

Accessing lexical ambiguities during sentence comprehension: Effects of frequency of meaning and contextual bias

WILLIAM ONIFER and DAVID A. SWINNEY
Tufts University, Medford, Massachusetts 02155

Two hypotheses concerning the nature of lexical access, the exhaustive access and the terminating ordered search hypotheses, were examined in two separate studies using a cross modal lexical priming task. In this task, subjects listened to sentences that were biased toward either the primary interpretation (a meaning occurring 75% or more of the time) or a secondary interpretation (a meaning occurring less than 25% of the time) of a lexical ambiguity that occurred in each sentence. Simultaneously, subjects made lexical decisions about visually presented words. Decisions to words related to both the primary and secondary meanings of the ambiguity were facilitated when presented immediately following occurrence of the ambiguity in the sentence. This effect held under each of the two biasing context conditions. However, when they were presented 1.5 sec following occurrence of the ambiguity, only visual words related to the contextually relevant meaning of the ambiguity were facilitated. These results support the exhaustive access hypothesis. It is argued that lexical access is an autonomous subsystem of the sentence comprehension routine in which all meanings of a word are momentarily accessed, regardless of the factors of contextual bias or bias associated with frequency of use.

Much of the work that has examined the effects of various sentential and nonsentential contexts upon lexical access has focused on the processing of lexical ambiguities. The reasons for this are fairly obvious. The various meanings of unsystematic lexical ambiguities can be differentiated rather easily, thus allowing examination of the selective effects of different contextual conditions upon the functional activation of those meanings. Given the large number of lexical ambiguities in the language (and the related fact that nearly all words exhibit some type of indeterminacy in characterizations of their meaning), this approach to examining lexical access, and the effects of context upon that access, seems well-founded. This work has led to a number of the established facts and current theories about lexical processing.

Before directly considering the status of these theories, however, it is worth noting that a great number of the facts that have been discovered about lexical processing are intimately tied to the various methodologies that were used to discover them. While this is

certainly not a novel observation, it does suggest that it will be important to consider a few methodological issues before we examine these theories. It has been demonstrated, for example, that certain stages in the time course of lexical processing are differentially available to various experimental tasks. The key here is typically the relative point of application of the task. That is, experimental techniques that examine lexical processing only following comprehension of the sentence containing the word of interest (such as occurs in some recall, recognition, paraphrase, and sentence classification tasks) appear to reflect aspects of lexical processing different from those reflected by tasks that occur temporally close to the critical word during processing of the sentence (such as in phoneme monitoring, on-line word detection, cross-modal lexical priming, and certain click-detection tasks). Garrett (1970) was the first to point out and examine this fact, and many others have since demonstrated its essential truth (see, e.g., Cutler & Norris, 1979; Forster, 1979; Foss, 1970). To summarize the major differences, it appears that on-line or "perceptual" tasks more accurately reflect the nature of the processes used to gain access to the representation of lexical items and that postperceptual tasks appear to reflect the final outcome of such processes (or manipulations of this outcome). An interesting and related point is that it is generally only the final result of any perceptual process that can be brought to the conscious awareness of a listener. Thus, the verbal report or analysis of a listener as to the nature of material he heard is typically not a direct reflection of the series

The authorship of this paper was a joint and equal undertaking, and the order of authors is given alphabetically. William Onifer is currently at Bell Laboratories. The authors express their gratitude to Max Rirshkowitz, Penny Prather, Anne Cutler, and Marie Banich for their theoretical and practical contributions to this paper. We also thank one of the reviewers, Ken Forster, for his valuable suggestions. This paper was written in August 1979 and revised in July 1980. Requests for reprints should be sent to David Swinney, Psychology Department, Tufts University, Medford, Massachusetts 02155.

of unconscious (and in most cases, automatic, non-interruptible) stages involved in the access process (for related discussion, see Foss & Swinney, 1973; Posner & Snyder, 1975; Shiffrin & Schneider, 1979).

