Journal of Experimental Psychology: Human Perception and Performance
1976, Vol. 2, No. 2, 243–256

Lexical Ambiguity, Semantic Context, and Visual Word Recognition

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Some alternative hypotheses about the recognition of ambiguous words are considered. According to the selective-access hypothesis, prior semantic context biases people to access one meaning of an ambiguous word rather than another in lexical memory during recognition. In contrast, the nonselective-access hypothesis states that all meanings of the word are accessed regardless of the context. We tested certain versions of these hypotheses by having students decide whether selected strings of letters were English words. The stimuli included test sequences of three words in which the second word had two distinct possible meanings, whereas the first and third words were related to these meanings in various ways. When the first and third words were related to the same meaning of the ambiguous second word (e.g., SAVE-BANK-MONEY), the reaction time to recognize the third word decreased. But when the first and third words were related to different meanings of the second word (e.g., RIVER-BANK-MONEY), the reaction time for the third word was not reliably different from a control sequence with unrelated words. These and other data favor the selective-access hypothesis. Selective access to lexical memory is discussed in relation to models of word recognition.

Lexical ambiguity poses one of the most basic problems in word recognition and sentence comprehension. Throughout the English language there are numerous words that have two or more distinct definitions. However, by relying on contextual cues that other words provide, a person can usually determine which meaning of an ambiguous word is intended. The word *bank*, for example, may be interpreted either as the land beside a body of water or a place to store money. But semantic context makes it very probable that a statement such as, "The thieves stole a million dollars from the bank," refers to the financial rather than the geographical meaning of *bank*.

While people obviously use semantic context to deal with ambiguity, a number of questions can be raised about the way the process works. These questions have led to several different proposals about how the meanings of ambiguous words are accessed during word recognition and about how semantic context influences the process (e.g., Conrad, 1974; Foss, 1970; MacKay, 1970). The proposals include three general hypotheses. First, there is the *strong selective-access hypothesis*, which states that only one meaning of an ambiguous word is accessed on a given occasion. When the semantic context is related to one meaning of an ambiguous word, this

A portion of this research was first presented at the 1974 meeting of the Psychonomic Society (Schvaneveldt, Meyer, & Becker, Note 1) and at the 1975 meeting of the American Association for the Advancement of Science (Meyer & Schvaneveldt, Note 2). We thank L. Gomez and M. Ruddy for their assistance with the experiment and M. Johnson, J. Johnston, S. Keele, T. Landauer, A. Ortony, H. Rubenstein, S. Springer, S. Sternberg, J. Tweedy, and E. Winograd for their comments on the manuscript. The manuscript was partly written while the first and third authors held visiting positions in the Thomas J. Watson Research Center of IBM Corp. We thank the members of the Behavioral Science Group at the Center for their hospitality.

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hypothesis holds that access is biased toward the related meaning. At the other extreme is the *nonselective-access hypothesis*, which holds that all meanings of an ambiguous word are accessed whenever the word is recognized. Context does not bias the process of accessing meanings. Instead, contextual information is used later to choose one meaning from the set of accessed alternatives. An intermediate position is represented by the *weak selective-access hypothesis*. It assumes that all meanings consistent with the prevailing context are accessed in recognizing an ambiguous word. When contextual information is related to one meaning, access is selective. With no context or an unrelated context, access is nonselective.

Previous Research on Lexical Ambiguity

Several experimental paradigms have been used to study ambiguity, but for various reasons, available data do not greatly favor any one hypothesis over the others. Some experiments have shown that people are slower at processing sentences when they contain ambiguous words (Cairns, 1973; Foss, Bever, & Silver, 1968; MacKay, 1966; MacKay & Bever, 1967). These findings, together with familiar phenomena such as puns, suggest that people can access more than one meaning if the situation requires it. Accessing multiple meanings also appears to require time. However, the extra time could result either from accessing new meanings or from recovering previously discarded ones (cf. Foss & Jenkins, 1973).

Using a phoneme monitoring technique (Foss, 1970), Foss and Jenkins (1973) found that prior semantic context did not affect a difference in processing time for ambiguous and unambiguous words. They concluded that multiple meanings of ambiguous words are always accessed nonselectively, and the extra meanings add processing time for ambiguous words. Subsequent research with the same paradigm, however, shows that stronger contexts eliminate the effect of ambiguity (Cutler & Foss, Note 3; Swinney, Note 4). Because these experiments provided no indication of which meanings of the ambiguous words were accessed, various explanations are possible. Semantic context could produce rapid selective access of one meaning, or it could facilitate discarding irrelevant meanings after all meanings are accessed.

Studies in the recognition-memory paradigm do provide an index of the semantic processing of ambiguous words. These studies generally suggest that only one meaning of an ambiguous word is retained as a part of a person's memory about a specific encounter with the word (DaPolito, Barker, & Wiant, 1971; Gartman & Johnson, 1972; Light & Carter-Sobell, 1970; Rowe, 1973; Winograd & Conn, 1971; Winograd & Raines, 1972). When semantic context biases people toward the same interpretation of an ambiguous word in both the acquisition and test phases of an experiment, it is more likely to be judged a repetition than when the contexts suggest different interpretations. These results, however, could be due either to the selective access of semantic information or the selective storage and retrieval of "episodic" information about ambiguous words (cf. Tulving, 1972).

In fact, experiments designed to study the semantic processing of ambiguous words when they are recognized have been taken as evidence for the nonselective-access hypothesis (Conrad, 1974; Lackner & Garrett, 1972; MacKay, 1973). Lackner and Garrett (1972) found that contextual information presented to one ear influenced the meaning of subjects' paraphrases of ambiguous sentences presented to the other ear. This could mean that alternative meanings are accessed nonselectively and that context biases the selection of a meaning for the paraphrase. On the other hand, subjects may have occasionally processed the contextual information before the ambiguous sentences, thus selectively biasing the meaning accessed for the ambiguity.

Warren (1972) demonstrated interference in naming the ink color of a test word when it followed a semantically related word. Conrad (1974) used this technique to determine which meanings were accessed for an ambiguous word at the end of a sentence. The semantic context of the sentence did not appear to influence what meanings were accessed. Comparable interference occurred when the context and test word were related to the same meaning of the ambiguous word and when they were related to different meanings. Conrad concluded that both meanings of the ambiguous word were accessed regardless of the context. One aspect of Conrad's procedure raises doubts about the generality of her findings, however. She presented the same ambiguous words repeatedly in different contexts to the same subjects. This might induce people to access multiple meanings even if they usually access them selectively.

Thus, the available research with ambiguous words does not suggest a clear choice among the hypotheses outlined earlier. The purpose of this paper is to report some additional research that may help resolve questions about the meanings accessed in recognizing ambiguous words. Our experiments were designed to allow subjects an option of accessing one or more meanings of an ambiguous word in various contexts. The task did not require subjects to discard any meanings. Performance on recognizing words presented immediately after the ambiguous word was examined for evidence about which of its possible meanings had actually been accessed in lexical memory.

The Lexical-Decision Task

Our experiment required subjects to process a large number of words and nonwords in a variety of contexts. Three strings of letters (e.g., JURY-ERTER-JUDGE) were presented successively on each trial. The subject classified each string individually, pressing a "yes" key if it was a word (e.g., *jury*) or a "no" key if it was a nonword (e.g., *erter*). Reaction time was recorded for each letter string from the onset of the stimulus to the keypress, yielding a total of three observations per trial. The sequence of events was similar to a method that we have described elsewhere (Meyer, Schvaneveldt, & Ruddy, Note 5).

Earlier research with this lexical-decision task has produced reliable effects of semantic context on reaction times for recognizing words (Meyer & Schvaneveldt, 1971; Meyer, Schvaneveldt, & Ruddy, 1975; Schvaneveldt & Meyer, 1973; Meyer et al., Note 5). After a person recognizes a word like *jury*, he is typically faster at recognizing a semantically related word like *judge* than an unrelated word like *bread*. This facilitation varies directly with the relative proportion of related words (Tweedy & Schvaneveldt, Note 6) and inversely with the time interval between the words (Meyer et al., Note 5). However, this facilitation is not eliminated by inserting an unrelated word between two related words (Schvaneveldt & Meyer, 1973; Meyer et al., Note 5). Furthermore, the degree of facilitation is the same in tasks requiring other responses, such as pronouncing the words (Meyer et al., 1975). Making the stimuli less legible increases the size of the effect (Meyer et al., 1975). Viewed overall, the data suggest that semantic context influences an early stage of word recognition.

The effect of semantic context in the lexical-decision task provides a basis for testing alternative hypotheses about the semantic processing of ambiguous words. To be specific, we examine performance on six types of word triples, representing different combinations of semantic relations as illustrated in Table 1. In each type, the second word has at least two possible meanings and is ambiguous, but its relations with the first and third words vary across types. The word triples include the following: (a) concordant associates, such as SAVE-BANK-MONEY and DAY-DATE-TIME, in which the first and third words of a triple are both related to the same meaning of the ambiguous second word; (b) discordant associates, such as RIVER-BANK-MONEY and FIG-DATE-TIME, in which the first and third words of a triple are related to different meanings of the ambiguous second word; (c) initial associates, such as RIVER-BANK-TIME and FIG-DATE-MONEY, in which the first word of a triple is related to one meaning of the ambiguous second

TABLE 1
TYPES OF WORD TRIPLES IN THE EXPERIMENTS

Type of word triple associates	Example
Concordant	SAVE-BANK-MONEY DAY-DATE-TIME
Discordant	RIVER-BANK-MONEY FIG-DATE-TIME
Initial	RIVER-BANK-TIME FIG-DATE-MONEY
Terminal	DAY-BANK-MONEY SAVE-DATE-TIME
Separated	SAVE-DATE-MONEY DAY-BANK-TIME
Null	RIVER-DATE-MONEY FIG-BANK-TIME

word, but the third word is not especially related to any of its meanings; (d) terminal associates, such as DAY-BANK-MONEY and SAVE-DATE-TIME, in which the third word of a triple is related to one meaning of the ambiguous second word, but the first word is not especially related to any of its meanings; (e) separated associates, such as SAVE-DATE-MONEY and DAY-BANK-TIME, in which the first and third words of a triple are related to each other, but neither is especially related to any meaning of the ambiguous second word; and (f) null associates, such as RIVER-DATE-MONEY and FIG-BANK-TIME, in which none of the words are especially related.

Predictions of the Hypotheses

Under the nonselective-access hypothesis, relatively fast responses should occur for the third words of discordant associates like RIVER-BANK-MONEY. Each triple of this type has a close relation between the third word and one meaning of the ambiguous second word. The presence of such a relation would facilitate responses to the third word since every meaning of the second word is supposedly accessed regardless of the prior semantic context established by the first word.

On the other hand, the selective-access hypotheses lead to a different prediction. They imply that no facilitation should occur in recognizing the third words of discordant associates. Instead, the prior context established by the first word would presumably bias people to access only a meaning of the ambiguous second word that is unrelated to the third word. After processing the word *river*, for example, a person would be much more likely to access the geographical rather than financial meaning of *bank*, thereby precluding any effect on the recognition of *money*.

As a corollary, the selective- and nonselective-access hypotheses also make different predictions concerning the terminal associates like DAY-BANK-MONEY. The first word establishes a neutral context that could not always preclude the beneficial effect of a close relation between the second and third words, even if access is selective on an individual trial. Each hypothesis therefore implies that some facilitation should occur in recognizing the third word of the terminal associates. But the hypotheses disagree about how much facilitation to expect. The nonselective-access hypothesis predicts that responses to the terminal associates would be speeded by the same amount as responses to the discordant associates because the third word is always related to an accessed meaning of the ambiguous second word in each type of triple. The selective-access hypotheses predict that responses would be speeded more for the terminal associates than for the discordant associates. This is because, as discussed earlier, they imply no facilitation at all for the discordant associates.

To evaluate the above predictions, we must analyze performance on corresponding "control" word triples as well. The controls include initial associates like RIVER-BANK-TIME and null associates like RIVER-DATE-MONEY in which no relation exists between the third words and preceding ones. According to some detailed recognition models, a relation between the first two words would influence reaction time for the third word, even if it is not related to them. For example, the relation between *river* and *bank* might produce a general bias toward fast positive responses to any third word. Alternatively, the relation might lead subjects to expect only certain third words, and when their expectation is disconfirmed, responding might be slower (cf. Posner &

Synder, 1974). Such possibilities preclude directly comparing performance on the discordant and terminal associates because they involve different relations between the first and second words. However, the problem may be handled by subtracting reaction times for the discordant associates from reaction times for the initial associates, in which the relation between the first two words is the same, and the difference in reaction times provides an uncontaminated estimate of any facilitation due to a relation between the second and third words in discordant associates. Similarly, we may estimate any facilitation for the terminal associates by comparing them with the null associates, since neither of these types of triples contains a relation between the first two words.

Last, consider the concordant associates like SAVE-BANK-MONEY and separated associates like SAVE-DATE-MONEY. Under each of the hypotheses discussed, responses to the third words of these triples should be facilitated. Even if selective access occurs, the first word of concordant associates establishes a context that would bias subjects toward a meaning of the second word that is related to the third word. They could also benefit from the "remote" relation between the first and third words, which is assessed by the separated associates. To check the general reliability and validity of our procedure, we can examine results for the concordant associates versus the control triples involving no relations between the third words and earlier ones. Either the initial or null associates provide the appropriate control, depending on exactly how the relation between the first and second words affects recognizing the third word. The null associates provide the proper control for determining the effect of the remote relation in separated associates because the first two words are unrelated in both conditions.

The experiments also permit some additional tests of the hypotheses, which are considered later. First, however, we discuss the findings which bear on the predictions developed so far.

Experiment 1

Method

Subjects. The subjects were 24 paid students who attended high school near Murray Hill, New Jersey.

Apparatus. The experiment was controlled by a digital computer with a millisecond timer connected to a display oscilloscope, random-noise generator, and response panel with finger keys for the right and left hands.

Procedure. The subjects wore a pair of headphones and sat in a darkened booth facing the display with their hands on the finger keys. They participated individually in a single 1-hr. session. The experiment included a short instruction period, two practice blocks of 20 trials each, and six test blocks of 20 trials. At the start of a trial, there was a 750-msec foreperiod, during which three central fixation points appeared one above the other on the display. Next, the first string of letters in a triple was presented where the top fixation point had been. The subject pressed a "yes" key with his right index finger if the string was a word, or he pressed a "no" key with his left index finger if it was a nonword. Following the response, the first letter string was removed, and the second string immediately appeared where the middle fixation point had been. The subject again decided whether the letter string was a word, pressing one of the two finger keys and thereby removing the stimulus. Then the third letter string in the triple was immediately presented where the bottom fixation point had been, and the subject made another response, thus terminating the trial.

The three strings of letters were formed from white capital letters on a dark background. Each string subtended approximate horizontal and vertical visual angles of 3° and .4°, respectively. The fixation points were separated vertically by about .7° and remained visible until they were replaced by the corresponding letter strings.

Reaction time was measured from the onset of each string to the corresponding keypress. After the response to the third string of letters on a trial, the display remained blank for about 2 sec before the next trial. If the subject made an error on one or more of the letter strings in a triple, this interval was extended to 3.5 sec, during which the word ERROR was displayed for the first second. White noise was presented at a low level over the subject's headphones throughout the trials.

When a trial block was complete, the subject was informed about his mean reaction time, total number of correct responses, and total number of errors for the block. There was a rest period of approximately 2 min. between test blocks. Each subject received $1.50 for participating in the experiment. In addition, a bonus was given to encourage fast and accurate responses.

Stimuli and design. An initial set of 175 ambiguous words was obtained by sampling words in *Webster's New World Dictionary* (1953) that appeared with two or more main (boldface) entries. Judges selected 36 of these words that appeared to best satisfy

TABLE 2

ITEMS USED TO CONSTRUCT THE WORD TRIPLES IN EXPERIMENT 1

Ambiguous words	Related words: Meaning A		Meaning B	
bail	bucket	boat	jail	court
ball	throw	round	dance	gown
bank	river	shore	money	save
bark	tree	birch	dog	howl
bowl	spoon	soup	alley	pins
box	fight	gloves	carton	chest
bridge	cards	game	span	water
calf	cow	baby	knee	muscle
date	fig	fruit	time	day
fair	circus	tent	just	equal
fan	sports	cheer	cool	blower
fast	hunger	eat	slow	quick
fleet	swift	nimble	navy	armada
hide	skin	fur	seek	cover
jam	block	wedge	jelly	toast
jar	shake	jolt	bottle	jug
lie	lay	bed	fib	false
light	heavy	weight	dark	lamp
lock	key	door	hair	curl
mine	yours	his	gold	coal
mint	coin	penny	candy	flavor
mold	cast	shape	mildew	stale
pen	cage	corral	write	ink
pick	shovel	tool	choose	select
pit	hole	crater	seed	peach
punch	hit	fist	drink	thirst
race	speed	run	creed	color
riddle	bullet	holes	puzzle	joke
ring	bell	phone	finger	hand
sage	spice	thyme	wise	seer
spit	roast	fire	saliva	mouth
stable	horse	barn	secure	steady
stern	strict	firm	ship	back
tap	faucet	spigot	knock	touch
tick	clock	second	insect	bug
tire	work	weary	wheel	rubber

the following criteria: (a) Each word had two distinct and unrelated meanings, referred to here as Meanings A and B; (b) both meanings were relatively common interpretations of the word; (c) each word had six or fewer letters; (d) the pronunciation of the word was the same for both meanings; and (e) two words related to each meaning could be agreed upon. The resulting 36 ambiguous words are shown in Table 2 along with the semantically related words.

Each triple of concordant associates contained one of the ambiguous words, and both of the words related to Meaning A or both of the words related to Meaning B. One word related to Meaning A and one word related to Meaning B were combined with the ambiguous word to form the discordant associates. We obtained the initial associates by randomly interchanging the third words of the discordant associates. The terminal associates were obtained by randomly interchanging the first words of the concordant associates, and the separated associates came from randomly interchanging the ambiguous second words of the concordant associates. The null associates were formed by interchanging the ambiguous second words among the discordant associates (cf. Schvaneveldt & Meyer, 1973).

This balancing procedure equated several factors across the different word triples. The stimulus arrangement guaranteed that the same individual words appeared as the third members in one triple of each type. Each meaning of the ambiguous second word was used once in each type of triple in which it was related to the first or third word (e.g., *money* and *river* occurred once each following *bank* in the concordant, discordant, and terminal associates). The same words appeared equally often, but not together, in types where the ambiguous second word was unrelated to the first or third words. No triples consisting solely of unambiguous words were included. We omitted such triples because comparing them to triples with ambiguous words would require the problematic assumption that semantic relations in the different word sets are equivalent. We know of no procedure for insuring such equivalence.

In addition to the word triples, 54 triples containing two words and one nonword (e.g., HARD-SPELL-POUSE, MAIL-KEALTH-LETTER, and DOUND-REAR-CHILD), 27 triples consisting of one word and two nonwords (e.g., TRUCK-CLEEP-VAIR, GLOKE-PUNT-DOY, and TRUIT-UDY-LINE), and 3 triples of nonwords (e.g., DIGHT-GREAL-ENPET) were constructed as foils. The words used in triples with nonwords never occurred elsewhere among the stimuli. Nonwords were obtained by altering the initial letters of common words and interchanging syllables among words. All of the nonwords were pronounceable and had lengths similar to the words. Since comparisons among triples with nonwords were not planned, the items in them occurred only once and were not counterbalanced. However, semantic relations among pairs of words in these triples occurred with about the same relative frequency as in the word triples. The triples with nonwords also included ambiguous words that helped to eliminate possible clues about the correct responses for subsequent letter strings.

During the test blocks of the experiment, the subject was presented six triples each of concordant, discordant, initial, terminal, separated, and null associates from the total stimulus set, plus all of the triples containing one or more nonwords. The relative frequency of words was approximately two thirds overall. The stimulus assignment counterbalanced the words across subjects so that no individual subject saw the same letter string more than once. In every test block, the different types of word triple were displayed with the same relative frequency as over the whole experiment. Aside from this constraint, the order of presentation was independently randomized for each subject. A different set of 12 word triples and 28 triples containing nonwords was used for the two practice blocks.

Data analysis. The arrangement used to balance individual letter strings over the various subjects and types of word triple yielded 12 stimulus lists for the experiment. Each list was assigned to two subjects. To obtain statistical tests, we averaged the results from subjects who received the same list, giving 12 sets of means. These sets of means corresponded to different nonoverlapping collections of subjects and word triples. By using them as the sampling units in the analyses reported below, we generalized the results to both the population of subjects and materials from which our samples were drawn (cf. Clark, 1973). This procedure is somewhat conservative because the estimated standard deviations contain extra variability due to different words. In one case, analyses performed separately over subjects and words suggest rejecting a null hypothesis, while the more conservative procedure does not, and we report the results of those analyses as well.

Reaction times and error rates for the letter strings belonging to triples with nonwords are not presented here. They were generally similar to findings reported elsewhere (e.g., Meyer & Schvaneveldt, 1971; Meyer et al., 1975; Schvaneveldt & Meyer, 1973; Meyer et al. Note 5).

Results and Implications

The primary results are the mean reaction times of correct responses and error rates for the word triples. Errors occurred on less than 5% of the trials and did not vary reliably across the different types of triples. Reaction times for the first word of a triple averaged 611 msec. Responses to the ambiguous second word took a mean of 528 msec when the first word was semantically related to one of its meanings (concordant, discordant, and initial associates), while reaction time for the second word averaged 546 msec when the first word was not related to any of its meanings (terminal, separated, and null associates). The difference between these two averages, plus or minus one standard deviation, was 18 ± 7 msec, $t(11) = 2.57, p < .01$.

These results are consistent with the selective-access hypotheses in that semantic context influenced the recognition of ambiguous words. Furthermore, it is interesting that the present reduction of 18 msec in reaction time for the ambiguous second word is somewhat less than what we have obtained previously. In five earlier experiments with pairs of essentially unambiguous words (Meyer et al., 1975; Tweedy & Schvaneveldt, Note 6; Becker, Schvaneveldt, & Gomez, Note 7), reaction time for the second word of a pair was 45 msec shorter on the average when it had a close semantic relation with the first word than when it had no relation. A possible reason for the smaller facilitation here is that people may recognize ambiguous words faster than unambiguous words when they occur in an unrelated context (Rubenstein, Garfield, & Millikan, 1970; Jastrzembski & Stanners, 1975). This could happen because ambiguous words have separate representations corresponding to each of their meanings in lexical memory. The process of recognizing ambiguous words might be relatively fast because any of the representations would provide a sufficient basis for recognition. Consequently, semantic context would produce less facilitation in recognizing ambiguous words compared with unambiguous words.

TABLE 3

Results for the Third Words of Various Triples in Experiment 1

Type of word triple associates	Example	Mean reaction time in msec	% errors
Concordant	SAVE-BANK-MONEY	505	1.5
Discordant	RIVER-BANK-MONEY	558	2.1
Initial	FIG-DATE-MONEY	551	3.5
Terminal	DAY-BANK-MONEY	521	2.9
Separated	SAVE-DATE-MONEY	516	4.3
Null	RIVER-DATE-MONEY	538	4.3

Still, the data so far do not preclude the possibility that more than one meaning of an ambiguous word is accessed during recognition. To determine which meanings were accessed here, the reaction times for the third words of the various triples must be examined. The results are shown in Table 3.

Initial versus null associates. First, let us consider the two types of control triples. Reaction times for the third words of initial associates were 13 ± 10 msec longer than reaction times for the null associates, $t(11) = 1.24, p > .20$. Although this difference failed to reach the standard level of statistical significance, it was sufficiently large to suggest that the choice of an appropriate control may be important. A close relation between the first two words of a triple could influence responses to the third word, regardless of how it is related to them. Thus, to estimate the facilitation that occurred in recognizing the third words of other triples, we will take the relation between the first two words into account as described earlier.

Discordant versus initial associates. Responses to the third words of the discordant associates were 7 ± 12 msec slower than responses to the third words of initial associates, $t(11) = .62$, $p > .50$. Contrary to the nonselective-access hypothesis, a close relation between the third word and one meaning of the ambiguous second word had no beneficial effect when the first word was related to another of its meanings. This outcome suggests that the first word biased subjects to access only the contextually related meaning of the ambiguous second word in the discordant associates, as predicted by the weak and strong selective-access hypotheses.

Terminal versus null associates. Responses to the third words of terminal associates were 17 ± 15 msec faster than responses to the third words of null associates. The difference was not reliable according to our conservative statistical analysis that included extra between-word variability bebesides treatment-by-word and treatment-by-subject variability, $t(11) = 1.15$, $p > .20$. However, separate tests based on pure estimates of the Treatment × Subject (T × S) and Treatment × Word (T × W) interactions provide some evidence of facilitation in the terminal associates [for T × S, $t(12) = 1.81$, $p < .05$, one-tailed test; for T × W, $t(5) = 3.33$, $p < .01$, where the degrees of freedom come from pooling over homogenous sets of subjects and words]. The facilitation (17 msec) observed for terminal associates was 24 ± 15 msec greater than the facilitation (-7 msec) observed for discordant associates, $t(11) = 1.68$, $p = .06$, one-tailed test. Such a result is certainly not surprising after the outcome of our earlier comparison between the discordant and initial associates. Still, the data provide supplementary evidence favoring predictions of the selective-access hypotheses over the nonselective-access hypothesis which implies that equal amounts of facilitation should have occurred in the above cases.

Separated versus null associates. Responses to the third words of separated associates were also faster (22 ± 11 msec) than responses to the third words of null associates, $t(11) = 1.98$, $p < .05$, one-tailed test. This finding confirms earlier experiments (Meyer et al., 1975) and demonstrates the sensitivity of the present experiment to the effects of semantic context.

Concordant versus initial and null associates. Responses to the third words of concordant associates were faster than responses to the third words of any other triple, thus supporting the reliability and validity of our general procedures. The total amount of facilitation can be estimated in either of two ways, depending on exactly how the relation between the first two words influences the recognition process. If the reaction times for concordant associates are compared with the reaction times for initial associates, the estimated total facilitation is 46 ± 8 msec, $t(11) = 5.49$, $p < .01$. If instead the reaction times for concordant associates are compared with the reaction times for null associates, the estimated total facilitation is 33 ± 15 msec, $t(11) = 2.19$, $p < .05$. Thus, concordant associates show facilitation relative to either of the control conditions.

Discussion

In summary, the nonselective-access hypothesis failed the major tests provided by our experiment. We found no evidence that the contextually inappropriate meaning was accessed in recognizing the ambiguous second words of discordant associates. Further, more facilitation occurred in recognizing the third words of terminal associates than in recognizing the third words of discordant associates.

However, the small facilitation observed for terminal associates does pose other problems. It is conceivable that the semantic relations between our second and third words were simply too weak for producing facilitation without an appropriately biased prior context. An absence of sufficiently strong relations would explain why no apparent facilitation occurred for discordant associates. Therefore, we decided to perform a second experiment, which was designed to increase the sensitivity to semantic-context effects.

EXPERIMENT 2

The second experiment included the same six types of word triples discussed for Experiment 1. There were three major changes. First, more ambiguous words (a total of 72) were used. This doubled the number of observations per condition for each subject and provided a greater variety of stimulus materials. Second, the particular combinations of subjects, words, and treatments were arranged to permit less conservative statistical tests. Finally, the third letter string in each triple was degraded by superimposing a field of other lines over it. Earlier we found that beneficial effects of semantic context increase when words are degraded (Meyer et al., 1975). This suggested that any facilitation produced by recognizing ambiguous words would also increase when the third word of a triple was degraded.

Method

Subjects. The subjects were 24 paid students who attended the State University of New York at Stony Brook.

Apparatus. The experiment was computer controlled with equipment similar to that used in Experiment 1.

Stimuli. More ambiguous words were obtained from several sources, including other studies of ambiguity (Cramer, 1970; Geis & Winograd, 1974; Perfetti, Lindsey, & Garson, 1971). Three judges selected the words according to the criteria described for Experiment 1. The two words related to each meaning of an ambiguous word were more strongly related to each other than they were overall in Experiment 1.

Procedure. The procedure was similar to Experiment 1. During the test blocks of the experiment, each subject was presented 12 instances of concordant, discordant, initial, terminal, separated, and null associates from the total set of word triples, plus 171 triples containing one or more nonwords. On each trial the third item was degraded by embedding it in a field of other lines.

Data analyses. By suitable averaging over subsets of subjects and words, data from the six types of word triples were reduced to a 6×6 Latin square with six treatments, six subsets of subjects, and six subsets of words. The expected mean square of the residual term from an analysis of variance of these data contains variability due to the three two-way interactions among the above variables plus the three-way interaction (Myers, 1972). By using the residual term as a pooled estimate of error in statistical comparisons, we generalized the results to both the populations of subjects and words from which our samples were drawn. In contrast to the statistics reported for Experiment 1, this procedure permits eliminating individual word effects from the estimate of error, and the statistical tests are less conservative.

Results and Implications

Reaction times for the first words of the triples averaged 642 msec. Responses to the ambiguous second words averaged 534 msec when the first word was related to one of their meanings (concordant, discordant, and initial associates), while reaction times for the ambiguous second words averaged 555 msec when the first word was not related to any of their meanings (terminal, separated, and null associates). Consequently, a related first word produced a 21 ± 4 msec facilitation in recognizing the ambiguous second word, $t(23) = 5.76$, $p < .001$. It is interesting to note that the effects of a related context on recognizing ambiguous words were similar in the two experiments (18 as opposed to 21 msec), despite differences in the sampled word and subject populations. Thus, our earlier remarks about the relatively small magnitude of this facilitation also apply here.

Performance on the third words of the triples is summarized in Table 4. Degrading the third word had the desired effect

TABLE 4

RESULTS FOR THE THIRD WORDS OF VARIOUS TRIPLES IN EXPERIMENT 2

Type of word triple associates	Example	Mean reaction time in msec	% errors
Concordant	DIME-BANK-MONEY	617	1.0
Discordant	RIVER-BANK-MONEY	662	12.8
Initial	FIG-DATE-MONEY	651	11.1
Terminal	DAY-BANK-MONEY	635	5.8
Separated	DIME-DATE-MONEY	640	7.6
Null	LAMP-DATE-MONEY	671	8.2

of lengthening reaction times and increasing some beneficial effects of semantic context. But error rates were substantially different across the various types of triples. Thus, we must consider the accuracy of performance along with reaction time differences.

Initial versus null associates. Compared with Experiment 1, there was an opposite difference between reaction times for the two types of control triples. Responses to the third words of initial associates were 21 ± 14 msec faster than responses to the third words of null associates, $t(20) = 1.52$, $p > .10$. Averaging reaction times from the different experiments therefore indicates that subjects had about equal difficulty with each of the controls overall. As in Experiment 1, however, the initial associates produced somewhat more errors than the null associates during Experiment 2 [mean difference = 2.9% ± 1.9%, $t(20) = 1.55$, $p > .10$]. The negative correlation between time and error differences suggests that a speed–accuracy trade-off may have occurred for the initial associates. This possibility, together with the marginal magnitude of the differences, makes it difficult to reach a firm conclusion about whether a relation between the first two words influences performance on a third unrelated word. Accordingly, let us follow our previous logic for estimating facilitation effects produced by the other types of word triples.

Discordant versus initial associates. Responses to the third words of discordant associates were 12 ± 14 msec slower than responses to the third words of initial associates, $t(20) = .87$, $p > .20$. Error rates were also slightly greater (1.7% ± 1.9%) for the discordant associates. As before, these differences estimate the beneficial effect of a relation between the second and third words when the first words had a different relation to the ambiguous second words. There was no apparent facilitation. This again supports the selective-access hypotheses over the nonselective-access hypothesis.

Terminal versus null associates. Responses to the third words were 36 ± 14 msec faster for terminal compared with null associates, $t(20) = 2.61$, $p < .02$. The terminal associates also produced slightly fewer errors [mean difference = 2.3% ± 1.9%; $t(20) = 1.24$, $p > .20$]. In a neutral context, an ambiguous word therefore facilitated recognizing a subsequent word related to one of its meanings. The facilitation was 48 ± 28 msec greater than obtained with discordant versus initial associates, $t(20) = 1.74$, $p < .05$, one-tailed test. Under the nonselective-access hypothesis, no difference is predicted here, and so again the data suggest rejecting it.

Separated versus null associates. Reaction times for the third words of separated associates were 31 ± 14 msec faster on the average than reaction times for the third words of null associates, $t(20) = 2.25$, $p < .05$.

Concordant versus initial and null associates. Compared with null associates, concordant associates speeded responses to the third words by 53 ± 14 msec, $t(20) = 3.84$, $p < .01$, and they also decreased errors by 7.2% ± 1.9%, $t(20) = 3.84$, $p < .01$. As in Experiment 1, these especially large differences suggest that performance on a third word benefited from having similar relations with both the first and second words. Again, this is consistent with all of the hypotheses and provides support to our general approach.

If we measure the overall facilitation by instead using the initial associates as the control triple, then the apparent time difference (33 ± 14 msec) is not so great, $t(20) = 2.39$, $p < .05$. But the alternative comparison was accompanied by an even larger error difference (10.0% ± 1.9%) in the same direction, indicating that the reaction time data may underestimate the true benefit for concordant associates.

General Discussion

Experiment 2 achieved its major purpose. Larger and substantially more reliable facilitation occurred for terminal associates. However, we again failed to observe facilitation for discordant associates. The major tests reveal a marked failure of the nonselective-access hypothesis. Our last results clearly demonstrate that an ambiguous word does speed recognition of subsequent words related to one of its meanings, though not when prior context biases subjects to access another meaning of the ambiguous word. This finding, along with our other results, is most easily handled by the selective-access hypotheses.

Of course, it is possible to save the nonselective-access hypothesis with additional assumptions. For example, one could assume that contextually inappropriate meanings of ambiguous words are discarded immediately after accessing them, so that they have no opportunity to produce subsequent benefit. Similarly, one could postulate an inhibitory process to offset the facilitation that arises from accessing all meanings of an ambiguous word (cf. MacKay, 1970).

At a more abstract level, revival of the nonselective-access hypothesis may rest on the definition of "access." Operationally, we have defined it as the process that deals with meanings in a way which yields subsequent facilitation of word recognition. According to this usage, there is strong evidence that all meanings of an ambiguous word are not accessed the same way. It is, of course, more difficult to establish that subjects do not process all the meanings somehow. In any case, the selective-access hypotheses require no further special treatment to handle our various findings, and considerations of parsimony dictate a decision in their favor.

So far we have concentrated on the effects of a related context on the meanings accessed in recognizing an ambiguous word. Now let us turn our attention to the situation where the context is not related to any meanings of the ambiguous word. Under these conditions, the weak and strong selective-access hypotheses make different assumptions about the meanings accessed for ambiguous words.

In particular, the two hypotheses disagree about the basis of the facilitation observed for terminal associates in the present experiments. The strong selective-access hypothesis implies that the relation between the second and third words in terminal associates would not always lead to facilitation in recognizing the third word. The reason is that people presumably access only one meaning of the ambiguous second word, regardless of context; and by chance, the accessed meaning would have no relation with the third word on some occasions because the neutral prior context does not bias the process. In fact, the design of our experiments should insure that the third word of terminal associates is related to a single accessed meaning of the second word on approximately 50% of the trials. Facilitation should occur then, but not otherwise.

In contrast, the weak selective-access hypothesis implies that the relation in terminal associates should always facilitate recognizing the third word because all meanings of the ambiguous word are accessed when prior context is neutral. The meaning related to third word should facilitate its recognition.

The facilitation obtained for terminal associates in the present experiments (17 and 36 msec for Experiments 1 and 2, respectively) was about 50% less than we have obtained in several previous experiments with pairs of unambiguous words (Meyer et al., 1975; Tweedy & Schvaneveldt, Note 6; Becker et al., Note 7). In these experiments close semantic relations produced beneficial effects averaging about 45 msec with normally displayed words as in Experiment 1, and about 70 msec with a degraded display as in Experiment 2.

Further, terminal and separated associates yielded approximately equivalent facilitation in recognizing the third word, even though the relation in separated associates is more remote. Some of our previous findings suggest that remote relations are less effective than contiguous relations (Meyer et al., Note 5). Thus, the present experiments suggest that, in a neutral context, ambiguous words are less effective than unambiguous words in facilitating the recognition of subsequent related words.

This conclusion is quite compatible with the strong selective-access hypothesis, but an additional assumption is required to bring the weak selective-access hypothesis in line with the data. We must assume that the facilitation produced by an accessed meaning of an ambiguous word decreases with the number of other meanings accessed. Under this assumption, the weak selective-access hypothesis can handle the data as well. Therefore, we can only reject a version of the weak selective-access hypothesis which states that the effect of an accessed meaning on recognizing subsequent related words is independent of the number of meanings accessed.

Overall, then, our findings suggest that a related context restricts the meaning accessed in recognizing ambiguous words. Furthermore, in a neutral context, alternative meanings of an ambiguous word are apparently not accessed as effectively as a single meaning of an unambiguous word, either because only one meaning is accessed or because multiple meanings are accessed and they compete in some way.

Implications for Models of Word Recognition

The present data impose certain constraints on various models of word recognition. The critical requirement for any viable model is that recognizing a word depends not only on sensory information but also on prior semantic context, as specified by the selective-access hypotheses. We will discuss two classes of models, including one where recognition is a relatively "passive" process and another where it is an "active" process (cf. Morton & Broadbent, 1967).

The passive models involve a set of lexical detectors (Corcoran, 1971; Keele, 1973; MacKay, 1970; Morton, 1969). They assume that each word has a corresponding detector. Each detector is sensitive to the graphemic and/or phonemic features that comprise the word identified with it. When a letter string appears, sensory information enters the detectors, which count how many features of the stimulus match features of the corresponding words. The meaning of a word is accessed as soon as its detector exceeds a certain threshold. This event primes the detectors of other words with related meanings, thereby decreasing the number of features that they require to exceed threshold. Priming could occur, for example, through a "spread of neural excitation" as we and others have described elsewhere (Collins & Quillian, 1970; Loftus, 1973; Meyer & Schvaneveldt, 1971; Schvaneveldt & Meyer, 1973; Meyer et al., Note 5). As a result, it would take less time to accumulate enough sensory information for recognizing subsequent related words.

Our findings suggest that the passive models must further assume an ambiguous word has a separate detector corresponding to each of its distinct meanings (cf. Morton, 1969; Rubenstein et al., 1970), and sensory information enters each of the relevant detectors. Because of random fluctuations when the word occurs in a neutral context, the feature count by any of these detectors may exceed its threshold before the others have. But in a biased context, the threshold of the detector with a related meaning must usually be exceeded first because the context has primed that detector. Presumably, this event further primes the detectors of other related words. In addition, it must terminate the feature counts of the detectors corresponding to different meanings of the ambiguous word, perhaps by gating sensory information away from the detector system or by inhibiting the detectors for the other meanings (cf. MacKay, 1970). Otherwise these meanings would be accessed before too long, since the effect of sensory information on the word detectors is nonselective.

On the other hand, our results also suggest constraints on active models of word recognition (Corcoran, 1971; Neisser, 1967; Becker et al., Note 7). Here recognition is based on comparisons between internal representations of words and sensory representations of stimuli.

The active models assume that a word has a representation of its sensory form (e.g., prototype or feature list) stored in memory. When a letter string appears, actual sensory information is compared with various stored representations. The comparison process depends on "hypotheses" generated about the identity of the stimulus. Each hypothesis serves to create a potentially complete representation of the stimulus from memory, which is then verified against sensory information. Both prior semantic context and a partial analysis of the stimulus (cf. Spoehr & Smith, 1973) constrain the generation of hypotheses. The operations of generating hypotheses, analyzing the stimulus, and comparing stored representations with sensory information continue until a satisfactory match occurs. The meaning of a word is accessed if its stored representation eventually produces the match. Immediately after the meaning of one word is accessed, the stored representations of other semantically related words provide high-priority hypotheses about subsequent stimuli. As a result, fewer comparisons would be necessary to recognize subsequent words with related meanings.

To accommodate our findings, the active model must further assume separate stored representations for each distinct meaning of an ambiguous word. The accessed meaning of an ambiguous word could be determined by the representation that first produces a match during the comparison process. This meaning then creates the context for recognizing subsequent stimuli. Overall, the new constraints on the active models are somewhat less than for the passive models. This is because a meaning is accessed when a stored representation matches sensory information. Since one representation of an ambiguous word is sufficient for a match, selective access of meanings naturally follows. In contrast, the passive models must invoke a mechanism to prevent contextually inappropriate detectors from exceeding their thresholds.

Conclusion

In conclusion, it should be stressed that the problem of ambiguity is not limited to word recognition. It occurs on several levels of linguistic analysis (Garrett, 1970). Ambiguity is also a problem for theories about the perception of visual scenes and patterns, including simple reversible figures like the Necker Cube and Peter-Paul Goblet (Lackner & Garrett, 1972; Neisser, 1967). Somehow a person assigns a unitary interpretation to such stimuli at any particular moment, although interpretations may alternate over time. Perhaps, the perceptual mechanisms that produce these interpretations combine sensory and contextual information just like the mechanisms used for recognizing ambiguous words. Thus, it may be valuable to determine the similarities and differences among various types of ambiguity.

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(Received July 25, 1975)