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Evidence for Multiple Stages in the Processing of Ambiguous Words in Syntactic Contexts

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A variable time delay naming latency paradigm was used to investigate the processing of noun–verb lexical ambiguities (e.g., *watch*) in syntactic contexts which either biased the noun or verb reading (e.g., *I bought the watch; I will watch*). Target words related to either the noun or verb reading were presented at 0, 200, and 600 msec following the sentence-final ambiguous word. At 0 msec, naming latencies related to either reading were facilitated regardless of the biasing context. By 200 msec, facilitation obtained only for targets related to the reading of the ambiguous word biased by the context. The results support a two-stage model in which all readings of ambiguous words are initially accessed and then the inappropriate readings are rapidly suppressed.

While a large proportion of the words in English have multiple semantically distinct meanings, listeners are usually able to determine the contextually appropriate meanings of such words without apparent difficulty and without becoming aware of their potential ambiguity. In order to accomplish this, listeners must make decisions based on the information provided by the local contexts in which the words occur. These decisions are extremely rapid and largely opaque to introspection. Although the processing of lexical ambiguities has been one of the most extensively researched areas in language comprehension, the literature does not yield a coherent characterization of the processes involved in these decisions (for reviews see Clark & Clark, 1977; Fodor, Bever, & Garrett, 1974; Foss & Hakes, 1978).

Most of the research on lexical ambiguity has focused on distinguishing between models which predict either selective or multiple access of meaning (Foss & Jenkins, 1973; Clark & Clark, 1977). The multiple access model maintains that all common readings of an ambiguous word are initially retrieved and listeners subsequently use contextual information to select a single reading. The selective access model maintains that natural language contexts typically constrain the lexical retrieval process such that only the contextually appropriate meaning is accessed. While there is consistent evidence that multiple readings of ambiguous words are accessed when presented in isolation (e.g., Holley-Wilcox & Blank, Note 1; Rubenstein, Garfield, & Millikan, 1970; Rubenstein, Lewis, & Rubenstein, 1971), evidence concerning the effects of biasing contexts is less clear. Using the lexical decision task, Schvaneveldt, Meyer, and Becker (1976) found that when ambigu-

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ous words were preceded by words related to one meaning, subjects accessed only that meaning. However, Warren, Warren, Green, and Bresnick (1978) presented subjects with homophones and homographs in biasing word lists and reported intrusions of the unbiased meanings on a subsequent Brown-Peterson task, suggesting that multiple access had occurred.

Studies of lexical ambiguities in sentential contexts also show mixed results. Most early studies examined whether lexical ambiguities increased transient processing load, using the phoneme monitoring paradigm. These studies generally found that reaction times to detect a target phoneme increased following an ambiguous word, relative to controls (Foss, 1970; Foss & Jenkins, 1973; Cairns & Kamerman, 1975). These longer phoneme monitoring times were interpreted as reflecting an increase in processing load, due either to the initial access of both readings or the decision process involved in selecting the appropriate reading. Foss and Jenkins (1973) found that biasing contexts did not reduce phoneme monitor times following ambiguous words. Holmes, Arwas, and Garrett (1977), using the RSVP technique, also obtained an ambiguity effect that was not reduced by biasing contexts. These results suggested that listeners do not use contextual information to select the single appropriate meaning of an ambiguous word as it is heard. Swinney and Hakes (1976), however, reported that phoneme monitor times following ambiguous words in more strongly biasing contexts were faster than those to ambiguous words in unbiased contexts, suggesting that selective access had occurred.

Results from the phoneme-monitor experiments have recently been called into question by Mehler, Segui, and Carey (1978), who demonstrated that phoneme-monitor times are dependent on the frequency and length of the word preceding the target phoneme, which previous researchers failed to control. Mehler et al. failed to find an ambiguity effect using materials controlled along these lines (see also Newman & Dell, 1978). Mehler et al.'s (1978) failure to find an ambiguity effect is itself an ambiguous outcome, however. It could be due, as they argue, to the fact that selective access had occurred on-line. Their results would also obtain, however, if the phoneme-monitor task were insensitive to the transient increase in processing load due to multiple access, or if the task were performed sometime after the selection process had taken place.

As an alternative to divided processing response measures such as phoneme monitoring, several investigators have recently turned to priming paradigms, widely used in semantic memory research (Conrad, 1974; Oden & Spira, Note 2). According to current models of semantic memory, encoding a word results in the activation of semantically related words in memory (Collins & Loftus, 1975; Morton, 1969). Supporting evidence comes from research using three response measures: naming (pronunciation), lexical decision, and color naming (Stroop). Naming latencies and lexical decisions to a target word are facilitated when it is preceded by a semantically related prime word (Meyer, Schvaneveldt, & Ruddy, 1975; Warren, 1977), while interference in color naming latencies obtains (Warren, 1972). These paradigms can be used to determine which readings of an ambiguous word are accessed. If a particular reading is accessed, then priming of targets related to that meaning should obtain.

Conrad (1974) used a color naming paradigm in which sentences containing lexical ambiguities in biasing and nonbiasing contexts were followed by target words which were either related to one meaning of the ambiguous word, or were unrelated. Conrad reasoned that color naming interference to target words related to a meaning of the ambiguous word would be compelling evidence for that meaning having been accessed. Targets related to both meanings of ambiguous words produced color naming interference compared to unrelated controls, regard-

less of context. Conrad interpreted this as evidence that subjects accessed multiple meanings and concluded that lexical retrieval was not constrained by context. Conrad's study, however, suffers from two criticisms. First, each ambiguous word was presented a total of five times during two days of testing. If subjects became aware that the stimuli were ambiguous, then they may have accessed meanings which would go unnoticed during normal language comprehension. Second, while Conrad did not find a reliable effect of context, more color naming interference was obtained to target words related to the meaning of the ambiguous word biased by the context.

Oden and Spira (Note 2) used the color naming paradigm to investigate lexical ambiguities in syntactic, semantic, and sentential contexts. They found a large difference between biased and unbiased readings, with target words related to biased readings showing more color naming interference in all contexts. In semantic and sentential contexts, both biased and unbiased readings showed substantial interference. In syntactic contexts, however, there was only minimal color naming interference for targets related to the unbiased meaning. Oden and Spira (Note 2) conclude that all readings are initially accessed (activated), with the strength of the activation determined by the context.

The apparent contradictions between Conrad's and Oden and Spira's findings may be due to several factors. Oden and Spira did not repeat ambiguous words and target words as frequently as Conrad. More importantly, Conrad presented target words immediately following prime sentences which ended in the ambiguous word. Oden and Spira, however, introduced a 500-msec delay between the end of the sentence and the onset of the target word.

This 500-msec interval could be critical. If, for example, multiple access is followed by a rapid selection process based on context, then the 500-msec interval may have provided enough time for the contextually appropriate reading to be selected. Hence, Conrad, probing at the beginning of the interval, found evidence for both readings and no effect of context, while Oden and Spira, probing after 500 msec, found a large difference between contextually biased and unbiased readings. This suggests that there may be different patterns of activation in semantic memory at various intervals following an ambiguous word. Thus, manipulating the interval between the ambiguous word and the target word may provide valuable information about the processes and time course of ambiguity resolution.

Evidence that context effects in word recognition may be critically dependent on temporal parameters is provided by a recent study by Neely (1977). Neely used the lexical decision task with a variable time delay manipulation. Subjects were presented with a prime word which was the name of a category followed by a target word which was a category exemplar. The stimulus onset asynchrony between the offset of the prime and the onset of the target word was varied. In addition, Neely factorially manipulated whether or not the target word was semantically related to the prime and whether or not the target word came from the category which the subject expected. At a stimulus onset asynchrony of 250 msec, lexical decision times to target words which were exemplars of the prime category showed facilitation relative to neutral (XXX) primes, regardless of the subjects' expectations. Beginning at 400 msec, however, unexpected targets showed inhibition, regardless of whether or not they were semantically related to the prime. Expected targets all showed facilitation, regardless of their semantic relationship to the prime.

In the present study, a variable delay naming paradigm was used to study the processing of noun–verb ambiguities in sentences. These words are ambiguous between two semantically distinct meanings, one a noun and one a verb (e.g., *watch*). Because the

component meanings fall into different grammatical classes (in contrast, for example, to noun–noun ambiguities such as *organ*), the sentential contexts in which the word appears provide syntactic information which typically is compatible with only one reading. For example, in Sentence (1) only the verb reading of *tire* is possible, while in Sentence (2) only the noun reading of *rose* is possible.

(1) John began to *tire*.

(2) John brought a *rose*.

Subjects heard sentences such as (1) and (2) followed by the presentation of a single word on a screen. Their task was to name the word aloud. Targets were either related to the meaning of the ambiguous word biased by the context (e.g., sleep in (1), flower in (2)), related to the nonbiased meaning (wheel and stand, respectively), or unrelated to either meaning. Targets appeared at three stimulus onset asynchronies following the sentence-final ambiguous word: 0 msec, 200 msec, and 600 msec. The logic of the experiment was similar to Conrad's (1974). If listeners access a particular meaning of an ambiguous word, then latencies to name a word related to that meaning should show facilitation relative to unrelated controls. If listeners only accessed the contextually-appropriate meaning, then facilitation should occur only for the target related to that meaning. Latencies to the target related to the unbiased, unaccessed meaning should be longer and equivalent to those for controls. If, however, listeners access both meanings of an ambiguity, there should be equivalent facilitation to both related targets.