Another methodological point that has come to be of importance in this literature concerns the degree to which subjects are presented with predictable experimental situations that allow and encourage the development of specialized processing strategies that may affect (change) the processes under investigation. In general, it is obvious that the less any experimental task permits such special strategies to develop, the more certain one can be that it is the desired, normal process that is reflected in the data.

With these points in mind, the evidence that has accumulated about the processing of lexical ambiguities during sentence comprehension and the effects of context on such processing can be organized into a relatively coherent story. First, in the absence of any strongly biasing context, it appears as though all meanings of a lexical ambiguity are accessed, at least momentarily. Such access is not available to conscious introspection, and the listener eventually becomes aware of only one of the meanings accessed for the ambiguity. Swinney (1979), for example, has shown that in the absence of a biasing context, lexical decisions for words related to each meaning of an ambiguity are facilitated when these words are presented immediately after occurrence of the ambiguity in a sentence. From this, it was concluded that both meanings of the ambiguity were accessed, at least momentarily, thus providing the facilitation for lexical decisions to words related to each of those meanings. In other recent work, Holmes, Arwas, and Garrett (1977) have shown that time to classify an unbiased sentence as meaningful is increased by the presence of a lexical ambiguity and that the number of words correctly recalled under the rapid serial visual presentation technique is, likewise, smaller in the presence of an ambiguity (Chodorow, 1979, has found a similar result in the auditory domain). Cairns and Hsu (1980) have also recently supported this contention using a phoneme monitoring technique (as have Holley-Wilcox & Blank, 1980, in nonsentential lexical decision experiments).

A number of other studies exist that, although their results also appear to support this same conclusion about ambiguity processing in unbiased contexts, have been confounded by factors such as length and/or phonological properties of the stimuli. Such studies include Cairns and Kamerman (1975), Foss (1970), Foss and Jenkins (1973), and Cutler and Foss (Note 1). Whether or not the confounds are critical is uncertain at this time and may vary across experiments (for a discussion of these confounding factors, see Mehler, Segui, & Carey, 1978; Newman & Dell, 1978; Swinney, 1979). Similarly, work by Conrad (1974) supports the general view that all meanings of a word are accessed, but her work was

potentially compromised by use of a task that brought the existence of ambiguities (and their position in the experimental materials) directly to the listener's attention. Thus, specialized processing strategies may have played a significant role in the results. In all, while some experimental attempts to demonstrate that more than a single meaning of an ambiguity is accessed have met with failure (e.g., Cutler, cited by Cutler & Norris, 1979; Mehler et al., 1978; Newman & Dell, 1978), and while other experiments supporting this hypothesis have been potentially compromised, experimental evidence does exist that provides reasonably strong evidence in support of the position that all meanings are momentarily accessed for lexical ambiguities, at least in unbiased sentence contexts.

Further there is some evidence to support the claim that, even in the presence of a strongly biasing semantic context, all meanings of an ambiguity are still accessed. However, here the waters become slightly muddy. In support of this basic position, we find, among other work, studies by Cairns and Hsu (1980), Holmes et al. (1977), Lackner and Garrett (1972), Swinney (1979), and Tanenhaus, Leiman, and Seidenberg (1979), each of which has used different experimental tasks to examine the effects of context on lexical access.

We will focus momentarily on both the experimental technique and the results of the work by Swinney (1979), in order to examine the general position in more detail. Swinney employed a cross-modal lexical priming task in which subjects listened to (and comprehended) sentences containing lexical ambiguities in strongly biasing semantic contexts. Simultaneously, they performed a lexical decision task on visually presented letter strings. Lexical decisions for words that were related to each of the meanings of the ambiguity were facilitated (in comparison with control words) when these words were presented simultaneously with the offset of the lexical ambiguity. However, when the visual words were presented at a point four syllables following offset of the ambiguity, only lexical decisions for words related to the contextually relevant meanings of the ambiguities were facilitated. The assumption behind this cross-modal task is that automatic priming (facilitation) of lexical decisions will occur only for material related to meanings of the ambiguity that actually have been accessed. It is worth noting that this cross-modal priming task appears not to draw the listeners' attention to the presence of ambiguities in the materials, that it is not predictable (in terms of where the visual word appears), and, further, that it does appear to be a task that is fairly sensitive to lexical access and processing.

