clauses. This result suggests that skilled comprehenders use discourse information and connectives to construct a discourse representation. Supportive contexts provide expectations about the causal relations that underlie the text. This information is more relevant for the discourse interpretation of *although* than *because*. Skilled comprehenders appear to use these expectations on-line to form a discourse representation. For average comprehenders, meaning was more accessible in supportive contexts regardless of connective. Considering average comprehenders in isolation, one might conclude that the script that underlies supportive contexts activates logogens that correspond to certain events and suppresses others. Once again, however, the data from skilled comprehenders suggests that such an interpretation is not correct: supportive contexts may simply facilitate the construction of a discourse representation and not the construction of a sentence representation.

Experiment 5

This experiment tested the processing shift hypothesis against the integration hypothesis of surface information loss. Subjects read texts like (1) and (2) with a rare word such as *dehiscent* in the critical clause. The texts were presented line by line as complete or incomplete clauses, as in (6a) versus (6b). The critical clauses were introduced by either *although* or *because*.

(6a) Although Harry took off the dehiscent tire,

(6b) Although Harry took off the dehiscent

After reading several complete texts, the subjects received a surprise word recognition test in which they had to indicate which words from a list had appeared in the stories. The distractors were either words that were orthographically similar to the target, or common words that plausibly could have occurred in place of the rare words.

Lexical knowledge can be divided roughly into two kinds -- form versus meaning. Knowledge about the form of a word includes its grammatical class, its pronunciation and spelling, and constraints on its syntactic usage. Knowledge about the meaning of a word includes the real-world situations in which it may occur. For example, the meaning of *dehiscent* is related to the general concept of "deflated," but it is clearly inappropriate to use *dehiscent* as a synonym of *deflated* in this context. Knowledge of the form and meaning of a word must be distinct, in some sense, because to know a word, language users must be able to use information about form as a retrieval cue for meaning during comprehension, but they also must be able to use information about meaning as a retrieval cue for form during speaking or writing. Although descriptions of the meaning versus form of words are couched in different terms, and meaning versus form function in different ways during retrieval, these aspects of lexical knowledge also must be integrated in memory in the sense that one elicits the other. Thus, effective lexical knowledge requires an integration of two distinct independent, and separately-describable types of information. Lexical items for which meaning and form are less well-integrated are a frequent source of communication failures, such as the tip of the tongue phenomenon (e.g., Brown and McNeill, 1966).

The representational model maintains that comprehenders integrate surface information more effectively with meaning at the point of obtaining a discourse representation. In the case of unfamiliar words that appear in natural contexts, discourse level integration processes should influence the integration of the meaning and form of target words. Comprehenders should associate the form of an unfamiliar word with contextual meaning more effectively when the representations of form and meaning are both available during comprehension, that is, when the word appears (a) in a complete clause, and (b) the discourse context provides information that is needed to construct a discourse representation. In both cases, relevant conceptual information is more available at a time when the form of the word is also available. The processing shift hypothesis maintains that loss of surface information occurs when comprehenders shift to building a

new substructure, for example at the beginning of a new clause. Since a clause boundary follows the unfamiliar word in both (6a) and (6b), the processing shift hypothesis predicts similar levels of surface information loss for (6a) and (6b). It also predicts that there will be less surface information loss for clauses that maintain a causal chain than for those that are followed by a break in the causal chain. That is, comprehenders will forget more when the target word had appeared in an *although* clause, which explicitly denies a causal relationship with the following clause.

Method

Materials. The same text materials were used as before, except that one word from the critical clause was replaced with a rare word that was loosely a far synonym. For example, *dehiscent* replaced *flat* in (1) and (2). The far synonyms were selected from Roget's thesaurus (Lewis, 1961). The average frequency of occurrence of the target words in English text is 0.87 in a sample of one million words (Francis and Kucera, 1982). The replacing word was always an adjective. Six other rare words were inserted randomly throughout the passages. Either *although* or *because* introduced the critical clauses. The critical clauses appeared only in active form.

Procedure. Subjects read the passages as before in a self-paced reading task with instructions to construct a title for each passage. The passages were presented one line at a time. The critical lines contained either the entire target-containing clause, or all but the last word, as in Experiment 1. Subjects advanced to the next line by pressing a response key. After reading eight passages, subjects received a surprise word recognition test in which they had to indicate whether each of 27 words had appeared in any of the passages. Eight of these were the rare target words that actually had appeared in the critical clauses, and 19 were distractors that had appeared in none of the passages. Eight distractors were common synonyms of target words, and eight were similar in form to the targets in terms of initial syllable and number of syllables. The word recognition test was presented one word at a time on the computer screen, and subjects indicated their response by pressing "Y" or "N." Their responses were timed from the onset of each test item.

Subjects. The subjects were 24 right-handed, native English speaking graduate students at Montclair State College who participated as a course requirement. They were classified as before in terms of VSAT. There were 8 subjects in the skilled group and 16 in the average group.

Results and Discussion

Line Reading Times. To eliminate biases from the number of words in critical lines, line reading times were converted into average word reading times by dividing line reading times by the number of words in the line. Average word reading times were 490 msec per word in supportive contexts and 485 msec per word in neutral contexts, $F(1, 22) < 1$. Subjects read complete clauses only 9 msec per word faster than incomplete clauses, $F(1, 22) < 1$. However, there was a significant interaction between format, connective, and skill, $F(1, 22) = 5.59$, $p < .05$, as shown in Table 4. The fact that skilled comprehenders showed the completeness effect of Experiment 1 only for *because* clauses suggests that they treated *because* clauses as complete sentences. The interaction between supportiveness, connective, and skill was similar to that of Experiments 3 and 4, but it fell short of significance, $F(1, 22) = 2.01$, $p > .10$.

Table 4

MEAN READING TIMES PER WORD (MSEC) FOR CRITICAL LINES

	Skilled		Unskilled	
	Incomplete	Complete	Incomplete	Complete
Although	418	556	535	435
Because	533	455	481	487

Memory. Skilled comprehenders were more accurate than average comprehenders on the word recognition test, $F(1, 22) = 3.91$, $p < .10$. Accuracy was greater when target words had appeared in complete clauses (85%) than in incomplete clauses (70%), $F(1, 22) = 5.46$, $p < .05$. Subjects correctly recognized target words faster when they had appeared in incomplete clauses (2042 msec) rather than in complete clauses (2376 msec), $F(1, 22) = 6.07$, $p < .05$. The processing shift hypothesis predicted no overall difference depending on the clausal completeness of the line, since processing shifts and surface information loss occur most readily *after* a major phrase boundary. Both the accuracy and target recognition time results, therefore, favor the integration hypothesis -- complete sentences function as more complete units of discourse, and they produce better integration of the form of the target word with conceptual information from context. A possible explanation of the speed accuracy trade-off is that subjects access primarily the surface properties of target lexical items that had appeared in incomplete clauses, but their judgments about targets that had appeared in complete clauses depend on both form and meaning. This could yield faster response times and poorer accuracy for incomplete clauses.

Figure 6 shows the supportiveness effects for target recognition times. For skilled comprehenders, supportiveness reduced recognition times for targets that had appeared in *although* clauses, but not for those that had appeared in *because* clauses. In contrast, the supportiveness effects for average comprehenders were similar across connectives. The interaction between context, connective, and skill was significant, $F(1, 22) = 8.84$, $p < .01$. This result supports the discourse representation hypothesis -- supportive contexts facilitate the formation of a discourse representation for *although*. Consequently, comprehenders integrate the form of the target word more effectively with the meaning that the context provides.

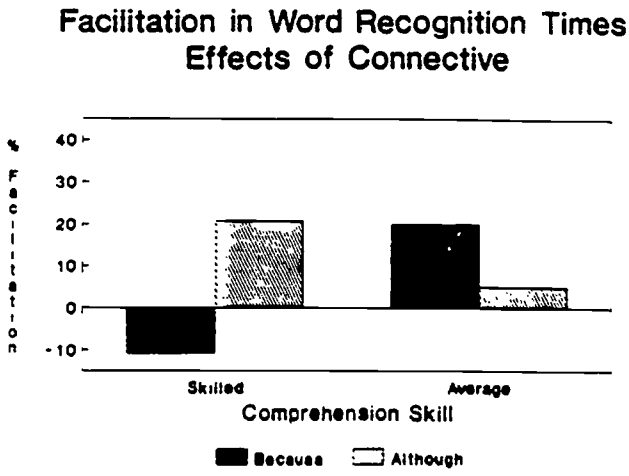

Figure 6. Contextual Facilitation in Target Word Recognition for Skilled and Average Comprehenders on Targets from Because and Although Clauses

The effects of connectives, clausal completeness, and their interactions with comprehension skill on target recognition reflect fairly accurately the more on-line results of Experiments 1, 3, and 4. They therefore suggest that learning, like comprehension, depends on an interaction between prior knowledge and processing the structural properties of sentences during comprehension. The fact that the context effects that were observed in earlier experiments did not occur for reading times, but did occur for subsequent word recognition, suggests that prior knowledge has greater effects on integrative processes than on perceptual processes. The simpler materials in the preceding experiments may have allowed comprehenders to focus resources more on the discourse representation. But the presence of an unfamiliar word in these materials apparently draws some resources away from the discourse level and toward the lexical level during comprehension. As a result, the interaction of context, connective, and skill does not appear in reading times, but it does appear in memory.

There is distributional evidence for the hypothesis that sentence and discourse representations are functionally distinct in lexical acquisition. Gross, Fischer, and Miller (1989) demonstrated experimentally a distinction between two kinds of antonyms: knowledge of "direct" or "lexical" antonyms includes a lexical opposition -- for example, the opposite of *dry* is specifically *wet* -- whereas knowledge of "indirect" or "conceptual" antonyms like *arid*, *humid*, and so on, does not include specific lexical terms for their opposites. Furthermore, Charles and Miller (1989) reported that lexical antonyms are more likely to co-occur in sentences, compared to conceptual antonyms (Francis and Kucera, 1982). This statistical evidence itself supports the claim that there is a functionally-relevant sentence-level representation: The surface properties of words that co-occur within sentences become associated in semantic memory. However, Table 5 shows that lexical antonyms occur proportionately more often than conceptual antonyms in adversative sentences in the Brown corpus, $p < .05$ by sign test. These estimates are based on a sample of 4,152 sentences that contain *though*, *but*, *because*, or *if*, and one of 49 adjectives that Charles and Miller (1989) classified as lexical versus conceptual antonyms. The distribution of lexical and conceptual antonyms across discourse contexts suggests that adversative contexts induce learning specific associations for conceptual oppositions. Such a distribution is consistent with the discourse representation hypothesis: comprehenders obtain the discourse representation of causal sentences "directly," but that of adversative sentences requires additional information, which may extend the availability of its surface properties. The distributional evidence, therefore, suggests that a sentence-level representation accounts for certain aspects of lexical knowledge but also that this representation interacts with linguistically-cued semantic relations to influence the mental organization of lexical knowledge. This result extends the integration hypothesis of the loss of surface information.

Table 5

ESTIMATED PERCENTAGE OF PRINTED ENGLISH SENTENCES THAT CONTAIN TARGET ANTONYMS AND ADVERSATIVE OR CAUSAL CONNECTIVES

	Lexical Antonyms (n=14)	Conceptual Antonyms (n=35)
Adversative (though, but)	13.2	9.0
Causal (because, if)	7.7	8.0

General Discussion

The texts in these experiments are rich in "thematic integrity," but they certainly are not challenging. Their sentences are simple, and their words common. They are about familiar topics, and they are, in effect, co-authored by subjects who are comparable to those that

participated in the experiments. Yet, these texts induced different patterns of performance in mature comprehenders from average to superior levels of skill. These differences in performance cast doubt on several single-factor explanations of individual variations in comprehension skill. The fact that the texts are about familiar topics suggests that skill differences do not depend solely on the amount of *prior knowledge* that is relevant for interpreting the text. Since the sentence structures were simple, it is difficult to imagine that *syntax* presents any particular difficulties. And since the texts mostly contain grade school vocabulary, it is doubtful that basic *word recognition* processes alone could account for skill differences. Considering the lexical, syntactic, and discourse properties of these texts together, it is difficult to imagine that the texts overloaded the general *information processing capacities* of either average or skilled comprehenders.

Neither can the results be explained simply in terms of one group having more rapid access to existing conceptual knowledge. In some of the experiments, skilled comprehenders showed greater effects of discourse supportiveness than average comprehenders (Experiments 1 and 3), and in other experiments the opposite effects occurred (Experiments 2, 4, and 5). Furthermore, the fact that average comprehenders showed smaller effects of contextual supports compared to skilled comprehenders in only two out of five experiments contradicts the view that average comprehenders do not use contextual constraints to suppress inappropriate memory cells. If average comprehenders "have difficulty mapping congruent information in order to develop a coherent structure" (Gernsbacher, 1985, p. 354), they should have shown smaller effects of congruity between a sentence and the discourse context.

In order to distinguish the performance of skilled and average comprehenders, it seems necessary to distinguish between sentence information and discourse information. Sentence-level constraints such as phrase structure and syntactic form influence average comprehenders more than skilled comprehenders, but connectives that are relevant for the discourse representation influence skilled comprehenders more than average comprehenders. These results suggest that skilled and average comprehenders differ in the representational level on which they habitually focus processing resources. The finding that the format in which texts were presented reversed the relative size of supportiveness effects on reading active versus passive sentences shows that external conditions can influence the focus of processing resources toward one or the other level of representation: clause-by-clause presentation allows a focus on discourse representations, if the comprehender is so inclined, whereas word-by-word presentation shifts some resources toward sentence representations. Other studies have demonstrated shifts away from sentence representations. For example, increasing the rate of presentation of spoken or printed language, within certain limits, leads comprehenders to perform more poorly on tests of surface information without impairing performance on tests of meaning (e.g., Chodorow, 1979; Cocklin, Ward, Chen, and Juola, 1984; Townsend and Bever, 1983), just the opposite effect of imposing word-by-word presentation during reading.

Direct Models

The results present a number of problems for models of comprehension that do not recognize independent levels of representation. Two assumptions in this class of models require modification. First, the predictability assumption -- that information at higher levels of structure can suppress lower level hypotheses -- was not supported when it was found that discourse constraints have little effect on reading incomplete sentences. Since comprehenders generally read complete sentences more quickly than incomplete sentences, we cannot reject the view that sentence-level constraints do not facilitate recognition of the final word of a sentence: the reduced reading times for complete sentences may have occurred because of sentence-level constraints on the final word. Similarly, since supportive contexts reduced reading times for complete sentences, we cannot reject the view that discourse-level constraints do not facilitate the organization of sentence information into a discourse representation. We can, however, reject the claim that sentence- and discourse level constraints are *equally* available at all points during comprehension. If they were, increased discourse constraints should have reduced reading times for complete and incomplete sentences to the same extent. Since discourse constraints had greater effects for

complete than for incomplete sentences, discourse-level and sentence-level constraints must not be equally available at all points during comprehension.

The results also present problems for the processing shift explanation of surface information loss. This hypothesis proposed that loss of surface information occurs when comprehenders shift processing resources to a new structure, that is, to one that is less constrained in any way by preceding context. The results of Experiment 5 demonstrated that poorer retention of surface information occasionally occurs when the processing shift hypothesis predicts that it should not -- for example, when the displayed text unit does not contain a complete sentence. Since comprehenders do not initiate new structures for either complete or incomplete sentences, the size of the displayed text unit should not have influenced surface information loss. The results of Experiment 5 also showed that surface information loss does not occur when the processing shift hypothesis predicts that it should --namely, when a denied cause follows a target word. Since *because* clauses are more causally cohesive than *although* clauses, retention of the surface form of *because* clauses should have been enhanced, according to the view that causally cohesive clauses are less likely to induce processing shifts. In both of these cases, the loss of surface information follows naturally from the view that a mechanism for surface information loss is integration of sentence information into a discourse representation. The mechanism of a processing shift could increasing the rate of presentation of spoken or printed language, within certain limits, leads comprehenders to perform more poorly on tests of surface information without impairing performance on tests of meaning (e.g., Chodorow, 1979; Cocklin, Ward, Chen, and Juola, 1984 Townsend and Bever, 1983), just the opposite effect of imposing word-by-word presentation during reading.

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integration of sentence information into a discourse representation. The mechanism of a processing shift could account for these results if it were extended to "vertical" shifts of processing resources -- shifts from a sentence-level representation to a discourse-level representation. That, however, is the integration hypothesis.

The difficulties with the predictability assumption and the processing shift hypothesis arise from the failure to acknowledge a level of representation of sentence information that is (occasionally) independent of representations of lexical content and discourse meaning. A major function of sentence representations is to relate the words of an utterance to units of meaning in the discourse representation. This is not to say, however, that sentence representations do not have other functions. They may persist beyond the completion of a proposition, as in the case of sentence representations of adversative clauses. For adversative sentences, sentence representations have a role in determining relations *between* propositions in the discourse representation in addition to their role in determining propositional content. There are other instances of persisting sentence representations. For example, comprehenders access "sentence"-level information after passing sentence boundaries when they read a noun anaphor that refers to a concept that was mentioned in an earlier sentence (Clottre and Bever, 1988). They also access sentence-level representations of jokes and personal comments more than those for lecture statements (e.g., Bates, Masling, and Kintsch, 1978; Keenan, MacWhinney, and Mayhew, 1977; Kintsch and Bates, 1977). In some cases, the specific details of an utterance may be critical for the point of the utterance. Jokes aren't funny if they're not told the right way.

In each of these cases there is extended access to surface information after meaning has been extracted. Conversely, there are cases in which surface information is lost when little meaning has been assigned. For example, when one listens to a speaker of an unfamiliar language, there is retention of neither meaning nor form. Similarly, an American may listen to an account of a game of cricket, and demonstrate fragmentary retention of the details of speech, compared to someone who is familiar with the game. Thus, obtaining a propositional representation is not a necessary and sufficient condition for losing the corresponding surface information. Rather, such integration is only one factor among several that marks a shift in processing resources away from form toward meaning. Surface information may persist beyond the point of obtaining a propositional representation, but fluctuations in access to a sentence representation may also occur depending on whether its form is particularly relevant for the discourse representation that the comprehender constructs. Meaning and form often are closely related, but they are not identical.

This discussion has leveled many distinctions between different kinds of information. The category of "sentence" information as I have used it is actually an artificial one that includes such diverse types of information as lexical content, grammatical categories, syntactic constraints on words, thematic requirements of verbs, word order, and inflections. Similarly, there is a variety of types of information that I have placed into the "discourse" category --semantic relations between propositions, relations between propositions and prior knowledge, the speaker's intended speech act, and the argument structure of text. The discussion has proceeded as if the information types within categories were equivalent, but there may actually be independent processes within categories. Furthermore, different types of information within a category may differ in their implications for the other category. Consider the ordering of noun phrases within sentences, which Gernsbacher et al. (1989) have shown to be a relevant factor in subsequent anaphoric processing. At one level of analysis, the order of noun phrases is in the category of "sentence" information. But the ordering of noun phrases within sentences may also have a special status in the discourse representation. Indeed, the argument structure of text is the basis for Kintsch and van Dijk's (1978) approach to memory and discourse processing, which relies on both surface and discourse organization of arguments. This special status of noun phrases, however, does not mean that all surface information has the same status. For example, the position of *off* in *Tina and Lisa took off the tire*, though governed by sentence-level constraints -- for example, it can occur before *the* or after *tire*, but not between them -- may be less relevant for the discourse representation than is the ordering of *Tina* and *Lisa*, which may be governed by a variety of constraints (see for example, Cooper and Ross, 1975). Neither does it mean that accessibility to the referents of noun phrases cannot interact with other

