JOURNAL OF VERBAL LEARNING AND VERBAL BEHAVIOR **22**, 189–202 (1983)

What Kind of Pitcher Can a Catcher Fill? Effects of Priming in Sentence Comprehension

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Subjects read sentences that ended in an ambiguous noun that had been disambiguated by preceding selectional restrictions. Each sentence began with a subject noun and a relative clause that could either prime the selected meaning of the final word, the nonselected meaning, or neither. Three experiments used comprehension time and interpretation errors to determine how context integrates with selectional restrictions. There were effects of positive priming on comprehension time and effects of negative priming on interpretation errors. The effects of priming were additive. These results support a threshold model of concept activation.

Consider the following sentences: *The dentist, who filled cavities, marched in the drill. The rabbi, who spoke to the congregation, was hit on the temple.* The comprehender who appreciates the pun in sentences like these has the impression of a "double take," that these sentences take longer to comprehend than nonpun sentences. One goal of this paper is to address the question of whether there are inhibition effects in the comprehension of sentences such as these.

One of the principal focuses of research on language comprehension has been on lexical access and lexical disambiguation, that is, how the comprehender retrieves the appropriate meaning of a word from context. Research using nonsentential context has shown facilitation in lexical decision tasks (e.g., Meyer & Schvaneveldt, 1971; Tweedy, Lapinski, & Schvaneveldt, 1977), and research using sentential context has also shown facilitation in both lexical decision tasks and in phoneme monitoring tasks (e.g., Blank & Foss, 1978; Foss, Cirilo, & Blank, 1979; Kleiman, 1980; Morton & Long, 1976; Swinney, 1979; Onifer & Swinney, 1981). One of the most common explanations for the facilitation effects obtained with the appropriate context involves the notion of *spreading activation.*

The notion of *spreading activation* assumes a long-term memory structure involving concept nodes connected by relational links. A specific concept is activated in memory by external stimulation (e.g., the concept is referred to in speech or in print) or by internal stimulation (e.g., the concept is suggested by some idea already "active" in memory). Activation spreads to related concepts via the relational links connecting them. The closer the concept is to an activated concept, the more activation it will receive, since activation diminishes as a function of the number of links sharing the activation and the distance the activation travels.

Experiments (e.g., Meyer & Schvaneveldt, 1971) can affect the speed with which a string of letters is recognized as a word by presenting to the subject a semantically related word prior to the critical word's exposure. This technique is called semantic *priming*. The spreading activation explanation of this phenomenon is that activation has spread to this word through paths in the semantic net and made it more available. The activation spread to the word sums with activation deriving from reading or hearing the word. This explanation of semantic priming assumes that a certain level of "activation" is required before a lexical decision can be made, similar to the "threshold" in Morton's (1969) logogen model.

Despite the large amount of research look-

The author thanks J. R. Anderson, D. Charney, and C. Wible for comments on the manuscript. The ideas for these experiments developed from discussions and earlier studies done in collaboration with G. H. Bower and from discussions with A. Ortony. Correspondence concerning this paper should be sent to the author at the Department of Psychology, Carnegie–Mellon University, Pittsburgh, Pa. 15213.

0022–5371/83 $3.00

ing at contextual effects on lexical access, especially sentential context, there has been little research that looks at lexical access as *part of the process* of sentence comprehension. That is, although there are numerous studies that have varied contextual information and/or syntactic information to determine factors affecting lexical access, *the criterion tasks* have not required sentence comprehension, as a rule. Some research has looked at time to detect a phoneme or a word within a sentence that contains a lexical ambiguity (e.g., Foss, 1970; Foss & Jenkins, 1973; Marslen-Wilson & Tyler, 1980). Other research has looked at the time to decide whether a letter string is or is not a word as a function of the semantic properties of a sentence that is being processed at the same time (e.g., Kleiman, 1980; Swinney, 1979). Forster (1979) has studied lexical access by using a matching task for sentence-length strings of letters. He varied the approximation to English or the plausibility of the sentences that are to be matched and found that string matching is fastest when the strings are plausible sentences and slowest when they are nonsense strings. Fischler and Bloom (1979) presented the critical word as part of a sentence, but the task was lexical decision, not comprehension. Carpenter and Daneman (1981) have looked at reading times for sentences that contain lexical ambiguity. That study biased the interpretation of the ambiguous word prior to its appearance; however, the correct interpretation was not resolved until after the word had been read.

It is unclear how comprehension of a sentence is affected when context primes a particular meaning of a word when the (typically verb-based) selectional restrictions *preceding* the word disambiguate it. The experiments described here explore the effects of contextual information on sentence comprehension when they are integrated with selectional restrictions. In the sentence, "The rabbi, who chastised his congregation, was hit on the temple," "temple" is an ambiguous word that is disambiguated by the predicate within which it appears.