Thus, these data (and those of the other cited studies), taken in conjunction with the evidence from ambiguity studies in which no biasing context was present, provide the basic support for what can be called the exhaustive access hypothesis of lexical processing. By this hypoth-

esis, when an ambiguity (or any word) is encountered, all of its senses or meanings are at least momentarily made available to the comprehension device. Such access may be either serial (and exhaustive) or parallel in nature, as either condition would satisfy the requirements of this model. (Other types of evidence argue for the serial exhaustive choice: see Forster, 1976, 1979.) All access, however, occurs independently of contextual constraints. Thus, lexical access is viewed as being an isolable subprocess in the comprehension routine, one that operates in a bottom-up fashion based entirely on the (acoustic/phonetic) form of the word. The effects of contextual constraints are seen to operate on the assessed candidates in a subsequent, independent process.

However, several pieces of work, originating with that of Hogaboam and Perfetti (1975), have raised an interesting and possibly crucial objection to the conclusion just drawn (see also Holmes, 1979; Hogaboam, Note 2, Note 3). The argument they raise is that most (if not all) of the results cited thus far may be artifacts of the type of ambiguity used in these investigations. In these studies so-called equibiased lexical ambiguities were used, ambiguities for which each reading was equally likely to be functional in an unbiased sentence. Hogaboam and Perfetti (1975) suggest that the data from most such studies could reflect a process in which subjects actually access only one meaning at a time for an ambiguity. They argue that about half of the subjects in these experiments may be deciding that their first-accessed meaning is appropriate. The other half, however, are not, in which case they then access the next meaning for the ambiguity. This possibility, together with the fact that there is undoubtedly some fluctuation in the exact bias of words for different subjects, could result in grouped data that would look as though several meanings of a word are always accessed when that is only the case part of the time. Thus, Hogaboam and Perfetti (1975) argue that lexical access may actually involve a terminating ordered search process, one that is ordered by frequency of the meanings (from high to low) and terminates when a contextually appropriate meaning is found. Only if the most frequent meaning fails to satisfy contextual constraints are other meanings accessed. Such a search process could occur either in serial or in parallel, although in the latter case, one must posit that the more frequent entries distinguish themselves earlier than do the less frequent entries, thus terminating the search. (See also Forster, 1976, and Holmes, 1979, who propose very similar models.) Hogaboam and Perfetti (1975) report experimental data that they argue support this terminating ordered search model. They required subjects to listen to sentences and to determine whether or not the last word in the sentence was ambiguous. When sentential context required the secondary (least likely) meaning of an ambiguity, reaction time to detect that ambiguity was faster than when the context required the primary (more likely) meaning. Hogaboam and Perfetti argue that

subjects access only the more likely meaning of an ambiguity when it is appropriate to the context, and thus it is more difficult- in such situations for subjects to discover that a word is ambiguous than it is in situations in which the context requires both primary and secondary meanings to be retrieved. A recent paper by Holmes (1979) replicated the findings of Hogaboam and Perfetti and also reported that in, a sentence classification task (in which subjects determine whether or not a sentence is meaningful), the presence of sentential contexts that bias an ambiguity toward the sentence's primary interpretation results in faster classification times than do contexts biased toward the secondary meaning. Holmes argues that this supports the terminating ordered search hypothesis in that when the most frequent interpretation is appropriate to the context, no further meanings need to be processed, thus allowing sentence classification to take place rapidly.

However, it appears premature to claim that this evidence necessitates acceptance of the terminating ordered search hypothesis and rejection of the exhaustive access hypothesis. The reasons for this center on some of the methodological grounds discussed previously. If one uses an ambiguity detection task to examine lexical access, one makes the assumption that the time to make conscious decisions about the number of meanings that a word can have directly reflects properties of lexical access (and not some other lexical process). It is not clear that this is the case. It seems equally possible that in this task situation, all meanings of a word may be accessed and made available at an unconscious level and, following that, a single appropriate meaning from among those accessed is brought to consciousness. Only then may a subject be able to interrogate the representation associated with the acoustic entry for the consciously obtained meaning in order to determine whether or not another meaning exists for this entry. Such a model would fit well with what we know of the operation of highly automatic processes such as lexical access and more consciously controlled tasks such as that involved in determining the number of meanings of a word (for some relevant arguments about conscious access, see Foss & Swinney, 1973; Posner & Snyder, 1975). That is, it seems quite possible that it is only at a point long following lexical access that the operations reflected in Hogaboam and Perfetti's (1975) data take place. Certainly, the conscious discovery of a second meaning for a word may well be more difficult for low-frequency than for high-frequency meanings. In addition, because place of occurrence of the target ambiguity was always predictable in these experiments, specialized task performance strategies may have been at least partially responsible for the results. In short, the possibility of specialized strategies and the use of a postperceptual experimental technique compromise the immediate acceptance of Hogaboam and Perfetti's interpretation of their data. (Similar postperceptual technique arguments also hold

for the sentence classification results reported by Holmes, 1979.) Nevertheless, the arguments of Hogaboam and Perfetti concerning the current state of the literature are quite valid. Hence, a more sensitive evaluation of the exhaustive access and terminating ordered search models is necessary.

In order to examine the distinguishing predictions of these models, a technique is needed that is capable of reflecting access of the various distinct meanings (both primary and secondary) of nonequibaised (polarized) ambiguities. The cross-modal lexical priming task discussed earlier appears to be one such candidate, and it was thus adopted for these studies (see Swinney, Onifer, Prather, & Hirshkowitz, 1979, for further discussion of the technique; also see Tanenhaus et al., 1979, for a similar technique). Relative to this task, if the terminating ordered search model is correct, only lexical decisions made to words that are related to the primary (higher frequency) meaning of the ambiguity will be facilitated if the sentential context is biased toward that meaning; lexical decisions to words related to the secondary (lower frequency) meanings should not be facilitated in the presence of such contexts. Alternatively, under the exhaustive access model, both primary and secondary interp stations will be accessed for the ambiguities, regardless of the contextual bias, and thus at least momentary priming should occur for lexical decisions made to words related to both meanings. Note that when the sentential context provides a bias toward the secondary meaning of an ambiguity, both the terminating ordered search and the exhaustive access model predict that lexical decisions to words related to both primary and secondary interpretations of the ambiguity will be facilitated. Thus, the critical test between the hypotheses centers on the condition in which sentence context provides a bias toward the primary meaning of a polarized ambiguity. Experiment 1 provides a test of these hypotheses.

EXPERIMENT I

Method

Subjects. Forty undergraduates from Tufts University participated in this study, most in partial fulfillment of a course requirement. All subjects were native English speakers. Five subjects were randomly assigned to each of the eight experimental groups. A criterion of 13 of the 16 experimental trials correct was required for participation in the experiment. Three subjects failed this criterion and were replaced.

Design and Materials The set of unsystematic lexical ambiguities to be used in this study was derived from a pretest in which the relative dominance (frequency) of each meaning of each ambiguity was assessed. Twenty-five Tufts University undergraduates were presented a large typed list of lexical ambiguities and were instructed to describe the first meaning of each word that came to mind. From this List, 16 unsystematic lexical ambiguities were selected for inclusion in this study. Each included ambiguity contained both a very high-frequency primary interpretation and a very low-frequency secondary interpretation. The primary interpretation for each word was chosen by a minimum of 75% of the pretest population as their

first meaning for that word. The secondary meaning was never chosen by more than 25% of the pretest population. The mean relative frequency of the primary meanings for all of the words used in this study was 89%, and that for the secondary meanings was 11%. These relative frequency ratings correlated extremely highly with a similar set of ratings obtained on elicited associations to auditorily presented ambiguities.

For each experimental ambiguity, two different sentences were constructed. One sentence contained a biasing context that occurred prior to the ambiguity and constrained the interpretation of the ambiguity to its primary meaning. In the other sentence, the context constrained the meaning to the word's secondary meaning. The ambiguous word was used as the same part of speech (with one exception) and appeared in approximately the same serial position in both sentences (typically, it was the sentential object). The ambiguous word also never occurred at the end of a sentence; the sentence always continued for a minimum of 2 sec (based on a normal speaking rate) beyond occurrence of the ambiguity.

A set of four words was also constructed for each experimental ambiguity. These words were to be visually presented for lexical decisions during occurrence of the experimental sentences. One of these four words was highly related (it was usually a high associate) to the primary meaning of the ambiguity, and the other was highly related to the secondary meaning of the ambiguity. The degree of relatedness was not equated for these two words. The other two visual words were controls. One was matched in frequency (Kucera & Francis, 1967) and length (in letters) with the visual word related to the primary meaning of the ambiguity, and the other was equated on the same factors with the visual word related to the secondary sense of the ambiguity. Neither of these words was related in any direct manner to any word in the sentences. Mean frequency and number of letters for words related to the primary sense of the ambiguity were 83 and 5.68 (respectively), and the equivalent figures for their control words were 84 and 5.68 (respectively). Mean frequency and number of letters for words related to the secondary senses of the ambiguity were 25 and 4.87 (respectively), and for the controls, they were 26 and 4.81 (respectively).

Two sets of materials were constructed by assigning eight of the primary-meaning biased sentence versions to one set along with the secondary-meaning biased sentence versions from the other eight sentences. The second set comprised the remaining sentence versions. Thus, each set contained an equal number of sentences constrained toward the primary and secondary meanings, and only one occurrence of any particular ambiguity appeared in each set.

Forty filler sentences were added to the 16 experimental sentences in each set. Filler sentences were identical for the two sets. These were arranged pseudorandomly among the experimental sentences, with the restriction that the first six sentences be filler sentences and that no more than three experimental sentences ever occur in a row. The resultant two sets of 56 sentences were recorded at normal speaking rate on separate audiotapes by a practiced speaker.

For presentation purposes, four different lists of words (which were to be presented visually) were constructed. Each list contained one of the four visual words (either the primary- or secondary-meaning associate or one of their controls) for each experimental ambiguity. The lists were arranged so that they contained equal numbers of each of the four types of visual words. In addition to the 16 experimental visual words in each list, there were 40 other visual letter strings (these were identical in all lists). These additional letter strings were arranged to coincide with the filler sentences. Fourteen of these "filler" letter strings constituted words that were unrelated to the sentences with which they were matched. The remaining 26 letter strings constituted orthographically legal, pronounceable non-words. Note that visual words that were contextually appro-

priate and related to the experimental material occurred in only 4 of the 56 trials. This ratio is sufficiently low to preclude development of conscious control strategies for dealing with these materials, and thus it appears reasonable to assume that any obtained priming effects are automatic in nature (see, e.g., Tweedy, Lapinski, & Schvaneveldt, 1977).

Thus, there were eight presentation conditions two audiotapes (containing 56 sentences) and four visual word lists (each containing 30 words and 24 nonwords). A list of the experimental sentences and their accompanying visually presented words is given in Appendix A. A 1,000-Hz signal was placed on a separate channel of the tape exactly coincident with the offset of the ambiguous word in each experimental sentence (and with the offset of a pseudorandomly chosen word in the filler sentences). These signals, which were inaudible to the subjects, instructed a PDP-8/e computer to present the appropriate visual word and to initiate a timing mechanism that was terminated by the subject's buttonpress. Visual materials were presented on an oscilloscope in capital letters, for a period of 1 sec. Each letter in the display subtended approximately .8 deg of visual angle. (See Onifer, Hirshkowitz, & Swinney, 1978, for a discussion of the hardware and software involved in this procedure.)

Procedure Each subject was seated in a booth that contained an oscilloscope screen and headphones. Subjects were presented the 56 sentences binaurally over the headphones. They were instructed to listen carefully to, and to comprehend, each sentence. Subjects were told that they had a second, and equally important, task. It was explained that a string of letters would appear on the visual display screen at some point during the sentences. Subjects were to indicate, as quickly as possible, whether or not each letter string formed a word by pressing one of two buttons upon which they rested their hands throughout the experiment. Subjects were cautioned to continue listening to each sentence while making their lexical decisions. Four practice trials were then given (two with visual words and two with visual nonwords). On practice trials, the words were unrelated to the sentential material. Following this, the 56 trials described above were presented. Subjects' responses and reaction times were recorded (up to a maximum of 2 sec).

Results

Mean reaction times for each of the eight experimental conditions, calculated across materials and subjects, are presented in Table 1. It can be seen by inspection that lexical decision for words related to both readings of the ambiguity were facilitated (relative to lexical decisions for appropriate control words) in each of the sentential bias conditions. Thus, it appears that the results support the exhaustive access hypothesis,

rather than the terminating ordered search hypothesis. Further statistical analysis supports this argument.

The individual data were submitted to an analysis of variance employing both subjects and materials as random factors (min F' , Clark, 1973). The data in this analysis were normalized by use of a log transformation. Overall, the experimental/control main effect was significant [min $F'(1,24) = 5.244$, $p < .05$]. However, neither the main effect for meaning type (visual words related to the primary or secondary meaning of the ambiguity) nor that for sentential bias was significant [min $F'(1,16) = .1$] and min $F'(1,36) = .46$, respectively]. Importantly, none of the interactions was significant under subject, item, or min F' analyses. (The F values for the interaction of sentence bias and meaning type, employing first subjects and then items as random factors, were 3.05 and 2.94, respectively. The F values for the interaction of experimental/control variance with sentence bias, employing first subjects and then items as random factors, were 1.21 and .60, respectively. The F values for the interaction of experimental/control and meaning type, employing first subjects and then items as random factors, were .11 and .05, respectively.) Similarly, the interaction of experimental/control, meaning type, and sentence bias variables was not significant under either subjects [$F(1,32) = .26$] or items [$F(1,15) = .22$] analysis.

The fact that no interactions involving the experimental/control variable were significant indicates that reaction times to the associates of both the primary and secondary meanings of the ambiguity were faster than their relative controls and that this effect did not vary significantly in either absolute or relative order across the various experimental conditions. While this analysis supports the interpretation of the data already given, further and somewhat more specific examinations of the important comparisons were also made. In these, each of the experimental/control differences was examined under each of the sentential bias and meaning type conditions. When sentential context biased interpretation toward the secondary meaning of the polarized ambiguity, lexical decisions were significantly faster for experimental words (than for control words) related

Table 1
Experiment 1 Mean Reaction Times (in Milliseconds) for Lexical Decisions Made to Words Related to the Primary and Secondary Interpretations of an Ambiguity or to Control Words in Sentential Contexts Biased Toward Either the Primary or Secondary Meanings of the Ambiguity

| Visual Test | Probe Type | Sentential Bias | | | | | |
|-------------------|--------------|-----------------|-------------|-------------------|-------------------|-------------|-------------------|
| | | Primary Meaning | | | Secondary Meaning | | |
| | | Mean RT | N of Errors | Amount of Priming | Mean RT | N of Errors | Amount of Priming |
| Primary Meaning | Experimental | 706 | 2 | 47 | 740 | 4 | 31 |
| | Control | 753 | 6 | | 771 | 9 | |
| Secondary Meaning | Experimental | 734 | 6 | 99 | 718 | 3 | 58 |
| | Control | 833 | 10 | | 776 | 8 | |

to the primary (high-frequency) meaning of the word [$t(32)=2.15$, $p<.051$] as well as the the secondary (low-frequency) meanings of the word [$t(32) = 3.18$, $p < .01$]. More important, when sentential context biased interpretation toward the primary meaning of the polarized ambiguity, lexical decisions were also significantly faster for experimental words related to the primary [$t(32) = 3.87$, $p < .001$] and the secondary [$t(32) = 3.79$, $p < .001$] meanings of the ambiguity (compared with control words).¹

Discussion

The results provide fairly straightforward support for the exhaustive access hypothesis. That is, all meanings of in ambiguity appear to be accessed momentarily regardless of the relative frequency of use of those meanings or the bias provided by the semantic context in which those words occur. Most important, the results supporting this interpretation held in the critical case that distinguishes the hypotheses under investigation: that case in which the primary, high-frequency interpretation of the ambiguity was most compatible with the sentential context. Here, lexical decisions for words related to the secondary, less frequent interpretation of the ambiguity were facilitated, indicating that the secondary meaning had been accessed, at least momentarily in the presence of context biased toward the more frequent meaning. Thus, the data do not support the terminating ordered search model proposed by Hogaboam and Perfetti (1975).

Because exhaustive access will not yield a unique interpretation for an ambiguity (or nearly any word), it must be posited that the effects of biasing sentential contexts take place following access. Such a postaccess decision process has been argued elsewhere to be the locus of these context effects (see, e.g., Cairns & Hsu, 1980; Swinney, 1979). It is at this stage of processing that the relative a priori likelihoods (frequency of use) of the various meanings of words, as well as the biases provided by the various types of prior contextual information, are evaluated. The result of this process is viewed as the choice of a unique interpretation for the word, one that is the most likely (frequent) interpretation that is still consonant with the contextual information. Whatever the exact nature of such a stage, one assumes it must accept information from a number of sources and, most likely, must act extremely rapidly, often not waiting for contextual information before beginning its course of action. There is thus a prediction that, shortly following access, only a single contextually appropriate meaning will be available to the processing device and to conscious access.

Knowledge of the time course of activation of the various meanings of ambiguous words is thus quite important for establishing the nature of the posited postaccess decision process. In order to examine this process, a second experiment was performed. This study

examined the activation of the primary and secondary meanings of a new set of polarised ambiguities both immediately following occurrence of the ambiguity in a biasing sentential context (thus replicating Experiment 1) and also 1.5 sec following occurrence of the ambiguity in the sentence.

EXPERIMENT 2

Method

Subjects. Sixty-four undergraduates from Tufts University, all of whom were native English speakers, participated in this experiment in partial fulfillment of a course requirement. Ten of the original 64 subjects were dropped from the study due to their failure to score at preset criterion levels (90% or more correct in their lexical decisions and 70% or more in the sentence recognition test). Ten additional subjects replaced those dropped from the study.

Design and Materials. Forty-eight unsystematic lexical ambiguities were selected in a manner analogous to, but independent from, that used in the preceding study. The bias-differential criteria of the previous study (relative frequency-of-use bias of 75% and 25% for the primary and secondary meanings, respectively) was employed here.

Two differentially biasing sentences (one toward the primary and one toward the secondary meaning) were constructed for each ambiguity in the manner described in Experiment 1. Sentences were required to continue beyond the occurrence of the ambiguity for a minimum of 4 sec (based on a normal rate of speech). The 48 sentence pairs were divided into two sets, and each set contained an equal number of primary and secondary meaning sentences, such that each member of any one pair occurred in opposite sets. Sentences within the first set were randomly ordered, and this order was duplicated within the second set, so that members of the sentence pairs for each ambiguity had common positions in the two sets. In addition, 84 filler sentences were included in each list. These filler sentences were constructed to be generally comparable to the experimental sentences in terms of length and grammatical structure. These additional sentences were pseudorandomly intermixed with the experimental sentences, utilizing the restrictions described in Experiment 1. The two lists of sentences were recorded on audiotape by a practiced speaker. A copy was made of each of the two tapes. For each sentence, a signal was placed on an inaudible channel of the tape at the point at which the visual item was to be presented (test point). Test points were assigned such that for one half of the sentences in one copy of each list, test points coincided with the offset of the ambiguity in the sentence; the other half had test points delayed 1.5 sec following ambiguity offset. For the other copies, the assignments were reversed. Test-point assignments were further counterbalanced with respect to primary and secondary frequency of meaning across both sentence lists and tape copies.

For each ambiguity, a set of four words was constructed, following the procedure described in Experiment 1. Each four-word set included a word highly related to the primary meaning of the ambiguity and a matched control, as well as a word highly related to the secondary meaning and its control. In order to insure that experimental and control pairs were adequately matched in terms of base lexical decision reaction time, all words were tested in an isolated lexical decision task on a pretest population of 30 Tufts University undergraduates. Words were presented in random order intermixed with 407, nonwords. Related word/control word pairs for which the mean reaction time difference was less than 50 msec and which did not differ significantly on the basis of a *t* test were accepted for use in the study. For pairs not meeting this criterion, replacements were selected for the control words.

Four lists were constructed from these words in a manner analogous to that used in Experiment 1. These lists, in addition to the experimental and control materials, contained 57 orthographically legal, pronounceable nonwords and 27 filler words.

Procedure. The procedure was identical to that in Experiment 1, with the exception that subjects were required to perform a sentence recognition task to insure that they attended to the sentences. Prior to the start of the experiment, subjects were instructed to expect a recognition test for the sentences they would hear. Just beyond the midpoint of the experiment, and again at the conclusion of the session, subjects were asked to indicate whether or not they had heard each of 10 sentences. Of the 20 recognition sentences presented, one half were filler sentences that had been presented and the remaining half were new sentences that had not been presented to the subjects.

Results

Mean reaction times for the experimental and control words in each condition are presented in Table 2, along with the amount of facilitation (priming) for experimental words. For conditions in which the test point immediately followed the occurrence of the ambiguity, the pattern of facilitation observed in the first study was unequivocally replicated both primary and secondary meanings were facilitated independently of the contextual constraint provided by the sentences.

The pattern of facilitation observed 1.5 sec following the ambiguity, however, showed striking differences from that observed at the immediate test point. As can be seen in Table 2, only the contextually relevant meanings showed facilitation effects at this test point. Statistical analysis of the results supports the validity of these observations.

An initial min F' analysis treating subjects and material as random factors was applied to the data. Significant effects were observed only for the factors of experimental vs. control words [$\text{min } F'(1,33) = 7.21, p < .05$] and the triple interaction of Experimental vs. Control Words by Sentence bias (primary vs. secondary meaning) by Probe Relation (primary vs. secondary meaning) [$\text{min } F'(1,48) = 8.64, p < .01$]. No other main factors or interactions reached accepted levels of significance under this analysis.

The critical comparisons for this second study are given by the experimental/control mean contrasts for the eight presentation conditions. These a priori comparisons were evaluated using a t statistic based on the

mean square error estimated from the subjects component of the min F' analysis. Specifically, for conditions with sentence bias toward primary meaning, significant facilitation was observed for words related to the primary meaning immediately following the ambiguity [$t(48) = 2.51, p < .01$] and 1.5 sec later in the sentence [$t(48) = 2.13, p < .05$]. For the same sentence-bias condition, priming was observed for words related to the secondary meaning in the immediate test [$t(48) = 2.54, p < .01$] but not in the 1.5-sec delay condition [$t(48) = 2.0, p < .20$]. For conditions with sentence bias toward the secondary meaning, facilitation was observed at both the immediate test point [$t(48) = 5.32, p < .01$] and 1.5 sec later in the sentence [$t(48) = 3.85, p < .01$] for words related to the secondary meaning. Finally, for the same sentence-bias condition, significant facilitation was observed at the immediate test point [$t(48) = 1.89, p < .05$], but not at the 1.5-sec delay test point ($t(48) = .081$ for words related to the primary meaning.

Error data for the experimental and control lexical decisions are presented in Table 2. Individual chi-square tests were applied to these value pairs. No significant differences were observed.

GENERAL DISCUSSION

In all, the results of these experiments provide strong support for the exhaustive access model of lexical processing. It is not simply that these experiments provide additional support for an already strongly established model. Earlier work has been compromised by problems raised in the Hogaboam and Perfetti (1975) arguments, as well as by a number of other factors that were mentioned at the start of this paper. The present data, then, seem critical to support of the exhaustive access position; to accept this theory and rule out the serial self-terminating access model, it was necessary to establish evidence that a low-frequency meaning for an ambiguity is accessed, even in the presence of biasing context that is compatible with the high-frequency meaning for that ambiguity. As argued previously, it appears likely that the Hogaboam and Perfetti results are a function of the use of a technique

Table 2
Experiment 2 Lexical Decision Latency Means and Priming Scores (in Milliseconds)

| Visual Test | