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Lexical Access during Sentence Comprehension: (Re)Consideration of Context Effects

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The effects of prior semantic context upon lexical access during sentence comprehension were examined in two experiments. In both studies, subjects comprehended auditorily presented sentences containing lexical ambiguities and simultaneously performed a lexical decision task upon visually presented letter strings. Lexical decisions for visual words related to each of the meanings of the ambiguity were facilitated when these words were presented simultaneous with the end of the ambiguity (Experiment 1). This effect held even when a strong biasing context was present. When presented four syllables following the ambiguity, only lexical decisions for visual words related to the contextually appropriate meaning of the ambiguity were facilitated (Experiment 2). Arguments are made for autonomy of the lexical access process of a model of semantic context effects is offered.

Sentence comprehension requires the integration of information derived from a number of ongoing cognitive processes. It is clear, for example, that semantic and syntactic contexts interact with moment-to-moment comprehension processes to affect our interpretation of individual words and sentences; observations that contexts act to determine sentential interpretations abound in the literature. However, while this effect is well documented, the process by which it occurs is not. Until the manner in which contexts exert their effects (i.e., the nature of information interaction) can be detailed, claims relying on the concept of "contextual determination" are empty and merely beg the question. Certainly, any attempt at a performative description of sentence comprehension must incorporate the details of this process. One of the important debates arising from concern over how (and when) contexts have their effects involves the question of whether comprehension processes are, in general, of a highly interactive, directable, nature (so that any stage of a process can come under the direction of some other, contextual, process; e.g., Marslen-Wilson, 1975; Marslen-Wilson & Welsh, 1978; Swinney & Hakes, 1976; Jenkins, Note 1) or whether these processes are basically isolable and autonomous (so that context effects exert themselves only on the output of these processes; see, e.g., Forster, 1976; Garrett, 1978).

One domain in which some effort has been made to examine this question is that of lexical access. The studies of interest have typically examined the processing of lexical ambiguities during sentence comprehension. Experiments involving a number of different tasks have shown that the occurrence of an ambiguous word, in comparison with that of an unambiguous control word, increases the processing complexity of an unbiased sentence (e.g., Foss, 1970; Foss & Jenkins, 1973;

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Holmes, Arwas, & Garrett, 1977; Chodorow, Note 2). Such an increase presumably reflects comprehension processes which, at least momentarily, are involved in the retrieval and consideration of the several meanings of an ambiguous word. This effect occurs even though most people eventually become aware of only a single meaning for ambiguities in these conditions. The question of interest, then, is one of exactly how and when a biasing context aids in the final selection of a single relevant reading for an ambiguous word. It is particularly important to examine the nature of these effects for the most critical of contextual conditions for the issues raised here, that in which the biasing context occurs prior to the ambiguity.

Two general classes of hypotheses have been offered in explanation of such effects. The first of these, which have variously been termed "prior decision" (Foss & Jenkins, 1973) or "unitary perception" hypotheses are all versions of the highly interactive sentence processing view (see also Hogaboam & Perfetti, 1975; MacKay, 1970; Schvaneveldt, Meyer, & Becker, 1976). These hold that prior contextual information can act to direct lexical access so that only a single, relevant reading is ever accessed for an ambiguity. It is important to note that the nature of the claim made by such hypotheses is not limited to ambiguity alone; rather, it is a claim that lexical access, in general, is a contextually restricted, nonindependent process. The alternative class of hypotheses—postdecision or multiple-meaning hypotheses—holds that prior context has its effect only after all information is accessed for an ambiguity. Under these hypotheses, lexical access is viewed as an independent and relatively autonomous process in which context has its effects only following complete access of all the information about a word.

Data exist which appear to support both classes of hypotheses. Several studies (e.g., Conrad, 1974; Foss & Jenkins, 1973; Holmes et al., 1977; Lackner & Garrett, 1972; Cutler & Foss, Note 3) have reported support for the Postdecision Hypothesis. However, a number of these utilized tasks which appear likely to have lead subjects to employ some very specialized processing strategies (see Swinney & Hakes, 1976, for further discussion). Further, even the most compelling of the remainder have supported the Postdecision Hypothesis largely by virtue of failing to find support for the Prior Decision Hypothesis; they have not actually demonstrated the access of more than a single meaning for an ambiguity in the presence of a prior, biasing context.[1] Studies by Foss & Jenkins (1973) and Cutler & Foss (Note 3) provide good examples of this point. Both papers reported that phoneme monitoring latencies increased in the presence of an ambiguity (in comparison with an unambiguous control word) in an unbiased sentential context. Further, both studies failed to find any decrement in the ambiguity effect when a biasing context was introduced. Because such a decrement was expected if the Prior Decision Hypothesis was true, they interpreted this failure as support for the Postdecision Hypothesis. Unfortunately, support by default can often prove, for a number of reasons, to be a treacherous position to take. The work of Swinney & Hakes (1976), in fact, demonstrated that the ambiguity effect does decrease significantly in the presence of a *strongly* biased context, a result which forced reinterpretation of these previous results. The Swinney & Hakes (1976) result thus appeared to provide strong evidence that context can, at least under some conditions, direct the lexical access process; context would appear to be capable of interaction with lexical information during the access phase.