These outcomes should vary as a function of stimulus onset asynchrony if multiple stages are implicated in ambiguity resolution. In particular, subjects may access multiple meanings at short stimulus onset asychronies but select a single meaning some time after. Hence, there may be facilitation to both related targets at one stimulus onset asynchrony, but facilitation to a single related target at a longer stimulus onset asynchrony. Conversely, listeners may access a single meaning initially, but activate a second meaning at longer latencies. Finally, if listeners access only a single meaning, then equal facilitation should be seen at all stimulus onset asynchronies for the target related to that meaning.

Method

Subjects. Sixty Wayne State University students served as subjects in the experiment.

Stimulus materials. A list of 24 ambiguous words with independent noun and verb readings was constructed (e.g., *watch*). Two sentential contexts were constructed for each word. One assigned a noun reading to the ambiguous word and the other assigned a verb reading. The ambiguous word was always the last word in the resulting sentence. Examples of sentential contexts in which the word was a noun and a verb are given in (3) and (4), respectively.

(3) I bought the *watch*.

(4) I will *watch*.

Two control sentences were also constructed for each ambiguous word. These were identical to the noun and verb sentential contexts with the exception that a neutral word was substituted for the ambiguous word. The neutral words were approximately equal to the words they replaced in length and frequency (Kučera & Francis, 1967). Examples of control sentences for the noun and verb readings of *watch* are given in (5) and (6), respectively.

(5) I bought the *cake*.

(6) I will *park*.

Thus, there were four sentences associated with each ambiguous word: a sentence which assigned the ambiguous word a noun reading, a sentence which assigned the ambiguous word a verb reading, and a noun and verb control sentence. Altogether, then, there were 96 stimulus sentences.

Each ambiguous word was also assigned a target word which was an associate or syn-

TABLE 1
EXAMPLES OF THE SENTENCES AND TARGET WORDS USED IN EACH CONDITION

Target type	Sentence	Target word
	Noun context	
Noun target	She held the rose.	Flower
Verb target	They needed a new sink.	Swim
	Control noun context	
Noun target	She held the post.	Flower
Verb target	They needed a new joke.	Swim
	Verb context	
Noun target	They all rose.	Flower
Verb target	They began to sink.	Swim
	Control verb context	
Noun target	They all touch.	Flower
Verb target	They began to lift.	Swim

onym of either its noun or verb reading. Half of the ambiguous words were assigned noun targets, while the other half were assigned verb targets. The target word assigned to a particular ambiguous word was paired with each of the four sentences constructed for that word. Including controls, there were a total of eight different sentence-target combinations. Examples of the sentence-target combinations are presented in Table 1. Ten practice sentences were also constructed. The target words assigned to these practice sentences were not related to the meanings of any of the words in the sentences.

The 96 stimulus sentences were divided into four blocks, each containing 24 sentences. One of the sentences constructed for each ambiguous word was randomly assigned to each of the blocks with the restriction that each block contain six exemplars of each sentence type. Furthermore, half of the exemplars of each sentence type in each block were paired with noun targets and half with verb targets. The order of the sentences within a block was randomized. Thus, the eight sentence-target conditions were equally represented within the four blocks (three exemplars per block). The order of blocks was counterbalanced, resulting in four presentation versions.

The four blocks of stimulus sentences were recorded on one channel of a stereo tape with a 12-second interval between sentences. A timing tone coinciding with the end of each sentence was placed on a separate channel of the tape. The target words were typed on 2×2 slides.

Procedure. Subjects were randomly assigned to one stimulus onset asynchrony and one version. Within a particular stimulus onset asynchrony, five subjects were assigned to each of the four versions. Subjects were instructed to listen to each sentence and then read the word presented on the screen as quickly as possible. The subjects were then presented with the 10 practice trials followed by the four blocks of test trials.

On each trial the subject heard a stimulus sentence binaurally over headphones followed by the presentation of a target word. Target words were rear-projected onto a screen in front of the subject using a Kodak Carousel slide projector. At a viewing distance of 54 cm, the target words subtended a visual angle of about 5.6° horizontally and 1.2° vertically.

TABLE 2
MEAN NAMING LATENCY (IN MSEC) FOR EACH CONDITION IN EACH STIMULUS ONSET ASYNCHRONY[a]

Condition	Stimulus onset asynchronies (msec)		
	0 msec	200 msec	600 msec
Noun context–Noun target	677	622	636
Control noun context–Noun target	714	647	659
Verb context–Verb target	678	623	652
Control verb context–Verb target	708	654	670
Noun context–Verb target	682	658	672
Control noun context–Verb target	705	656	668
Verb context–Noun target	687	659	663
Control verb context–Noun target	708	650	679

[a] An index of the variability of the means at each stimulus onset asynchrony was calculated as follows. Within each stimulus onset asynchrony the mean square error was pooled and divided by 20 (the number of subjects). Taking the square root of these figures resulted in values of 11.82, 17.99, and 15.24 for 0 msec, 200 msec, and 600 msec, respectively.

The timing tone at the end of each sentence was fed into a voice relay which in turn initiated an interval timer. This timer was set to the appropriate interval (0, 200, and 600 msec). At the end of the interval a shutter in front of the projector opened and a millisecond clock began timing. Subjects made their responses into a microphone connected to a second voice relay. When this relay was triggered, the shutter closed and the millisecond clock stopped. The experiment lasted approximately 40 minutes with a two-minute break between each block.

RESULTS

Out of a possible total of 5760 naming latencies, 415 (7.20%) were missing. Of the missing latencies, 308 were due to the subject not speaking loudly enough to trip the voice relay, 79 were due to mechanical failure, 17 were due to experimenter error, and 11 were due to the subject saying the wrong word. These missing latencies were distributed approximately evenly across conditions. Mean latencies for each sentence-target condition for each stimulus onset asynchrony are presented in Table 2.

For purposes of analysis, the sentence target conditions were divided into three factors each containing two levels: Target type, Ambiguity, and Congruency. Target type referred to whether the target was related to the noun or verb reading of the ambiguous word and Ambiguity to whether or not the sentence ended with an ambiguous word. Congruency referred to the relationship between the sentence and target. Sentences which biased the reading of the ambiguous word related to the target and their controls were considered congruent while sentences biasing the reading of the ambiguous word which were unrelated to the target and their controls were considered incongruent. For all analyses, separate ANOVAs were performed treating subjects and items (target words) as random factors. In the subject analysis, Subjects, Ambiguity, Target type, and Congruency were completely crossed, while in the item analysis, Items were nested within Target type. The subject analyses were performed on subject means for each sentence-target condition. For the item anal-

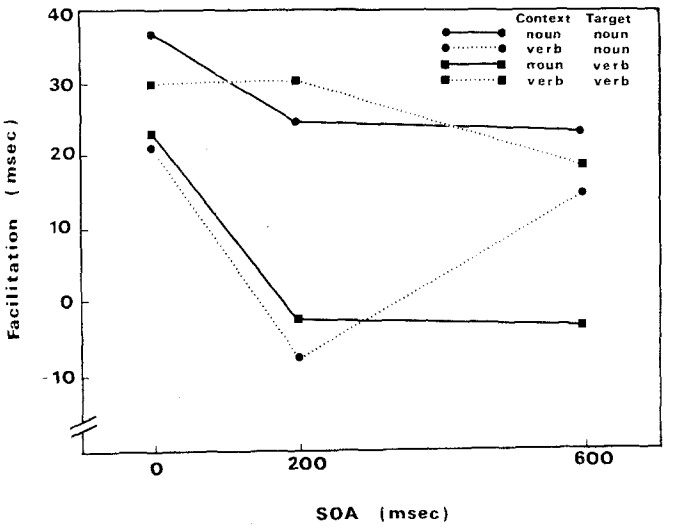

FIG. 1. Facilitation in naming latencies to noun and verb target words related to the contextually biased and unbiased reading of the preceding ambiguous word at 0, 200, and 600 msec stimulus onset asynchronies (SOA) between the end of the ambiguous word and the onset of the target

yses, naming latencies were collapsed across subjects for the four conditions in which each target word appeared. Only min F's will be reported wherever both subject and item analyses were significant.

An overall ANOVA was performed using naming latencies for all eight sentence-target conditions at each stimulus onset asynchrony. Subjects were nested within Stimulus Onset Asynchrony which was crossed with items. There were significant effects of Congruency, min $F'(1,40)=7.57$, $p<.01$ and Ambiguity, min $F'(1,34)=14.53$, $p<.001$. The Congruency by Ambiguity interaction was also significant, min $F'(1,35)=4.14$, $p<.05$.

The effect of Stimulus Onset Asynchrony reached significance in the item analysis $F(2,44)=158.00$, $p<.001$, but not the subject analysis, $F(2,57)=3.01$. Stimulus Onset Asynchrony by Congruency and Stimulus Onset Asynchrony by Ambiguity interactions were significant only in the subject analysis, $F(2,57)=5.67$, $p<.01$ and $F(2,57)=6.33$, $p<.01$, respectively.

This pattern of results can be seen most clearly by examining separate ANOVAs computed at each stimulus onset asynchrony in conjunction with Figure 1. In Figure 1 the amount of facilitation in naming targets related to the contextually appropriate and inappropriate readings of the ambiguous word is plotted for each stimulus onset asynchrony. Facilitation scores were obtained by subtracting latencies to targets preceded by sentences containing ambiguous words from their respective controls.

At 0 msec there was a significant effect of Ambiguity, min $F'(1,31)=15.04$, $p<.001$. Neither Congruency nor Target type approached significance and there were no significant interactions. This pattern of results was due to the fact that there was facilitation following all sentences ending in an ambiguous word, regardless of whether or not the target word was related to contextually appropriate reading of the ambiguous word.

At 200 msec there was a significant effect of Congruency, min $F'(1,29)=5.31$, $p<.05$, but

not Ambiguity, $\min F'(1,41)=3.23$. The Congruency by Ambiguity interaction was significant, $\min F'(1,35)=5.73$, $p<.05$. This interaction obtained because facilitation occurred only when the context and target were congruent. No other main effects or interactions approached significance.

At 600 msec there was also an effect of Congruency, $\min F'(1,39)=5.14$, $p<.05$, but no effect of Ambiguity, $\min F'(1,35)=3.55$. The Congruency by Ambiguity interaction, however, failed to approach significance. The pattern of facilitation at 600 msec is somewhat puzzling. While facilitation occurred to verb-related targets only when they were preceded by congruent contexts, facilitation obtained to noun-related targets in both congruent and incongruent contexts. An examination of Table 2, however, suggests that the facilitation scores to noun-related targets may be misleading. Naming latencies to noun-related targets were 27 msec faster when the context selected the noun reading of the ambiguous word (noun context–noun target) than when the context biased the verb reading (verb context–noun target).

Figure 2 presents the difference obtained by subtracting naming latencies to targets related to the contextually biased reading of the ambiguous word from naming latencies to targets related to the unbiased reading, for each stimulus onset asynchrony. This provides an index of the effect of contextual appropriateness on naming latencies to targets following sentences containing ambiguous words. At 0 msec, there was only a minimal effect of context (10 and 4 msec for noun and verb targets, respectively), while at 200 and 600 msec there was a large context effect for both noun and verb targets.

A second set of analyses which excluded the controls was performed. ANOVAs including stimulus onset asynchrony as a factor revealed a significant effect of stimulus onset asynchrony in the item analysis, $F(2,44)=37.81$, $p<.001$, but not the subject analysis, $F(2,57)=2.09$. There was a significant effect of Congruency, $\min F'(1,35)=10.49$, $p<.01$. The Stimulus Onset Asynchrony by Congruency interaction was significant in the subject analysis, $F(2,57)=7.31$, $p<.01$, but not in the item analysis $F(2,44)<1$. No effects of Target type

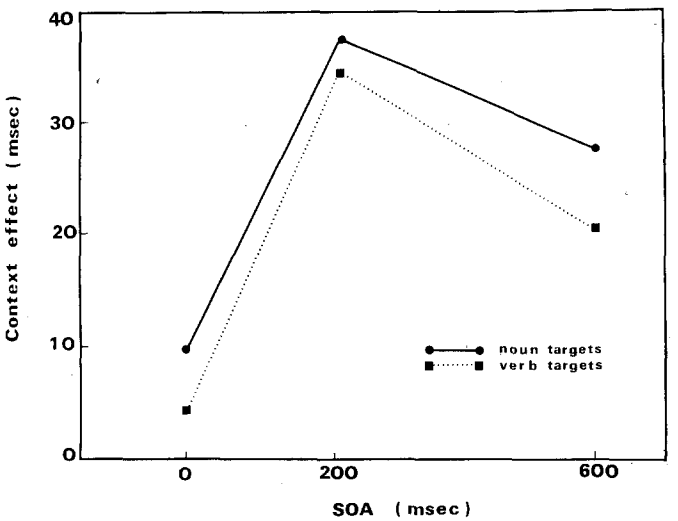

FIG. 2. Differences in naming latencies to noun and verb targets related to the contextually biased and unbiased readings of the preceding ambiguous word at stimulus onset asynchronies (SOA) of 0, 200, and 600 msec.

or Target interactions approached significance.

Separate analyses were also performed at each Stimulus Onset Asynchrony. No effects of Target type or Target interactions approached significance in any of these analyses. At 0 msec, there was no effect of Congruency, min $F'(1,35)=1.06$ while at 200 and 600 msec, the effects of Congruency were significant, min $F'(1,30)=7.72$, $p<01$, and min $F'(1,35)=5.26$, $p<.05$, respectively.

Most subjects were aware that some sentences and targets were repeated although no subject reported being aware of the ambiguity manipulation. Because of the possibility that the repetition of targets and ambiguous words may have caused the subjects to adopt special strategies, analyses using the first block data for each subject were performed. Recall that within a block ambiguous words and targets were not repeated. Since each of the four blocks occurred first in one of the four presentation versions, data from all of the items used in the experiment were included in these analyses. The results for the first block analyses closely correspond to the overall analyses. At 0 msec there was a significant effect of Ambiguity min $F'(1,41)=4.91$, $p<.05$ with no other effects or interactions approaching significance. At 200 msec only the Congruency by Ambiguity interaction approached significance min $F'(1,35)=4.05$. At 600 msec, there were effects of Congruency in the subject analysis $F(1,19)=8.29$, $p<.01$ and in the item analysis, $F(1,22)=4.71$, $p<.05$; however the min F' was not significant. No other main effects or interactions approached significance.

An analysis excluding the control conditions showed no effect of Congruency at 0 msec, $F<1$ for both subject and item analyses. Significant effects of Congruency obtained at 200 and 600 msec in the subject analyses, $F(1,19)=17.74$ $p<.01$ and $F(1,19)=7.04$ $p<.01$, respectively, but not in the item analyses.

Since the pattern of results for the first block analysis is similar to the overall analyses (although the statistics are weaker as would be expected), it appears unlikely that the results obtained in this study are due to the repeated presentation of targets and ambiguous words.

Discussion

The most striking aspect of the data is that target naming latencies depended not only on the congruency of the target word with the meaning of the ambiguous word biased by the target, but also on the latency at which the target word appeared. At the 0 msec stimulus onset asynchrony, facilitation obtained to target words related to both the contextually appropriate and inappropriate readings. While more facilitation obtained when the target word was related to the contextually appropriate reading than the inappropriate reading, this difference was not significant. At 200 msec, however, facilitation obtained only when the target word was related to the contextually appropriate meaning of the ambiguous word. There was no evidence of facilitation when the target was related to the contextually inappropriate meaning.

At 600 msec, facilitation to verb targets obtained only when the verb reading of the ambiguous word was biased by the context. However, approximately the same amount of facilitation in naming noun targets obtained in both contexts which biased the noun and contexts which biased the verb reading. This suggests that there was only a minimal effect of contextual appropriateness for the noun readings of the ambiguous words at 600 msec. However, the analyses which excluded control conditions revealed a large context effect for both noun and verb targets. Thus, the facilitation to contextually inappropriate noun readings at 600 msec (noun targets in verb contexts) is possibly an artifact of the control conditions.

The overall pattern of results suggests that both noun and verb readings of the ambiguous word were initially accessed with the appropriate reading selected within 200 msec

on the basis of the syntactic context. There are two alternative explanations for the rapid drop in facilitation to targets related to the contextually inappropriate reading of the ambiguous word between 0 and 200 msec. One is that activation to the unselected reading decays. This seems unlikely, however, given other evidence suggesting that activation in semantic memory decays much more slowly. Warren (1970), for example, used a naming paradigm and found evidence for activation several seconds after the presentation of the prime word. A more plausible possibility is that there was active suppression of the inappropriate reading (see MacKay 1970; Oden & Spira, Note 2).

Our results are superficially similar to those of Neely (1977). Recall that Neely found that prior to 400 msec lexical decisions to targets which were semantically related to a prime showed facilitation, regardless of the subject's expectations. After 400 msec, however, lexical decisions to expected targets were facilitated, while unexpected targets showed inhibition even when they were semantically related to the prime. Neely interpreted these results in terms of Posner and Synder's (1975) distinction between automatic and controlled processes. According to Neely's explanation, encoding a word automatically activates the semantic structures associated with the word. The subject can subsequently suppress activation to certain semantic structures and activate others by directing his attention to various locations in memory. This process, however, takes time and processing resources. Despite the similarity between our results and Neely's, there are several critical differences. First, Neely's subjects were conscious of the attention shifting strategy that they were adopting. In processing a sentence with a lexical ambiguity, however, subjects are not consciously aware of having to select the contextually appropriate reading. Second, our results show rapid suppression of the inappropriate reading, occurring within 200 msec, while Neely did not find inhibition of semantically related but unexpected targets until about 400 msec after the prime. Finally, Neely found strong evidence for inhibition of unexpected targets, while no significant inhibition was obtained in the present study.

The process that listeners appear to be using to select the contextually appropriate readings of lexical ambiguities can be more aptly characterized by Shiffrin and Schneider's (1977) notion of veiled controlled processes. They divide controlled processes into two general categories: veiled and conscious. Veiled controlled processes, according to Shiffrin and Schneider, are opaque to conscious introspection, faster than conscious controlled processes, and make fewer demands on limited processing resources.

Extending Shiffrin and Schneider's notions leads us to characterize the selection of contextually appropriate readings of noun–verb ambiguities as a dual process involving the automatic activation of all readings of the ambiguous word followed by a veiled controlled process which makes use of the context to rapidly suppress the inappropriate reading.[1]

There is no reason to believe, however, that all lexical ambiguities are resolved in this manner. It is likely, for example, that certain biasing semantic contexts might lead to selective access by priming one of the readings of the ambiguous word (Oden & Spira, Note 2). It is also possible that selection mechanisms for different classes of ambiguous words, for example noun–noun ambiguities, operate differently than noun–verb ambiguities. In addition, the relative dominance of the readings

[1] Since there was slightly more facilitation to target words when they were preceded by syntactic contexts which biased the meaning of the ambiguous word related to the target word at 0 msec, it is possible to argue that syntactic contexts may partially constrain initial lexical access. An alternative possibility is that the syntactic context may have already begun to suppress the inappropriate reading. The target word did not appear until the end of the ambiguous word, and it seems reasonable that lexical access may have occurred prior to the end of the ambiguous word on some proportion of the trials.

of an ambiguous word may determine whether or not selective access occurs. We are presently investigating these issues using the variable time delay methodology.

Finally, the present results illustrate the importance of studying temporal parameters in language comprehension. If we had used a standard psycholinguistic paradigm, for example, phoneme monitoring, or if we had used just one interval between the end of the sentence and the presentation of the target, then we would not have been able to observe the multiple stages in ambiguity resolution. The present results suggest that the variable time delay paradigm provides a powerful methodology for studying the temporal course of certain aspects of language comprehension (see Taylor, 1977).

APPENDIX: STIMULUS MATERIALS

Types of Context

(a) Noun context
(b) Control noun context
(c) Verb context
(d) Control verb context

Priming sentence	Target words related to the noun reading of the ambiguous word
1. (a) It was a good trip.	Travel
(b) It was a good team.	
(c) They began to trip.	
(d) They began to enter.	
2. (a) He holds the dice.	Gamble
(b) He holds the cups.	
(c) He prepared to dice.	
(d) He prepared to leap.	
3. (a) She held the rose.	Flower
(b) She held the post.	
(c) They all rose.	
(d) They all touch.	
4. (a) Put it in the can.	Garbage
(b) Put it in the back.	
(c) They all can.	
(d) They all will.	
5. (a) He bought a new belt.	Pants
(b) He bought a new bird.	
(c) He prepared to belt.	
(d) He prepared to suffer.	
6. (a) Lets make plans in the fall.	Season
(b) Lets make plans in the building.	
(c) She was afraid to fall.	
(d) She was afraid to talk.	
7. (a) He cut the roll.	Bread
(b) He cut the grass.	
(c) They began to roll.	
(d) They began to comment.	
8. (a) I saw it in the press.	Paper
(b) I saw it in the army.	
(c) They all began to press.	
(d) They all began to march.	
9. (a) He bought a new saw.	Hammer
(b) He bought a new case.	
(c) They didn't believe what they saw.	
(d) They didn't believe what they felt.	

APPENDIX—*Continued*

	Priming sentence	Target words related to the verb reading of the ambiguous word
10.	(a) They laughed at the kid.	Child
	(b) They laughed at the speech.	
	(c) They all started to kid.	
	(d) They all started to eat.	
11.	(a) It was made of steel.	Metal
	(b) It was made of ice.	
	(c) They had to steal.	
	(d) They had to throw.	
12.	(a) They walked on the sand.	Beach
	(b) They walked on the trail.	
	(c) The table was difficult to sand.	
	(d) The table was difficult to nick.	
13.	(a) She ate the chop.	Cut
	(b) She ate the cakes.	
	(c) He likes to chop.	
	(d) He likes to cheat.	
14.	(a) We saw beautiful leaves.	Goes
	(b) We saw beautiful hills.	
	(c) She often leaves.	
	(d) She often pushed.	
15.	(a) I bought the watch.	Look
	(b) I bought the coffee.	
	(c) I began to watch.	
	(d) I began to park.	
16.	(a) It was in the ship.	Send
	(b) It was in the rules.	
	(c) I plan to ship.	
	(d) I plan to dance.	
17.	(a) I put it in the box.	Fight
	(b) I put it in the wine.	
	(c) They began to box.	
	(d) They began to clean.	
18.	(a) He was in the plant.	Seed
	(b) He was in the hotel.	
	(c) It was time to plant.	
	(d) It was time to stop.	
19.	(a) She prepared the punch.	Hit
	(b) She prepared the altar.	
	(c) They started to punch.	
	(d) They started to adapt.	
20.	(a) She liked the print.	Write
	(b) She liked the guitar.	
	(c) She liked to print.	
	(d) She liked to relax.	
21.	(a) They looked at the bust.	Break
	(b) They looked at the canoe.	
	(c) It will bust.	
	(d) It will fold.	

APPENDIX—*Continued*

Priming sentence	Target words related to the verb reading of the ambiguous word
22. (a) We walked along the coast.	Glide
(b) We walked along the streets.	
(c) It began to coast.	
(d) It began to advance.	
23. (a) They needed a new sink.	Swim
(b) They needed a new joke.	
(c) They began to sink.	
(d) They began to lift.	
24. (a) He was a real creep.	Crawl
(b) He was a real chef.	
(c) She began to creep.	
(d) She began to knit.	

REFERENCES

CAIRNS, H. S., & KAMERMAN, J. Lexical information processing during sentence comprehension. *Journal of Verbal Learning and Verbal Behavior*, 1975, **14**, 170–179.

CLARK, H. H., & CLARK, E. V. *Psychology and language*. New York: Harcourt Brace Jovanovich, 1977.

COLLINS, A. M., & LOFTUS, E. F. A spreading-activation theory of semantic processing. *Psychological Review*, 1975, **82**, 407–428.

CONRAD, C. Context effects in sentence comprehension: A study of the subjective lexicon. *Memory & Cognition*, 1974, **2**, 130–138.

FODOR, J. A., BEVER, T. G., & GARRETT, M. F. *The psychology of languages: An introduction to psycholinguistics and generative grammar*. New York: McGraw-Hill, 1974.

FOSS, D. J. Some effects of ambiguity upon sentence completion. *Journal of Verbal Learning and Verbal Behavior*, 1970, **9**, 699–706.

FOSS, D. J., & HAKES, D. T. *Psycholinguistics*. Englewood, N.J.: Prentice-Hall, 1978.

FOSS, D. J., & JENKINS, C. M. Some effects of context on the comprehension of ambiguous sentences. *Journal of Verbal Learning and Verbal Behavior*, 1973, **12**, 577–589.

HOLMES, V. M., ARWAS, R., & GARRETT, M. F. Prior context and the perception of lexically ambiguous sentences. *Memory & Cognition*, 1977, **5**, 103–110.

KUČERA, H., & FRANCIS, W. N. *Computational analysis of present-day American English*. Providence: Brown Univ. Press, 1967.

MACKAY, D. G. Mental Diplopia: Towards a model of speech perception at the semantic level. In G.B. Flores d'Arcais & W. S. M. Levelt (Eds.), *Advances in psycholinguistics*. New York: American Elsevier Publishing Company, 1970.

MEHLER, J., SEGUI, J., & CAREY, P. Tails of words: Monitoring ambiguity. *Journal of Verbal Learning and Verbal Behavior*, 1978, **17**, 29–35.

MEYER, D. E., SCHVANEVELDT, R. W., & RUDDY, M. G. Loci of contextual effects on visual word recognition. In P. M. A. Rabbitt & S. Dornic (Eds.), *Attention & Performance, V*. London: Academic Press, 1975.

MORTON, J. Interaction of information in word recognition. *Psychological Review*, 1969, **76**, 163–178.

NEELY, J. H. Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General*, 1977, **106**, 226–254.

NEWMAN, J. E., & DELL, G. S. The phonological nature of phoneme monitoring: A critique of some ambiguity studies. *Journal of Verbal Learning and Verbal Behavior*, 1978, **6**, 364–371.

POSNER, M. I., & SNYDER, C. R. R. Attention and cognitive control. In R. L. Solso (Ed.), *Information processing and cognition: The Loyola symposium*. Hillsdale, N.J.: Erlbaum, 1975.

RUBENSTEIN, H., GARFIELD, L., & MILLIKAN, J. A. Homographic entries in the internal lexicon. *Journal of Verbal Learning and Verbal Behavior*, 1970, **9**, 487–494.

RUBENSTEIN, H., LEWIS, S. S., & RUBENSTEIN, M. A. Homographic entries in the internal lexicon: Effects of systematicity and relative frequency of meanings. *Journal of Verbal Learning and Verbal Behavior*, 1971, **10,** 57–62.

SCHVANEVELDT, R. W., MEYER, D. E., & BECKER, C. A. Lexical ambiguity, semantic context and visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, 1976, **2,** 243–256.

SHIFFRIN, R. M., & SCHNEIDER, W. Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review*, 1977, **84,** 127–190.

SWINNEY, D. A., & HAKES, D. T. Effects of prior context upon lexical access during sentence comprehension. *Journal of Verbal Learning and Verbal Behavior*, 1976, **15,** 681–689.

TAYLOR, D. A. Time course of context effects. *Journal of Experimental Psychology: General*, 1977, **106,** 404–426.

WARREN, R. E. *Stimulus encoding and memory*. Unpublished doctoral dissertation, University of Oregon, 1970.

WARREN, R. E. Stimulus encoding and memory. *Journal of Experimental Psychology*, 1972, **94,** 90–100.

WARREN, R. E. Time and the spread of activation in memory. *Journal of Experimental Psychology: Human Learning and Memory*, 1977, **3,** 458–466.

WARREN, R. E., WARREN, N. T., GREEN, J. P., & BRESNICK, J. H. Multiple semantic encoding of homophones and homographs in contexts biasing dominant and subordinate readings. *Memory & Cognition*, 1978, **6,** 364–371.

REFERENCE NOTES

1. HOLLEY-WILCOX, P., & BLANK, M. *Processing ambiguous words: Evidence for multiple access.* Paper presented at the Annual Meeting of the Midwestern Psychological Association, Chicago, May 1978.
2. ODEN, G. C., & SPIRA, J. L. *Influence of context on the activation and selection of ambiguous word senses.* Wisconsin Human Information Processing Program, No. 6, August 1978.

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