properties of discourse representations. For example, we might expect that at certain points during comprehension, the ordering of noun phrases has different consequences depending on the causal versus adversative role of the clause (see Bever and Townsend, 1979). Thus, it would be useful to determine the organization of processes that compute finer-grained properties of sentences and discourses and their interactions. The present research has demonstrated the following conservative conclusions: (a) It is useful to draw at least one line somewhere between lexical and discourse representations. (b) Variations in comprehension skill may depend on how comprehenders access representations and constraints at different levels. It remains to determine whether skilled and average comprehenders differ in how they organize sub-types of information, such as preferred word order versus thematic requirements of verbs during comprehension.

The Representational Model

With those caveats in mind, an account of the present results in terms of distinct "sentence" and "discourse" representations is:

(A) Information flows "upward" from sentence representations to discourse representations, such that the output of sentence processes is the input to discourse processes. Sentence and discourse processes are autonomous in that they operate only on information in a particular form: for example, sentence processes operate on lexical representations, discourse processes on sentence representations. Information becomes available to discourse processes when sentence processes produce a representation of sentence meaning. These representations of sentence meanings become more available to discourse processes upon the completion of more sentence-like sequences. Two results supported this natural unit hypothesis. First, increased discourse constraints reduce reading times for complete sentences but not for incomplete sentences. Second, complete sentence units facilitate longer term retention of unfamiliar words.

(B) Information may flow "downward" from discourse representations to sentence representations, as when speakers generate sentence representations during speech production (e.g., Garrett, 1980). These generated representations may interact with the upward flow of information when each is represented similarly. For example, expectations that comprehenders derive from discourse context interact with sentence processes when comprehenders have assigned specific sentence representations to these expectations. This linguistic prediction hypothesis was supported by the finding that word-by-word presentation reversed the effects of increased discourse constraints on reading times for active versus passive sentences.

(C) Discourse information may facilitate the formation of a discourse representation. The finding that discourse context influences the processing of *although* clauses more than *because* clauses supports the discourse representation hypothesis. The discourse representation of *although* clauses requires information that supportive contexts can provide. On the other hand, the discourse representation of a *because* clause is relatively independent of context.

The representational model of comprehension reconciles previous results which have seemed contradictory -- the near immediacy of access to discourse representations versus the initial independence of sentence representations (e.g., Marslen-Wilson, 1975; Ravner et al., 1983). The resolution of this apparent contradiction hinges on the three assumptions of the model, which have received independent support.

(i) Sentence and discourse processes occur simultaneously, but relatively independently, to obtain representations of sentence information and discourse information.

(ii) The two processes occasionally share limited processing resources.

(iii) Representations that the two processes have produced occasionally interact.

These assumptions have two important consequences. First, there are several ways in which results might appear to support direct models, but actually do not, as shown by the natural unit, linguistic prediction, and discourse representation hypotheses. Second, the fact that sentence and discourse processes may share processing resources means that we can expect variations in the apparent independence of sentence processing that depend on how comprehenders allocate limited resources toward processes of different types. Thus, future investigations into the organization of the component processes of comprehension need to take into account how comprehenders allocate processing resources toward different levels of representation.

The representational model accounts for the present pattern of variations in comprehension skill. One possible account is that representations at a variety of levels of structure become available "automatically." Skilled and average comprehenders differ in how they allocate limited attentional resources to these representations. The fact that the difficulty level of the present materials is appropriate for comprehenders at much lower levels of comprehension skill suggests that the two groups understood the critical sentences equally. Indeed, the two types of comprehenders did not differ in their ability to recall the meaning of the critical sentence. This result suggests that skilled and average comprehenders obtain similar discourse representations of the critical sentence. The results suggest that skilled comprehenders are more flexible in shifting processing resources between sentence and discourse levels. They show greater interactions of discourse information with cues to integrate propositions into a discourse representation, and greater interactions of discourse information with syntactic processing, subject to constraints (A)-(C). Average comprehenders focus resources more on superficial, sentence-level representations. As a result, they show less sensitivity to linguistic cues to discourse representations, but greater sensitivity to the syntactic properties of sentences and discourse constraints on sentences. They focus processing resources on discourse representations more exclusively at the boundaries of discourse units.

A second possible account of individual variations is that skilled and average comprehenders differ in how they allocate limited computational resources to construct representations at different levels. It seems likely that materials of increased complexity at the sentence-level or the discourse-level would magnify the differences in performance between skilled and average comprehenders. If so, it seems to imply that processes at a particular level may share computational resources with another level. A related question is: to what extent does the comprehender control resource allocation strategies, and to what extent do variations in the efficiency of lower level processes condition them? Perfetti (1985; Lesgold and Perfetti, 1978) has argued that inefficient lexical processing may produce forgetting of higher-level representations that comprehenders need for subsequent higher level processes. Certain results present difficulties for this explanation. First, the effects of contextual supports at different levels of skill varied from experiment to experiment, even though the lexical content was similar across experiments. Second, at certain points in linguistic development, comprehenders appear to experiment with alternative ways of organizing linguistic information (e.g., Townsend and Ravelo, 1990). Thus, the present results suggest that some differences in comprehension skill depend on strategies for allocating attentional resources. It remains to determine whether there are processing resources that are ear-marked for processing at specific levels of representation rather than under the comprehender's control.

Relationship to Other Models

The representational model is partly consistent with the extension of the interactive compensatory model that was discussed earlier. The representational model does differ from that model with respect to the claim that:

> In top-down models, semantic processes direct lower-level processes, whereas in interactive models, semantic processes *constrain* the alternatives of lower levels but are themselves constrained by lower-level analyses (Stanovich, 1980, p. 35, emphasis added).

Since processes at several levels occur in parallel, and since there is some sharing of processing resources between levels, what appear to be semantic constraints on lower levels of structure may not be. Instead, constraints on a discourse representation may draw processing resources toward the discourse representation and eliminate the need for processing at lower levels of representation. This feature of the representational model captures the flexibility of processing strategies that comprehenders use in various situations, such as analyzing an argument versus skimming for a main point.

The flexibility of language processing and the sharing of processing resources between levels also distinguishes the representational model from one of the more restrictive models that Fodor (1983) suggested -- "architectural modularity." That model proposed distinct sentence and discourse representations, but also distinct pools of processing resources for each. To account for individual variations in comprehension skill, architectural modularity requires either variations in the content of a knowledge source, such as syntactic knowledge or discourse knowledge, or variations in the processing resources that are available for processing *at a particular level*. While there is some evidence for neurologically-distinct processes from disabled (e.g., Caplan, 1987) and normal comprehenders (Bever, Carrithers, Cowart, and Townsend, 1989), certain aspects of the present studies seem inconsistent with architectural modularity. Since the present materials consisted of topics and linguistic forms that most likely are familiar to both skilled and average mature comprehenders, the knowledge source account of individual differences is implausible. And since presentation format influenced accessibility to different knowledge sources, the account based on the availability of processing resources at a particular level seems untenable. The language processing system is more flexible than architectural modularity allows.

The representational model is agnostic with regard to the issue of whether it is useful to model comprehension with a connectionist architecture. The representational model does make specific claims, however, about the organization of a potentially connectionist architecture First, unlike direct models, representations at a particular level do not have unconstrained access to representations at all other levels. There must be a means of distinguishing bottom-up versus top-down activation of some representation (see Townsend Bever, 1991 for further discussion). Second, to account for individual variations, the connectionist architecture must provide a mechanism for activating or suppressing representations at a particular level. Such a mechanism has traditionally been referred to as "attention." Recent connectionist models have implemented this type of mechanism (e.g., Pfaf, Van den Heijden, and Hudson, 1990), and it does appear to be essential in explaining the organization of sentence and discourse processes.

Endnotes

[1]I am indebted to Tom Bever for discussion on this point.

[2]I use the term "causal" loosely. See Bever and Townsend (1979), Fillenbaum (1975), Lakoff (1971), Townsend (1983), and van den Broek (1990) for discussion.

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