In spite of the intuitive appeal of this result,

[1]The experiment by Lackner and Garrett (1972) may be an exception to the particular problems stated here. However, their data do not actually allow a decision concerning whether context acted in a prior access or post access fashion (see comments in Holmes, Arwas, & Garrett (1977) and Lackner & Garrett (1972)).

and its accordance with the highly interactive view of sentence perception, two problems deserve some consideration. First, it is obvious that the tasks used to study any process, and particularly those used to obtain on-line measures of comprehension (i.e., tasks examining the process during its operation, in contrast to examinations made after it is finished), must be appropriately applied in order to detect that process. This fact would appear to hold particular importance for examinations of ambiguity processing which use the phoneme monitoring task. The phoneme target in such monitoring studies, of necessity, occurs "downstream" from the ambiguity which is being examined (it usually begins the word following the ambiguity). The temporal gap between occurrence of the ambiguity and detection of the phoneme target in a following word is, thus, fairly extensive relative to the magnitude of the effects reported with this task. It is hoped that the problem here is self-evident: Claims related to lexical access which rely on monitoring data all contain the key assumption that the task actually measures lexical *access* and not some process that occurs *following* access. However, it is at least possible that the phoneme monitoring task actually reflects some type of postaccess decision process. If so, in situations where a prior biasing context is not very strong (as was the case in the Foss & Jenkins (1973) study) this postaccess decision process might take a relatively long time to complete, long enough so that the phoneme monitor decision for the following word is engaged while this process is still at work. Such a situation would thus produce the typical ambiguity effect. However, in the presence of a very strong biasing context (the Swinney & Hakes (1976) study) this postaccess decision process could occur sufficiently quickly so as to reduce the processing load caused by the ambiguity prior to the time when the phoneme monitor task comes into play. In short, it may be that the phoneme monitoring task does not actually reflect the access of information for ambiguous (or other) words preceding the phoneme target but, rather, that it reflects postaccess processing (see Cairns & Hsu (1979) and Swinney (Note 4) for related arguments). If true, the task is not appropriate for examination of the hypotheses under question.

The second of the problems surrounding some of the previous work has arisen from recent examinations of the phoneme monitoring task (which has provided the bulk of the on-line evidence in this field). Both Mehler, Segui, & Carey (1978) and Newman & Dell (1978) have convincingly demonstrated that the ambiguity effects reported by Foss (1970), Foss & Jenkins (1973), and Cairns & Kamerman (1975) are all confounded with length and phonological properties of the initial phoneme of the ambiguity, its control, and the word preceding the ambiguity. When these factors were carefully examined it appeared as though the ambiguity processing effects could be accounted for largely on the basis of these confo nding variables. While the existence of some effect of ambiguity upon sentential processing has not been disproved, the role of the phoneme monitoring task in reflecting such an effect is certainly open to question. (It should be noted that the claims of confounding asserted for the above-mentioned studies do not apply as strongly to the Swinney & Hakes (1976) results.)[2]

[2]Newman and Dell (1978) point to the apparent direct relationship between the magnitude of the obtained ambiguity effect and the magnitude of the difference in the number of phonological features shared between the target phoneme and the initial phoneme of the ambiguous and unambiguous control words. A similar direct relationship was shown to hold between the magnitude of the obtained ambiguity effect and the amount by which the length of the unambiguous control word exceeded that of the ambiguous word. The Swinney and Hakes (1976) materials have smaller differences between ambiguous and nonambiguous control words (on both the phonological and the length criteria) than any of the studies examined by Newman and Dell, and yet their data show the *largest* ambiguity effect of any of these studies. Further, and perhaps most importantly, the Swinney and Hakes (1976) results showed a decrement in this ambiguity effect in the face of a strong biasing context.

The key to examining the experimental hypotheses in question, and to resolving the problems raised above, lies in increasing the sensitivity of the experimental task. In order to be able to provide positive evidence for the Postdecision Hypothesis, the experimental task should be capable of reflecting access of each of the several meanings of an ambiguous word. In addition, the task must be flexible enough to minimize the temporal gap between occurrence of the ambiguous word and the measure of access. Finally, the task must be applicable during sentence comprehension, and not just after the sentence has already been processed. To these ends, a task was devised which coupled the auditory presentation of an ambiguous sentence with a visual, lexical decision task. Recent work with cross-modality semantic priming has demonstrated that visual lexical decisions are facilitated following auditory processing of a related word (Swinney, Onifer, Prather, & Hirshkowitz, 1979). This finding fits well with the visual mode priming effect reported by Meyer and his associates (e.g., Meyer, Schvaneveldt, & Ruddy, 1975, Note 5) and others (Fishler, 1977; Tweedy, Lapinski, & Schvaneveldt, 1977). In fact, the data suggest that cross-modal facilitation effects are at least as robust as those found solely within the visual modality. Several characteristics of the cross-modal priming task are worthy of note. One is that semantic priming holds when the primed (facilitated) word is presented visually during auditory sentence comprehension. The second is that subjects in this task are typically not aware of any particular relationship between the visually presented material and the auditory sentential material. (See Results and Discussion sections for further explanation.) The semantic priming effect to be used here, much like that demonstrated in other studies, can thus occur as an automatic process, one not under control of conscious direction (see, e.g., Fishler, 1977; Neely, 1977). In short, the task reflects the access of auditory (priming) words through the relative facilitation of lexical decisions made to visual words, without drawing particular attention to the relationships involved.

The major advantages of this task are, first, that the visual word can be presented simultaneously with the offset of the ambiguous word in the sentence (thus overcoming distance problems faced by the phoneme monitoring task), second, that it can be used during (rather than after) comprehension, and third, that it minimizes the possibility of attention being drawn to the experimental variables, a situation that has often compromised the results of previous experiments. Finally, this task can be used to measure activation of *each* of the meanings of an auditorily presented ambiguity. If a strong sentential context causes only a single reading to ever be accessed for an ambiguity in a sentence then only lexical decisions for visually presented words related to *that* reading of the ambiguity will be facilitated. On the other hand, if both (or several) readings of an ambiguity are accessed, even in the presence of a strong biasing context, then visual words related to each reading will display some facilitation in the concurrent lexical decision task.

In order to give the hypotheses under investigation a strong test, materials used in this first experiment were taken from the Swinney

Note that this change in the ambiguity effect occurs over sets of materials in which the critical phonemic and length features are identical. If the phoneme monitoring data is not reflecting an ambiguity processing effect, it is difficult to see what the basis for the observed decrement could be. Newman and Dell suggest that the semantic contexts may be attentuating a phonological search effect associated with the phoneme monitoring task rather than an ambiguity processing effect. However, that claim appears rather unlikely, particularly given that the decrement in processing latency occurs in the presence of semantic contexts which are in sentences which precede those containing the ambiguity and target phoneme. It would appear that a more parsimonious account of the results is that while length and phonological properties of the word preceding the target phoneme undoubtedly effect the phoneme monitoring task, the task also, given appropriate circumstances, reflects lexical processing complexity.

& Hakes (1976) study which had produced results supporting the Prior Effect Hypothesis.

EXPERIMENT 1

Method

Design and materials. Sentential materials for this study were taken, with a few changes and additions, from those used in the Swinney & Hakes (1976) study. These consisted of 36 sets of sentence pairs (two sentences presented sequentially) each set having four variations. The four variations derive from a factorial combination of two variables: Ambiguity and Context.

The Ambiguity variable was comprised of two conditions: inclusion of either an ambiguous word or an unambiguous control word which was roughly synonymous with one reading of the ambiguity. These words were all nouns and all appeared in the predicate of the second sentence of each sentence pair. Ambiguous and control words were matched for frequency, using the Kučera and Francis (1967) norms, and for length in syllables. All ambiguous words were approximately equibiased, as determined by a pretest in which 44 subjects recorded their first interpretation of auditorily presented experimental sentences from the "no context" condition (see below). The maximum proportion attained for any single reading of any of the ambiguities ranged between .50 and .70.

The context variable comprised two conditions: either no disambiguating context, or a prior, strongly predictive, disambiguating context. The latter was determined using a criterion (discussed at length in Swinney & Hakes, 1976) in which the context was not only more related to one meaning of the ambiguity than the others, but, as judged by two judges, was strongly predictive of one meaning of the ambiguity by virtue of being highly associated with that meaning and being incompatible with other possible meanings.

For each sentence pair, a set of three words (to be presented visually) was prepared. One of these words was related to the contextually biased reading of the ambiguity in the sentence, one was related to the "other," contextually inappropriate reading of the ambiguity, and the third was not related to any meaning of the ambiguity. The specific degree of relatedness of each visual word to its paired reading of the ambiguity was not specifically controlled. (All such materials, however, appeared to hold a moderate degree of relatedness.) The three words of each set were yoked for length and frequency. (Only moderate-frequency words were utilized.) All words used in these conditions were then compared in an independent, isolated lexical decision task. The experimental words, along with 36 other words and 44 nonword letter strings, were presented visually in random order to 24 subjects. Reaction times to make a word/nonword (lexical) decision were compared for words comprising the three conditions of experimental words. The mean times for these conditions were 0.661, 0.664, and 0.657 second, respectively. Both multiple t test comparisons and analysis of variance, $F(2, 46) = 0.918$, revealed no significant differences between reaction times to words in these three conditions.

The four sentence variations and the set of three words paired with them are presented schematically in Table 1. "Δ" represents the point at which one of the three words would be presented visually during the auditory comprehension of the sentence.

Four tape recordings were made from the sentential materials. Each tape contained one variation of each of the 36 sentence pairs chosen so that the four types of variation were equally represented on each tape. All tapes also included 46 filler sentence pairs, randomly interspersed among the test sentence pairs. Filler sentence pairs were identical for each tape.

For presentation purposes three separate lists were created from the words and nonwords which were to be presented visually.

TABLE 1

SCHEMATIZED SAMPLE OF EXPERIMENTAL MATERIALS

Context condition	Ambiguity condition: Ambiguous	Ambiguity condition: Unambiguous
No context	Rumor had it that, for years, the government building had been plagued with problems. The man was not surprised when he found several $bugs_{\Delta}$ in the corner of his room.	Rumor had it that, for years, the government building had been plagued with problems. The man was not surprised when he found several $insects_{\Delta}$ in the corner of his room.
Biasing context	Rumor had it that, for years, the government building had been plagued with problems. The man was not surprised when he found several spiders, roaches, and other $bugs_{\Delta}$ in the corner of his room.	Rumor had it that, for years, the government building had been plagued with problems. The man was not surprised when he found several spiders, roaches, and other $insects_{\Delta}$ in the corner of his room.
Visual words* Displayed at "Δ"	ANT	(contextually related)
	SPY	(contextually inappropriate)
	SEW	(unrelated)

Each list contained only one of the three visual words which were created in conjunction with each sentence pair. The three visual word conditions were equally represented on each list. Half of the materials on each list were words (36 experimental materials, and 2 words which were paired with filler sentences) and the other half (32) were nonwords (paired with filler sentences). For six of the filler sentences, no visual word appeared on the screen.

Thus, there were 12 presentation conditions: each of 3 lists paired with each of the 4 tape conditions. A 1000-Hz signal was placed on a separate channel of the tape exactly coincident with the *offset* of each ambiguous or control word in the experimental sentential materials, and with the offset of a pseudorandomly chosen word in the filler sentences. These signals, inaudible to the subjects, signaled a PDP8/e computer to present the appropriate visual word and to start the timing mechanism which measured the latencies for the subject's lexical decisions. (See Onifer, Hirshkowitz, & Swinney (1978) for discussion of hardware and software involved in this procedure.)

Subjects. Eighty-four undergraduates from Tufts University participated in partial fulfillment of a course requirement. Seven subjects were randomly assigned to each of the 12 experimental conditions. Data for six additional subjects were omitted from analysis for failure to achieve a score of at least 85% correct on the comprehension test.

Procedure. The subjects were seated in front of a CRT screen and listened through headphones to the 82 binaurally presented sentence pairs. Subjects were tested in groups of up to 3 at a time: each subject was in a booth isolating him/her from other subjects in a group. Subjects were instructed to listen carefully to each sentence and to understand it. They were told that they would be tested on their comprehension during the experiment, and that the result of this test was crucial to their successful participation in this experiment.

In addition, subjects were told that they had a second task. It was explained that a string of letters would appear on the screen during some of the sentences they listened to, and that they were to decide as quickly as possible whether each letter string formed a word or not. No hint was given that words and sentences might be related and, in the five practice trials, no such relationship existed.

At both the midpoint and the end of the experimental session, subjects were given a

sheet of paper containing 21 sentence pairs. They were required to decide whether each of these was either identical or similar to sentences they had heard, or whether the sentence had not occurred at all in the experiment. These materials were scored on a percentage correct basis. At the end of the experimental session, subjects were questioned about whether they had noticed ambiguities in the sentence material and about whether they thought the words on the screen related in any specific fashion to the sentences they had heard.

Results

The mean reaction times for the 12 experimental conditions, calculated across all materials and subjects, are presented in Table 2. It is apparent that lexical decisions for words related to *both* readings of the ambiguity are facilitated (relative to decisions for an unrelated control word) in conditions containing a lexical ambiguity and no biasing context. Similarly, and of greatest interest, this same effect holds for the condition in which there is a strongly biasing semantic context present; lexical decisions for words related to both the contextually relevant and the contextually inappropriate meanings of the ambiguity appear to be facilitated compared to decisions for unrelated control words. The effects for both of the unambiguous conditions also appear quite straightforward: Lexical decisions for the "related" word appear to be facilitated, but those for the other two words are not. Thus, by inspection, the results appear to support the Postdecision Hypothesis; even a very strong semantic context apparently does not direct lexical access. Statistical analysis supports this contention.

An analysis of variance revealed that main effects for Context, Ambiguity, and Visual Word Type were each significant for analyses employing both subjects and materials as random factors, min $F'(1, 79) = 7.01$, $p < .01$; Min $F'(1, 86) = 6.32$, $p < .025$; Min $F'(2, 188) = 52.6$, $p < .001$, respectively. Both the Context × Visual Word Type and the Context × Ambiguity interactions failed to reach significance, Min $F'(1, 119) = 0.42$; Min $F'(1, 74) = 0.1$, respectively. Most revealing for the present purposes, however, was the fact that Ambiguity interacted significantly with Visual Word Type, Min $F'(2, 157) = 4.71$, $p < .01$, but that the Context × Ambiguity × Visual Word Type interaction was not significant, Min $F(2, 161) = 0.04$.

In order to examine the predicted effects, planned multiple comparisons were made on the relevant Visual Word Type categories for each of the Ambiguity × Context conditions. For the condition containing a biasing context and an ambiguity, reaction times to visual words in both the contextually related and contextually inappropriate categories were significantly faster than latencies for unrelated words, $t(83) = -6.1$, $p < .0009$; $t(83) = -5.04$, $p < .0009$, respectively. The contextually related and contextually inappropriate categories, however, did not differ from each

TABLE 2

MEAN REACTION TIMES, IN MILLISECONDS, FOR CONDITIONS OF THE AMBIGUITY × CONTEXT × VISUAL WORD INTERACTION: EXPERIMENT 1

		Visually presented words		
Ambiguity condition	Context condition	Contextually related	Contextually inappropriate	Unrelated
Ambiguous	Biasing context	890	910	960
	No context	916	925	974
Unambiguous	Biasing context	887	958	963
	No context	914	967	972

other in this condition, $t(83) = -1.05$. This same overall configuration of results held for the no context condition containing an ambiguity, $t(83) = -5.2$, $p < .0009$; $t(83) = -4.94$, $p < .0009$, $t(83) = -0.98$, respectively. In the unambiguous conditions, reaction times to the contextually related words were significantly faster than those for the unrelated words in both the biasing context, $t(83) = -7.4$, $p < .0009$, and no context, $t(83) = -5.16$, $p < .0009$, conditions. However, reaction times to contextually related words differed significantly from contextually inappropriate words in each context condition, $t(83) = -7.2$, $p < .0009$; $t(83) = -5.2$, $p < .0009$, respectively. In neither case did reaction times to the contextually inappropriate words differ from those to the unrelated words, $t(83) = -0.55$; $t(83) = -0.6$, respectively.[3,4]

The post-test questionnaires were evaluated in order to determine whether subjects noticed any specific relationship between words in the sentence and the visually presented words. Of the 84 subjects, only 11 thought they noticed any time-locked relationship between materials in the sentence and the visual words. However, the relationships these subjects reported were almost entirely unrelated to the experimental manipulations; it appears that perceptual displacement typically occurs in this task, and that subjects report seeing the visual words one to two syllables downstream from where they actually occur. Thus, reported relationships are most typically unrelated to the experimental manipulations. (Because the ratio of related materials to unrelated materials is kept low, a strategy of attempting to relate visual words to immediately preceding auditory material would actually be detrimental rather than facilatory to task performance.) Because these 11 "aware" subjects came from eight different materials conditions, analysis of their data could only be made by comparison with data obtained from the same subject-group conditions. In these comparisons there was only a single case in which the basic direction of effects for Ambiguity, Context, and Visual Word Type did not hold. However, it is notable that the facilitation for the contextually inappropriate visual word condition did not appear to be nearly so robust for "aware" subjects as it was for the "unaware" subjects, although these differences were not statistically significant.

[3]It should be noted that the only appropriate comparisons to make for these data are those given. Because the level of associativity of the contextually related and contextually inappropriate words to each of the meanings of the ambiguity are not equated (a nearly impossible task given the other, more critical, constraints required in matching these words; see Design and Materials section), the appropriate comparisons are just those which examine for evidence of facilitation/priming between each of these visual words and its control. Levels of such facilitation cannot be meaningfully examined by direct comparison of reaction times to the "related" and "inappropriate" words or by comparison of the relative degree of facilitation for each of these words compared to its control (although these have been given in a few cases above, just for general interest purposes). This is, again, because the absolute degree of associativity of each visual word to its related sense of the ambiguity differ by an unknown amount. In addition, although the reaction times for the contextually related words are beguilingly similar for the ambiguous and nonambiguous conditions, no interpretable comparisons between these conditions are possible; the facilitation of the "contextually related" words occurs in response to different auditory contexts in the ambiguous and unambiguous conditions (e.g., to the word "bug" in the one and "insect" in the other, in the materials sample in Table 1). It is interesting to note that reaction times to the control words, which are legitimate sources for comparison, are remarkably similar for the ambiguous and unambiguous conditions. However, overall, the only relevant and interpretable comparisons are those involving the search for presence or absence of significant facilitation/priming for the "related" and "inappropriate" visual words in each of the individual experimental conditions; such evidence is sufficient and appropriate for examining the issues addressed in this paper.

[4]Although all paired comparisons made by multiple t tests were both planned and necessary in order to examine the hypotheses under question, a more conservative test, the Bonferroni t (Kirk, 1968), was also applied to the data. For this test, the critical value of d for $\alpha = .05$, was 46.1. As can be seen by inspection, all comparisons which were significant under the standard t tests were also significant under the Bonferroni t analysis.

Similarly, only 3 of the 84 subjects reported that they had noticed ambiguities in the materials during the experiment; due to the small number of cases no further analysis of this factor was undertaken.

Discussion

The results of Experiment 1 provide fairly strong support for a model of sentential processing in which lexical *access* is an autonomous process; because semantic facilitation was observed for lexical decisions to words related to both the contextually relevant and the contextually inappropriate meaning of the ambiguity, even in the presence of the very strong prior semantic contexts, it appears reasonable to conclude that semantic context does not *direct* lexical access. Rather, immediately following occurrence of an ambiguous word all meanings for that word seem to be momentarily accessed during sentence comprehension. Thus, the results which were previously obtained with the phoneme monitoring task would appear to be the consequence of some process which occurred following lexical access rather than a reflection of the access process itself (see also Cairns & Hsu (1979) for arguments supporting this position). It seems likely that semantic context has its effects upon a postaccess decision process, one which eventuates in the choosing of a single reading for an ambiguity. Certainly, a number of intriguing questions now present themselves. Foremost among these is one concerning the nature of the information interaction which occurs during this posited postaccess decision process.

In order to further investigate this, a second experiment was performed which focused on the time course of this process. The experiment also had the goal of providing further information concerning the cross-modal priming task. Cairns & Kamerman (1976) reported that the increased sentential processing complexity caused by an ambiguity disappears approximately two syllables following the ambiguity, when measured by the phoneme monitoring task. If these results are valid (again, see Newman & Dell, 1978) then any lexical ambiguity is apparently resolved by that time, even when no overtly biasing context is present. Even if these phoneme monitoring data are questionable, it is clear that lexical ambiguity must be resolved relatively quickly, certainly by the end of the clause containing that ambiguity (see, e.g., Foss, Bever, & Silver, 1968; Bever, Garrett, & Hurtig, 1973). It is thus important to determine the rate and manner in which the nonrelevant reading(s) of an ambiguity is discarded during this postaccess decision process. Available data do not permit us to even determine whether contextually irrelevant readings remain available at some level for processing or whether they are irretrievably lost to the comprehension device. Experiment 2 examines these questions utilizing the same basic experimental design as was used in Experiment 1. In this experiment, however, the visual (primed) materials appear three syllables following occurrence of the ambiguous word in the sentence as well as immediately following it. If the contextually inappropropriate meanings of an ambiguous word are immediately discarded or suppressed, then we should find that only the contextually relevant visual materials will be facilitated in this experiment. On the other hand, if all meanings of the ambiguous word remain under consideration until the end of the clause containing the ambiguity, then words related to both the contextually appropriate and the contextually inappropriate meanings of the ambiguous word should be facilitated.

EXPERIMENT 2

Method

Design and materials. This experiment was designed in two parts: a replication of Experiment 1 and an extension of that experiment. The replication was quite straightforward involving only minor changes in materials

used in Experiment 1. The extension duplicated this replication experiment with the single change being that the visual (lexical decision) materials appeared three syllables following the ambiguous (or control) word during the course of the sentence. Because the design of each of these studies is nearly identical to that for Experiment 1, only the important changes will be noted. Thirty-six sets of experimental sentences (not sentence pairs as were presented in Experiment 1) were used in each study. Each set contained four variations derived, controlled, and counterbalanced for presentation as in Experiment 1. In addition, half of the biasing semantic contexts were chosen to be in accord with the a priori more likely meaning of the ambiguity (as determined in pretests of materials for Experiment 1), and half were in accord with one of the less likely meanings of the ambiguous word. All lexical ambiguities were, however, chosen for their approximate equibias as measured in the pretest described in Experiment 1. There were 44 filler sentences interspersed among the experimental materials. For 8 of these, visual words were displayed during their presentation; during the other 36 filler sentences visual nonwords were displayed.

Visual words and tape recordings were constructed as in Experiment 1, and the three types of visual words (contextually related, contextually inappropriate, and unrelated) were again compared on an isolated lexical decision pretest using 33 subjects. The mean reaction times to each of these conditions (647, 641, and 650 milliseconds, respectively) did not differ significantly. Planned t test comparisons of the contextually related and contextually inappropriate, $t(32) = 0.68$, and of the contextually related and unrelated, $t(32) = -0.38$, as well as the contextually inappropriate and unrelated categories, $t(32) = -0.79$, all revealed no significant differences.

Subjects. One hundred and forty-four subjects participated in this experiment, half of these in the replication and half in the extension portion of the study. Six subjects were randomly assigned to each of the 12 experimental conditions in each half of the study.

Procedure. The procedure was identical to that for Experiment 1, except that no formal post-test for awareness of ambiguity was given.

Results

The mean reaction times for the critical conditions of the replication portion of the experiment, calculated across subject groups and materials conditions, are given in Table 3. Inspection of these data suggests that the results reported in Experiment 1 did, indeed, replicate in this second study. Analysis of individual subjects' data for this portion of the study substantiated this observation. An analysis of variance revealed that, overall, all main effects and interactions were nonsignificant except for a significant main effect for Visual Word Type (which was significant for an analysis utilizing both subject and material as random factors), Min $F'(2, 164) = 4.83$, $p < .01$, and for the Ambiguity × Visual Word Type interaction, Min $F(2, 141) = 3.09$, $p < .05$. Planned comparisons of relevant cells in this interaction revealed the following effects in this design: Lexical decisions made to words in the contextually related and contextually inappropriate categories were each significantly faster than those of unrelated visual materials in the sentential conditions containing an ambiguous word and a biasing context, $t(71) = 2.676$, $p < .01$; $t(71) = 2.131$, $p < .04$, respectively. Reaction times to contextually related and contextually inappropriate conditions did not differ significantly, however, $t(71) = 1.60$. These same relationships held for the sentential materials containing an ambiguity and no biasing context, $t(71) = 2.57$, $p < .015$; $t(71) = 2.56$, $p < .015$; $t(71) = 0.469$, respectively. In the sentential conditions containing unambiguous control words, lexical decisions were significantly faster for the contextually related category

TABLE 3

MEAN REACTION TIMES, IN MILLISECONDS, FOR CONDITIONS OF THE AMBIGUITY × CONTEXT × VISUAL WORD INTERACTION: EXPERIMENT 2 (REPLICATION)