The first issue to address is whether time to comprehend such a sentence is affected by priming a meaning of the final word given that the homograph was disambiguated in the predicate. Traditional theories of parsing do not use prior semantic information to aid in the lexical search needed for sentence processing. Diffuse, uncontrolled, automatic processes like spreading activation have no place in some linguistic and many computational linguistic models (e.g., Forster, 1979; Frazier & Fodor, 1978; Marcus, 1981). Forster (1979) believes that syntactic processing is autonomous and suggests that lexical access *may be* autonomous too. His response to semantic priming effects mentioned earlier is that they are perhaps an artifact of the paradigm and would not affect lexical access in normal comprehension:

> sentences do not normally contain strongly associated pairs of words. For example, consider the pair *mirth–glee*. Is it conceivable that a sentence containing *mirth* is likely to contain *glee*? Or that sentences containing *summer* have a high probability of including the word *winter*? (p. 74)

There are, of course, others who do believe that various components interact in language comprehension. For example, Marslen-Wilson & Tyler (1980) found that time to detect the presence of an item in a monitoring task was faster when the embedding context was normal English as opposed to only syntactically correct (not semantically) which was faster than random word order. This result of a benefit for a semantically acceptable sentence might generalize such that the *degree* of semantic relatedness will affect normal sentence comprehension time. That is, will comprehension time be affected by semantic associative strength when syntactic and semantic acceptability of the sentence is not varied?

The issue of whether context has an effect on ease of parsing when selectional restrictions are present contains a subsidiary question: If contextual effects exist in sentence comprehension, will there be both positive and negative effects? In lexical decision tasks, some have found substantial interference effects with little facilitation (e.g., Fischler & Bloom, 1979; Neely, 1977), while others have found predominantly facilitation (e.g., Neely, 1976; Schuberth & Eimas, 1977). It appears that inhibition is a less robust phenomenon and only occurs when subjects have a chance to establish wrong expectations. Consult Becker (1980) for a discussion of this apparent inconsistency.

A second question related to the issue of how context integrates with selectional restrictions is whether the effect of priming is additive or whether priming is all or none. Consider the following sentences: "The potter who was thirsty filled the pitcher," "The potter who was tall filled the pitcher," "The lawyer who was thirsty filled the pitcher." The first of these three sentences has both the subject and relative clause priming the correct interpretation of pitcher. An all-or-none view would predict no difference among these sentences. Foss, Cirillo, and Blank (1979) and Schvaneveldt, Meyer, and Becker (1976) would probably predict additive effects of the subject and relative clause. If one assumes a threshold model for critical amounts of activation, then with more sources of activation, threshold would be passed earlier, speeding comprehension time.

If two sources of activation are better than one, will subject and relative clause produce equal priming effects? The sentence subject seems closer to the predicate in a syntactic structure representation than the relative clause, suggesting a larger effect for the subject. On the other hand, the assumptions of spreading activation imply that the relative clause should have a greater impact since closeness in a syntactic structure representation should be less important than how *recently* the critical word had been primed by a preceding phrase. Activation is transient, thus the relative clause which is in closer temporal proximity to the homograph might have a greater effect on time to access the word's meaning.

To answer these questions, several experiments were designed to see if the time to comprehend an *unambiguous* sentence would be affected by contextual priming that biases either the correct or incorrect interpretation of the homograph.

Experiment 1

Overview

The top half of Table 1 shows the types of materials that were used in the experiments. In all cases the sentences end in an ambiguous word that is disambiguated by the preceding verb. All sentences have the structure sentence subject, relative clause, predicate. The sentences vary with respect to whether the sentence subject and relative clause are both associated with the intended meaning of the ambiguous word (positive prime) or are associated with the unintended meaning (negative prime) or have no effect on disambiguating the homograph (neutral). These factors are called *extent* and *direction* of priming.

Subjects were asked to read a sentence, like those in Table 1, displayed on a CRT and push a response button as soon as they comprehended the sentence. To ensure that subjects would bother to comprehend the sentences, half the "sentences" were nonsense, for example, "The catcher who walked to the cloud filled the pitcher," or, "The watchmaker who counted the seconds swam the tick." The subject's task was to judge as fast as possible each string as sensible or nonsense.

Method

Design and materials. The two principal factors, extent and direction of priming, each have three levels. (The extent factor can have the sentence subject prime, the relative clause prime, or both parts of the sentence prime. The direction factor has positive, negative, and neutral levels.) However, the design is not a 3 × 3 because it is not meaningful to talk about the extent of priming in the neutral condition. The seven basic conditions were crossed with the additional factor of sensibility, having two levels, to yield 14 conditions.

Seventy homographs were generated that seemed to the experimenter to have approximately equally dominant alternative meanings. One interpretation of each homograph was selected by writing a predicate that disambiguated the word. Which meaning was selected for a given homograph was randomly

TABLE 1
EXAMPLE SENTENCES FROM THE 14 CONDITIONS IN EXPERIMENT 1

Direction of priming	Extent of priming		
	Subject	Relative Clause	Both
		Sensible	
Positive	The smoker, who observed birds, lit his pipe.	The groom, who replaced his tobacco pouch, lit his pipe.	The smoker, who replaced his tobacco pouch, lit his pipe.
Negative	The plumber, who was very religious, lit his pipe.	The groom, who repaired the sewer, lit his pipe.	The plumber, who repaired the sewer, lit his pipe.
Neutral		The groom, who took the message, lit his pipe.	
		Nonsensical	
Positive	The smoker, who observed birds, wound his pipe.	The groom, who replaced his tobacco pouch, lit his stapler.	The smoker, who replaced his galaxy, lit his pipe.
Negative	The plumber, who was very religious, gargled his pipe.	The dog, who repaired the sewer, lit his pipe.	The infant, who repaired the sewer, lit his pipe.
Neutral		The groom, who took the message, lit his stapler.	

determined. For each of the 70 predicates two sentences were constructed of the form subject, relative clause, predicate. For example, ''pipe'' was disambiguated as ''lit his pipe'' and the following two sentences were constructed: *The plumber, who repaired the sewer, lit his pipe,* and *The smoker, who replaced his tobacco pouch, lit his pipe.* The former version primes the inappropriate meaning, while the latter one primes the appropriate meaning. Any one predicate was seen in only one condition for a particular subject.

Predicates were randomly assigned to one of the seven priming conditions. Subject and relative clause were then constructed to realize the assigned conditions. For sensible sentences in the ''both parts prime'' condition, the subject and relative clause were taken from the positive or negative sentences written for that predicate. The construction of the sensible sentences in the other conditions was slightly more complicated. The part of the sentence not intended to prime was interchanged with a corresponding part of another sentence assigned to the same condition. In the neutral condition, both the subject and relative clause were exchanged with another sentence assigned to that condition. In this case the subject and relative clause could be from either the positive or negative version of the predicate. For example, if the sentences ''The playboy, who seduced women, pitted a date'' and ''The catcher, who walked to the mound, filled the pitcher'' were both assigned to the ''sentence–subject, negative prime'' condition, the sentences actually presented might be ''The playboy, who walked to the mound, pitted a date'' and ''The catcher, who seduced women, filled the pitcher.''

Nonsense sentences were created from sensible sentences by substituting a word in the sentence with one that violates the surrounding selectional restrictions. A nonsense sentence could be nonsensical in four different sentence locations: subject of the sentence, relative clause, verb, or final noun of predicate. It was important that subjects not be able to predict what part of a sentence was nonsensical in advance, if it were a nonsense sentence. Otherwise, a simple strategy could be developed that would obviate reading the sentence. Examples of the forms of the nonsense modifications to the sentences are given in the bottom half of Table 1. In this manner, 35 nonsense sentences were created from a set of 560. They can be classified according to the condition of the sensible sentence from which they derive. All randomization was done separately for each subject so that variation due to materials would be part of the error term (see Clark, 1973).

Subjects. Twenty-eight undergraduates from Carnegie–Mellon University participated either for course credit or for pay. The pay was $2.50 for a session that lasted less than one-half hour.

Procedure. The subjects were seated in front of a video terminal controlled by a PDP 11/34 computer. Each subject was in an individual testing room. The task was explained to the subject and he/she was shown how to respond (indicate sense/nonsense) by pressing the appropriate response key.

The sentence or nonsense sentence was displayed in a left-to-right manner. First, the subject of the sentence appeared on the screen, then 500 milliseconds later the relative clause was added to it and 750 milliseconds later the predicate was added. The timer started at the onset of the predicate and stopped when the subject indicated a response by a button press. The delay between sentence portions was sufficiently small that subjects did not find this presentation style unnatural. There were two reasons for this serial presentation. First, I wanted to ensure that subjects read the material in a left-to-right manner, so that the priming material would be processed before the homograph. The second reason was to minimize the effects of sentence length and other irrelevant variables that would affect reading time. Timing began with the onset of the predicates which were identical across conditions.

Results

The data from Experiment 1 are displayed in Table 2. The principal dependent measure is response time which is given in seconds. The error rate is given in parentheses. The data are partitioned according to which part of the sentence primed the homograph (subject of the sentence, relative clause, or both), whether the priming was positive, negative, or neutral, and whether the statement was sensible or not.

TABLE 2
MEAN REACTION TIMES (AND PROPORTIONS OF ERRORS) TO MAKE SENSIBILITY JUDGMENTS AS A FUNCTION OF CONDITION IN EXPERIMENT 1

	Sensible			Nonsense		
	Subj.	Rel. cl.	Both	Subj.	Rel. cl.	Both
Pos.	2.22	2.18	1.68	1.97	1.94	2.13
	(.19)	(.04)	(.07)	(.24)	(.22)	(.24)
Neg.	2.40	2.10	2.10	2.17	2.12	2.16
	(.18)	(.21)	(.16)	(.21)	(.23)	(.23)
Neutral		2.30			2.39	
		(.21)			(.20)	

Note. Rel. cl., relative clause.

Several analyses of variance were performed on the data.[1] One analysis involved a 2 × 7 factorial design, representing the seven conditions and whether the sentence was sensible or not. A second analysis dropped the neutral condition so that the remaining conditions could be split into a 2 × 2 × 3 design (sensibility × direction of priming × extent of priming). The first ANOVA provided an estimate of the standard error, .14 seconds, for use in linear contrasts.

Analyses were performed using sensibility as a factor and on the sensible data only. Except where noted, both data sets provide the same conclusions. For simplicity, statistics will be given for the analyses that included sensibility as a factor. There was a main effect of positive versus negative priming on both response time, $F(1,27) = 4.45$, $p < .05$ and accuracy, $F(1,27) = 5.41$, $p < .05$. There was also an effect of sensibility on accuracy, $F(1,27) = 12.51$, $p < .01$. How a predicate was primed (subject vs relative clause vs both)

[1] By randomly assigning the predicates to conditions separately for each subject, "materials" are not nested within conditions. In other words, the effects due to condition are not confounded with the homographs selected for the experiment. An item analysis would be uninformative and probably would have unequal numbers of subjects in each predicate by subject condition.

was not a significant factor for the experiment as a whole, but "positive both" was significantly faster, $t(54) = 2.32, p < .05$, for sensible statements. Negative and "neutrally" primed statements did not differ significantly.

Discussion

The data indicate that priming had an effect in so far as positively primed sentences are comprehended faster than negatively primed or neutral sentences. This could mean that the interpretation of an ambiguous word's meaning is resolved by accruing enough positive evidence. Since there was no difference between negatively primed and neutral statements, it may mean that there is no inhibition associated with evidence accruing for the wrong interpretation.

On the other hand, it is not clear whether or not negatively primed statements are inhibited. A strategy of looking for a semantic or syntactic violation does not ensure that a thorough comprehension of a sentence is always achieved. Subjects may have misparsed the sentence, missing the appropriate meaning of the polysemous noun and responded "sensible." There was no way of knowing in this task whether subjects appropriately comprehended the input. The fact that subjects judged a statement to be sensible need not mean that they actually parsed the sentence in the appropriate fashion. A judgment of sensible means only that no anomalous phrase was detected.

Experiment 2 employed a task that forces subjects to comprehend the sentence and indicates whether they had interpreted the polysemous noun appropriately.

Experiment 2

In this experiment subjects demonstrated their comprehension of a sentence by generating a sentence completion. For example, if the sentence were "The rabbi, who chastised his congregation, was hit on the temple," an appropriate completion might be: "and got a bad headache." If a subject were to continue the sentence with "and some windows broke," the completion would be considered inappropriate.

The principal dependent measure in this task was time to start generating a completion. Presumably, subjects could not complete the sentence until they understood it. The secondary dependent measure was number of inappropriate completions.

There are several advantages to this procedure over that of Experiment 1. First, forcing subjects to generate a completion should yield larger priming effects than a comprehension task because the task takes longer (it is harder) and there is more mental processing for priming to affect. Second, the sentence completions will make it clearer whether the subject interpreted the noun correctly.

Method

Design, and materials and procedure. The materials were identical with those of Experiment 1 except that there were no nonsense versions of sentences. There were the same 70 predicates and 140 sentences, one positive and one negative priming sentence for each predicate. There were seven conditions, three that positively primed, three that negatively primed, and one not intended to prime the homograph at the end of the sentence. Again, predicates were randomly assigned to the seven conditions, and the presentation order of conditions was randomized separately for each subject.

As in Experiment 1, subjects were presented with the material on a video terminal controlled by a PDP 11/34. Sentences were displayed from left to right, with the presentation of the relative clause and predicate delayed slightly (same time delays as in Experiment 1) to ensure a left to right reading of the sentence. The timer started at the onset of the predicate on the screen and stopped when the voice key was triggered by the beginning of the subject's sentence completion. After speaking the completion into a microphone, subjects typed the same phrase into the computer which was stored in a file for later analysis.

Subjects could not change their mind about how they wished to complete the sentence after they began to utter one completion. Otherwise, the primary measure of time to generate a response would be a poor measure. Rather, subjects were encouraged not to say anything until they were sure of how they wished to complete the sentence. They were told to speak up as soon as they had an adequate completion and to generate a completion as fast as possible. An experimenter sat in the room with the subject to ensure that the subject typed in what he or she said and to discard any trials where throat clearing, or an "um," stopped the clock. In other respects the experiment was the same as Experiment 1.

Subjects. Twenty-two subjects participated in the experiment. They were tested one at a time with an experimenter present in the room. The experimenter could ensure that the voice key was activated by the subject actually starting a sentence completion rather than a cough or an "um," which would cause an invalid response time. The experimenter could also make certain that the subject typed in the continuation phrase that was first spoken into the microphone. The experiment took less than one hour and subjects were given credit towards fulfilling a course requirement.

Results

The principal dependent measure in this task was time to generate a continuation. A secondary measure was error rate. An error meant that a judge, blind to the experimental hypothesis, considered that the completion indicated that the subject misinterpreted the last noun of the sentence.[2] For example, the sentence, "The watchmaker, who counted the seconds, removed a tick" was continued with the word "tock." That was judged as an error. The continuations "with a tweezer," "from the dog," and so forth, would be acceptable.

The correct response time data from Experiment 2 are displayed in Table 3 in the same fashion as Table 2 for Experiment 1. The probability of an error is listed parenthetically. Again analyses of variance were

TABLE 3

MEAN REACTION TIMES (AND ERROR RATES) TO GENERATE A SENTENCE CONTINUATION AS A FUNCTION OF CONDITION IN EXPERIMENT 2.

	Subj.	Rel. cl.	Both
Pos.	13.63	12.59	11.01
	(.04)	(.03)	(.02)
Neg.	15.60	16.20	14.10
	(.14)	(.17)	(.26)
Neutral		14.98	
		(.06)	

done on the data both using a one-factor (priming condition) design with seven levels and using a two-factor design (direction of prime and extent of priming), dropping the neutral condition.

For both dependent measures, reaction time (RT) and error rate, using the one-way ANOVA, the difference among conditions was significant, $F(6,126) = 6.33$ and 12.31, respectively, $p < .01$. The standard error of estimate was .72 seconds, and 2.5% for errors. The speed advantage for the positive over the neutral conditions was significant, $t(126) = 3.08$; $p < .01$. The response time contrast between the negative and neutral conditions did not differ, $t(126) = .38$. On the other hand, the error rates did not differ for the positive versus neutral conditions, $t(126) = 1.04$, while the negative condition was much worse than the neutral, $t(126) = 4.04$; $p < .01$.

Dropping the neutral case, to allow a 2×3 ANOVA, there was a significant advantage on RT and on errors for positive priming over negative, $F(1,21) = 21.21$; $p < .01$, and $F(1,21) = 53.4$. There was also a significant effect on RT of what parts of the sentence were priming the predicate, $F(2,42) = 6.27$; $p < .01$, such that there seemed to be an advantage in both priming conditions to have *both* parts of the sentence prime the predicate. An explanation for that effect will be offered later. There was no significant interaction for RT.

On the other hand, error rates did not vary with the part of sentence priming the predicate, $F(2,42) = 2.53$; $p < .1$, but rather

[2] The expression "wrong" is used loosely here. It is only meant to distinguish the unintended interpretation from the interpretation intended by the predicate context preceding the homograph.

tended to interact with whether the priming was positive or negative, $F(2,42) = 6.5$; $p < .01$. Most errors occurred in the negative-both condition and the least occurred in the positive-both condition.

In the positive condition, the effect for the sentence subject was somewhat weaker than the relative clause. The positive prime relative clause was significantly faster than the neutral condition, $t(126) = 2.35$; $p < .05$, while the subject was not, $t(126) = 1.32$. Positive both was, of course, also significantly faster.

The priming effects appear to be additive; the speed advantage (when compared with the neutral condition) for the positive prime subject condition is 1.35 seconds and is 2.39 seconds for the positive prime relative clause condition. The speed advantage in the positive prime both condition is 3.97 seconds which is quite close to the 3.74 seconds of the other two conditions.[3] Given that the ''both'' condition has a similar number of errors to the two slower positive prime conditions, error rates do not cloud the suggestion of additivity.

Discussion

Experiments 1 and 2 both show facilitation, but no inhibition on the reaction time measure. Semantic priming can have a facilitative effect on time to comprehend a sentence containing an ambiguous word. However, contextual priming intended to bias an interpretation that is inconsistent with the meaning (required by the preceding selectional restrictions) does not hinder the semantic resolution in terms of comprehension time. There is an effect of negative priming in Experiment 2 that appears as an increase in the probability of an incorrect parse of the sentence, that is, selecting the wrong interpretation of the homograph. Experiment 1 did not give a good indication of whether or not the subject actually retrieved the appropriate sense of the word.

A model of lexical retrieval is suggested by this pattern. In this model, meaning selection involves a threshold such that sufficient activation must reach the appropriate node before that interpretation will be accepted. Consistent evidence (positive priming) causes activation to spread to the appropriate concept node and sum with or precede activation from the predicate's selectional restrictions. This means that the activation needed to exceed threshold will be achieved earlier, allowing an interpretation of the homograph and sentence faster than normal. In the negative priming condition the extra priming to the wrong concept node does not interfere with activation accumulating at the normal rate for the appropriate node. This would explain why there was no difference between the negative and neutral conditions. The reason that the effect of negative priming appears as an increase in the number of errors is that sometimes the activation accumulating at the wrong concept node goes beyond threshold. So long as the activation does not go beyond threshold, the activation does not interfere with activation accumulating at the appropriate node. When it passes threshold, a wrong interpretation is available and will sometimes be selected.

Potential Problems in Interpretation

There is an alternate explanation for the lack of an inhibition effect when contrasting the negative and neutral conditions. Note that the negative priming-both condition is actually faster than the negative prime-subject or negative prime-relative clause conditions. This is true for both Experiment 1 and Experiment 2. It is conceivable that the ''both'' conditions are faster than the subject and relative clause priming conditions because of the nature of the materials, rather than some intended property. The manner in which the materials were generated might also be the reason why the neutral condition is as slow as the negative prime condition. This particular property of the construction of the materials can be explained as follows: A positive priming sentence and a negative priming sentence had been written for each predicate. Only the positive-both condition and the negative-both condi-

[3] It is possible, however, that the part of the advantage of having both the subject and relative clause prime the predicate is due to the sentence subject facilitating the processing of the relative clause.

tions used these sentences that actually had been written. The sentences tested in other conditions were constructed by the computer by exchanging corresponding parts of various sentences. For example, a subject might see the sentence "the catcher, who counted the seconds, filled the pitcher" or "the sales lady, who walked to the mound, filled the pitcher" or "the sales lady, who counted the seconds, filled the pitcher." These "swap sentences" might have been less coherent or cohesive than the sentences that were originally constructed. An attempt had been made when the sentences were originally constructed to make the sentence subject and relative clause unrelated, although both had to be related to the predicate. Of course, it is difficult to be as successful as one would like.

A potential materials confound calls into question the conclusion about the absence of an interference effect. There may have been a *cohesiveness* effect such that the negative prime-both and the partially primed negative sentences were inherently more comprehensible than the neutral condition against which they are compared. A neutral condition with the same amount of cohesiveness as the "both" conditions would be desirable. This was the motivation for Experiment 3. A "cohesive" neutral condition provides a test to see if negative priming actually interferes with comprehension.

EXPERIMENT 3

Method

Experiment 3 was identical to Experiment 2 with the exception that the neutral condition sentences were constructed in a new way. Rather than interchanging the subject and relative clauses with other sentences, the sentences were identical to those in the negative prime both condition, except that the homograph at the end of the sentence was replaced by a single-meaning word related to it. For example, "The catcher, who walked to the mound, filled the pitcher" was replaced with "The catcher, who walked to the mound, filled the glass." There were still seven conditions, three that positively primed, three that negatively primed, and one for which there was no homograph to prime. Again, the assignment of predicates to the seven conditions and the order of presentation of the conditions was random. The randomization procedure was done separately for each subject. After the predicates were assigned to the neutral condition, the appropriate word replaced the homograph. The rest of the sentence in the neutral condition was the sentence that would have been used if the predicate had been assigned to the negative prime-both condition. In this way the coherence of the neutral condition was equivalent with its relevant comparison condition. The procedure was identical to that of Experiment 2.

Subjects. Twenty-four subjects participated in this experiment. Again, they were tested one at a time with an experimenter present in the room. The experimenter ensured that *false starts* were not included in the analysis. The experiment took 40 minutes to 1 hour to complete and subjects were given credit or money for participation.

Results and Discussion

One subject's data were excluded from analysis since he intentionally completed sentences in an ambiguous fashion. A second subject was excluded because he was a nonnative speaker. As before, the principal dependent measure was time to generate a continuation; the secondary measure was error rate. Completions were rated or classified into several categories that will be described below. The times to generate an acceptable completion as a function of priming condition are presented in Table 4 as are the percentage of errors made in each condition. Six of the seven conditions are identical in design with those of Experiment 2. The pattern of responses in these conditions seems to be the same, although the base RTs are somewhat faster.[4] That is, the data for the positively primed and the

[4] With normalized RT, that is, response times corrected for subject differences in mean completion time, the exact same results were obtained. The z scores are practically identical in corresponding conditions in Experiments 2 and 3, with the exception of the neutral condition.

TABLE 4
MEAN REACTION TIMES (AND ERROR RATES) TO GENERATE A SENTENCE CONTINUATION AS A FUNCTION OF CONDITION IN EXPERIMENT 3

	Subj.	Rel. cl.	Both
Pos.	6.47	6.57	5.88
	(.02)	(0)	(.01)
Neg.	8.45	8.35	7.97
	(.11)	(.13)	(.20)
Neutral		7.69	
		(0)	

Note. Rel. cl., relative clause.

negatively primed conditions are comparable with those of the previous experiment, in that again, the fastest condition is the positively primed-both condition, and the negatively primed conditions are much slower. Subjects are still faster in the negative-both condition than in either of the other two negative prime conditions.

The critical question is whether the neutral condition is faster than the negative condition when all parts of the negative sentence are lexically coherent, that is, the negative-both condition and the neutral condition have exactly the same words in the sentences with the exception of the final word. With this modification, the neutral condition is somewhat faster than the negative prime-both, so lexical coherence may have had some effect; however, the difference is small and is not statistically reliable, $t(126) = .5$. Therefore, the conclusion that the negative priming manipulation does not slow comprehension (when compared with the neutral condition) is supported by this control study.

The standard error (used in the t test) was obtained from a one-way ANOVA and is .41 second. A two-way ANOVA on the six conditions that form a 2×3 design produced the same results as Experiment 2. There was a main effect of positive versus negative priming $F(1,21) = 13.34, p < .01$, such that subjects took longer to comprehend negatively primed statements. No other effects or interactions reached significance. This time, the sentence subject was slightly more effective than the relative clause at facilitating comprehension when compared to the neutral case, $t(126) = 2.1, p < .05$, and $t(126) = 1.93, p < .05$, one tailed, respectively.

Error analysis. ANOVAs were also performed on the error data in a fashion analogous to the reaction time data. The striking pattern of error rate differences displayed in Table 4 yield a number of significant results. For the two-way ANOVA, there was a main effect of direction of priming, $F(1,21) = 42.01, p < .01$, such that subjects make more errors to negatively primed statements. There was also a significant interaction of direction of priming and part of sentence priming, $F(2,42) = 4.19, p < .05$, such that subjects made fewest errors in the positive-both condition and most errors in the negative both condition, as one might expect.

The standard error of the mean estimated from the one-way ANOVA is .019. The contrast between the neutral and negative-both condition, of course, is highly significant, $t(1.26) = 8.0, p < .01$. Again, negative priming seems only to affect error rate. It is clear that subjects are far more likely to misinterpret the ambiguous noun if it is negatively primed, however not all interpretations different from the intended should be called erroneous. Occasionally the negative prime will be so strong that subjects find a way to reinterpret the last word and generate an acceptable statement. For example, "bought a *speaker*" was supposed to refer to a piece of stereo equipment; however, in the context of "The club ladies, who heard a lecture, bought a speaker" one subject continued the sentence with "lunch." Another subject completed the sentence "The plumber, who repaired the sewer, lit his pipe" with the expression "with a flashlight."

For purposes of computing time to comprehend the sentence and parse the predicate *as intended*, the above example was treated as an "error." Actually those reinterpretations, in general, took longer to generate than the correct interpretations. The pattern of response times across conditions is the same with these data included, only more extreme. Since the question of interest was the time to com-

TABLE 5
PROPORTIONS OF CONTINUATIONS ACROSS CONDITIONS REFLECTING WRONG INTERPRETATIONS AND REINTERPRETATIONS OF THE PREDICATE FOR EXPERIMENTS 2 AND 3

	Wrong interpretations		Reinterpretations	
	Expt 2	Expt 3	Expt 2	Expt 3
Positive				
Subject	.04	0	0	.02
Relative clause	.03	0	0	0
Both	.02	.01	0	0
Negative				
Subject	.10	.07	.04	.04
Relative clause	.14	.09	.03	.04
Both	.20	.14	.06	.06
Neutral	.05	0	.01	0

prehend the *intended* meaning in various sentence contexts, all other interpretations, sensible or not, were excluded. Table 5 gives the percentage of reinterpretations and errors (ungrammatical or semantically anomalous parses) as a function of condition. The propensity to generate reinterpretations and wrong interpretations are highly correlated across conditions. The reason that there are a few reinterpretations in the positive condition is that a few predicates were more ambiguous than intended. Of the 70 predicates, three accounted for almost all reinterpretations in the positive conditions: "argued the suit," "rolled some grass," and "licked a seal." Since predicates were randomly assigned to conditions for each subject, these few ambiguous phrases would only add noise to the error term.

General Discussion

Three experiments were described that all measured time to comprehend a sentence. Comprehension time was expected to vary as a function of the match between the sentential semantic context in the early clauses of the sentence and the selectional restrictions of the predicate, both of which could potentially disambiguate the final polysemous noun. When the prior context matches the selectional restrictions, comprehension time is reduced. However, when the prior context suggests one meaning of the final homograph, and the constraints of the predicate suggest another interpretation, comprehension time is no longer than when the preceding sentential phrases are completely neutral with respect to the homograph.

On the other hand, the last two of the three experiments did show an effect of "negative priming" in terms of the number of "wrong" interpretations of the final word. That is, the meaning of the homograph intended by the choice of predicate (selectional restrictions) was not the interpretation chosen by the subject. Given that an interpretation was only considered incorrect when the sentence completion clearly indicated the other sense of the word, the measure of error rate is necessarily conservative, that is, an underestimate.

The data seem to rule out a model of lexical retrieval where activation accumulating for one interpretation affects the time for another meaning to become available or the amount of activation needed for a second meaning to be selected. This is because there was no interference in terms of comprehension time (as compared with the neutral conditions) for the "negative prime" conditions. The reason to assume a threshold model is that there was a large effect on error rates due to negative primes even though there was no comprehension time result. Presumably on some portion of trials, the activation accumulating at the wrong concept node is so large that this wrong meaning becomes available and is sometimes then used in parsing the sentence.

The type of model that seems most consistent with the data involves several assumptions, mentioned earlier. The model assumes a semantic network of interassociated concepts where connections among concepts differ in strength corresponding to degree of relatedness. Amount of activation passed from one concept node to another depends on the strength of the connection and the number of links activation must traverse. A critical amount of activation must be present at a concept node before the meaning of the activated word node becomes available. This notion of a criterion level of activation is consistent with four different results in the data: The positive priming effect on RT, the lack of a negative priming effect on RT, the effect on errors of negative primes, and the additivity of priming. Positive priming causes additional activation to be sent to the correct meaning node. This means that the criterion is passed sooner than if only the preceding verb provided activation. Negative priming does not slow comprehension over the nonprimed sentence because the amount of activation accumulating at the wrong node does not slow down activation accumulating at the correct interpretation's node. The effects of negative primes are felt only when activation passes threshold first for the wrong meaning and that interpretation is selected before the correct meaning becomes available. In this case, there will be an error, frequently observed in the negative prime conditions.

The facilitation for positive priming is biggest in the "both" condition, suggesting that both sources of positive priming are sending activation, allowing the critical amount of activation to accumulate at the correct meaning node more rapidly. Not only is the effect larger for the "both" condition than either of the other two, but the size of the facilitation is roughly twice as large when both the relative clause and the sentence subject prime rather than when just one of them primes. The finding of additivity when two parts of the sentence prime, rather than just one, has been found elsewhere in somewhat different tasks (Blank & Foss, 1978; Schvaneveldt et al., 1976) and is also predicted by models of spreading activation (e.g., Anderson, 1983). This view also correctly predicts that there should be more errors for the both condition among the negative prime types; the wrong interpretation will pass over threshold before the correct one more often in this condition.

The notion of activation accumulating at a meaning node faster when there are two sources of priming, (i.e., the both condition) can also be used to explain the faster response times for the negative-both condition than for the other two negative priming conditions. That is, there is a version of the speed–accuracy tradeoff (see Pachella, 1974) that is consistent with the model proposed here. As mentioned above, there are more errors in the negative-prime both condition than the other two negative-priming conditions because activation goes over threshold for the wrong meaning before the correct meaning more often. Given that the average time to pass over the threshold for the wrong meanings is faster in the both condition, the average time for the correct interpretations that beat the wrong interpretations typically will have to be faster in the both condition too. Of course, there will be fewer correct response times (more errors), but those trials that are successful will tend to be faster.[5]

It should also be noted that the concept node for the "wrong" interpretation can also send activation to other nodes. Indeed, there is evidence that both meanings of a word are available as sources of activation even when there is prior disambiguating information in a sentence (e.g., Swinney, 1979). This evidence comes from experiments employing a lexical decision task, not a comprehension task. When only one sense of a word is primed, people are normally unaware of any ambiguity, even though the other sense is somewhat "active."

One might wonder how people normally

[5] If this does not seem clear, consider an analogy to a horse race: If you have a horse that you enter in races where the competition is not stiff, he will win more races (greater accuracy), but his average win time will be faster for those races where he races against faster horses and therefore loses more often (lower accuracy).

appreciate the pun in a sentence yet take no longer to recognize the intended meaning. One explanation consistent with this model is as follows: When hearing "The catcher, who walked to the mound, filled the pitcher," the wrong interpretation of pitcher is primed and actually accessed before or after the correct meaning. However, this does not inhibit access of the correct meaning which occurs at the *normal* point in time. When the normal meaning is retrieved, it is recognized as correct. At the point both meanings are available, the pun is appreciated.

Typically, people are not exposed to puns and therefore multiple meanings of a polysemous noun do not cross over their thresholds. However, some activation of the unintended meaning will occur simply from spread from the intended meaning. That is why there is facilitation in lexical decision tasks for words related to the unintended meaning. In everyday life there is evidence of this facilitation in that we often select a particular word that is somehow related to recent prior experience. While writing this portion of the manuscript, I came across an illustration of this phenomenon from an early draft of a manuscript by Anderson (1983): "Another relevant aspect concerns Chomsky's proposal for various 'mental organs.' Looking at a very restricted aspect of language behavior . . ." The first occurrence of "aspect" was not even the appropriate term, but was heavily primed due to the strong link between Chomsky and his famous book *Aspects*.

The priming effects obtained in Experiments 2 and 3 were larger than in the first experiment. Using a sensibility judgment task may have attenuated the effects because the task is easier and subjects can guess. The notion that priming effects will be larger in more difficult tasks (e.g., in word completion—D——IVE—than in lexical decision) has been argued elsewhere (Anderson, 1983; Meyer, Schvaneveldt, & Ruddy, 1974).

In summary, the data support the notion that there are facilitation effects in parsing that come from diffuse activation and not just from a more syntactically organized parsing mechanism. The pattern of results obtained here are consistent with a broad perspective on human cognition, namely, that humans are highly parallel processors, and that information from many sources are used concurrently (e.g., parsing mechanisms and context). Yet, there are clever design features in our processing mechanisms (e.g., an activation threshold) so that inappropriate information rarely interferes.

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