Ambiguity condition	Context condition	Visually presented word: Contextually related	Contextually inappropriate	Unrelated
Ambiguous	Biasing context	708	715	746
	No context	703	708	743
Unambiguous	Biasing context	710	747	744
	No context	702	732	742

words than for the unrelated words in both the biasing context, $t(71)=2.43$, $p<.015$, and no context $t(71)=2.61$, $p<.01$, conditions. Similarly, reaction times to contextually related words were significantly faster than to contextually inappropriate words in both the biasing context and no context conditions, $t(71)=2.35$, $p<.02$; $t(71)=2.07$, $p<.05$, respectively. Reaction times to the contextually inappropriate words did not differ significantly from the unrelated words in either of these conditions, $t(71)=0.05$; $t(71)=0.075$, respectively.[5]

The results of the extension portion of this study differ markedly from those of the replication portion. Table 4 presents mean reaction times for the 12 major experimental conditions, calculated across materials and subjects conditions, for the extension study. It can be seen that facilitation of lexical decisions appears to occur only for the contextually related word category; this effect, however, occurs for each of the relevant experimental conditions. This observation is confirmed by the results of planned t tests and an analysis of variance. The analysis of variance performed on these data (again, with both subjects and materials as random factors) revealed significant main effects for Visual Word Type, Min $F'(2, 172)=19.87$, $p<.001$, but no significant main effects for Ambiguity, Min $F'(1, 80)=0.46$, or Context, Min $F'(1, 53)=0.008$), and no significant interaction of Visual Word Type with Ambiguity and Context, Min $F'(2, 161)=0.06$. Planned comparisons for the three Visual Word Type categories in sentential conditions containing an ambiguous word and a biasing context revealed that lexical decisions for contextually related words are significantly faster than those both for contextually inappropriate words, $t(71)=-4.76$, $p<.001$, and for unrelated words, $t(71)=-4.389$, $p<.001$. Additionally, reaction times for words in the contextually inappropriate and unrelated categories do not differ, $t(71)=0.08$. The same set of effects holds for each of the other three Context × Ambiguity conditions. That is, when the sentence contained an ambiguous word and no biasing context, lexical decisions to contextually related words were significantly faster than those for both contextually inappropriate words, $t(71)=-4.24$, $p<.001$, and unrelated words, $t(71)=-2.42$, $p<.02$, but words in the latter two categories did not differ, $t(71)=0.79$. When the sentential materials contained an unambiguous control word and a biasing context, lexical decisions to words in the contextually related condition were faster than for those in the contextually inappropriate, $t(71)=-3.10$, $p<.003$, or unrelated, $t(71)=-3.30$, $p<.002$, conditions,

[5] All comparisons found to be significant under standard t were also significant under the Bonferroni correction ($d=36.2$, $\alpha=.05$) with two exceptions. Comparisons in the unambiguous condition involving contrasts of the contextually related words to the unrelated words when no context was present, and the contrast of contextually related words to inappropriate words when a biasing context was present, both just failed to reach significance at $\alpha=.05$. Both are significant at $\alpha=.07$.

TABLE 4

MEAN REACTION TIMES, IN MILLISECONDS, FOR CONDITIONS OF THE AMBIGUITY × CONTEXT × VISUAL WORD INTERACTION: EXPERIMENT 2 (EXTENSION)

Ambiguity condition	Context condition	Visual word condition: Contextually related	Contextually inappropriate	unrelated
Ambiguous	Biasing context	795	849	848
	No context	800	846	845
Unambiguous	Biasing context	808	843	849
	No context	811	847	846

but the latter two categories did not differ significantly, $t(71) = -0.6$. Finally, in the sentential conditions containing an unambiguous control word and no biasing context, lexical decisions to words in the contextually related condition were responded to faster than those in the contextually inappropriate, $t(71) = -3.4$, $p < .001$, and unrelated, $t(71) = -3.2$, $p < .002$, conditions, but, again, the latter two categories did not differ significantly, $t(71) = 0.02$.[6]

Discussion

The results of the second experiment replicate those of the first, demonstrating that lexical decisions for words related to both the relevant and the contextually inappropriate meanings of an ambiguous word are facilitated, even in the presence of a strong, prior, biasing context, when these decisions are made immediately following occurrence of the ambiguity in a sentence. In addition, the experiment shows that when this test is applied three syllables following occurrence of the ambiguous word, only lexical decisions for words related to the contextually relevant meaning of the ambiguity are facilitated; at this point lexical decisions for words related to contextually inappropriate meanings of an ambiguity no longer show facilitation.

[6]Under Bonferroni t analysis (for $\alpha = .05$, $d = 28.4$), all significant effects reported for the multiple t tests are also significant under the more conservative Bonferroni t analysis.

It might be noted that in the extension portion of Experiment 2 (where the test point was three syllables following the ambiguity) only the "relevant" meanings of the ambiguities were found to be facilitated in the materials containing no biasing context. Because half of the materials had originally been chosen to have a priori biases toward the interpretation picked as the "related" meaning, and the other half chosen to have a priori biases toward the other (inappropriate) meaning, one might have expected that each of these interpretations would have shown some facilitation in the unbiased context condition. However, although all ambiguities were originally chosen to be approximately equibiased, with a balanced representation of whatever a priori biases they contained, interpretations of words change over time. The bias ratings used in Experiment 2 were based on those used for Experiment 1. Thus, at least 2 years separated the gathering of bias ratings and performance on those materials in Experiment 2. In order to discover whether changes in these biases had taken place over this period of time, a post-test was performed (for the unbiased context sentences) using 35 Tufts University undergraduates. It was found that, of the 36 experimental ambiguities, 29 actually had biases favoring the reading which had been chosen as the "related" meaning in the experiment (although some of these were very small). Adding this information to the fact that all biases, whatever their direction, were relatively small, leads to the conclusion

that the "related" meanings of the ambiguity were still facilitated at a point three syllables following the ambiguity, but the "inappropriate" meanings were not, even when no biasing context was present, because (overall) the a priori preferred interpretation for the ambiguities at the time of test tended to be those designated as "related" in this study. This fact, however, does not change the conclusions that have been drawn based on these results. In fact, the evidence suggests that not only are both (all) meanings for an ambiguity momentarily accessed, even in the presence of a strong biasing context, when the ambiguities are approximately balanced for most likely a priori interpretation (Experiment 1), but that all meanings are also immediately and momentarily accessed even when materials have a priori biases largely toward just one of the "senses" of the word tested. The fact that two meanings are available upon immediate access but that only one meaning is available three syllables later suggests that a very rapid postaccess decision process is at work. (In addition, it suggests that the task used in this experiment is sensitive to the "active" meanings of a word throughout their time course.)

An additional note should be made of the "drift" which we found for our bias ratings. The degree of drift which occurred over a 2-year period suggests that far more than sampling error is at work here. The favored interpretations of ambiguities do not remain fixed, at least for the words examined in this study. This recalls the old (and apparently true) theme in language research that, due to the rapidity of change in the language, reliance of preestablished norms must be done with care, and avoided where possible.

General Discussion

In all, the results from both of these experiments provide strong support for the conclusion that the *access* process for lexical items is isolable and autonomous at least with respect to effects of semantic context. That is, semantic contexts do not appear to direct lexical access, as was predicted by the Prior Decision Hypothesis. Thus, the access operation appears to be a stimulus (form)-driven process for which the entire inventory of information stored for a lexical form is made available to the sentence comprehension device. The results also support the existence of a postaccess decision process which acts to select a single meaning from those originally and momentarily accessed for involvement in further processing. This decision process apparently is completed at least by the time that three syllables of additional information have been processed (approximately 750–1000 milliseconds), even when no biasing context is present.

A few general comments concerning the posited postaccess decision process are in order. First, the normal time course of access, activation, and deactivation (for inappropriate meanings) in this process is clearly underestimated in this study. It is likely to be far less than the approximately 750–1000 milliseconds found in Experiment 2. Further as this decision process takes place within a 1000-millisecond period even for conditions containing no biasing context, one would expect it to be far faster in normal situations, where a context is typically present. Second, the nature of the decision process which chooses the relevant meaning of the ambiguity deserves some consideration. It may be that the process acts to suppress the level of activation of unchosen meanings. On the other hand, it may be that the single meaning which is chosen for an ambiguity is somehow made available to further (higher order) sentential processes in a manner which simply ignores the unchosen meanings. (For example, it could be that both meanings of the ambiguity are still somewhat activated following access, but that the relevant meaning is shifted to what might be considered the "current" level of processing; presumably, it would be just this "current" level which can provide automatic

semantic priming.) At present, there are no data which will allow us to directly choose between these quite different alternatives, and it is clear that further work on the nature of this decision process is in order.

Finally, because most words can, in fact, have different meanings (be these merely the different senses of a word or the totally different meanings comprising an unsystematic lexical ambiguity), it seems reasonable to suggest that the postaccess decision process posited here may be a general process. For any word, some subset of all the information which is originally accessed for that word may be selected for further processing and integration into ongoing sentential analysis. If so, only a single meaning for an ambiguous word, and only a single "sense" of an unambiguous word, would thus come to conscious awareness following this postaccess decision process. Semantic contexts apparently aid this selection process; the more the context restricts or determines the relevant sense of a word, the quicker the decision process will presumably take place. This model would fit with approaches taken by a number of authors (e.g., Collins & Loftus, 1975; Morton, 1969) on the access of semantic memory. It should be noted that while semantic contexts apparently do not affect access, there may be other types of information that will act upon the access phase of word recognition. Syntactic information, for example, may well serve to direct access in a way that semantic context cannot (see, e.g., Garrett, 1978; Fay, Note 6; Prather & Swinney, Note 7; Ryder, Note 8).

The model just sketched is, admittedly, underdetermined by the data. The nature of the claim being made is that sentence comprehension is not a totally interactive process; that is, that all kinds of information do not interact at all levels of processing. Certainly, it suggests that lexical access is basically a "bottom-up" or stimulus-driven process. This, however, is not at all to claim that this accessed information does not interact with other information. In fact, the data presented here could fit well with certain types of interactive models, such as that presented by Marslen-Wilson and his associates (e.g., Marslen-Wilson, 1975; Marslen-Wilson & Welsh, 1978), provided that certain constraints are placed on the interactions occurring around the access phase. In sum, however, these data appear to provide some evidence for autonomy of the lexical access process during sentence comprehension.

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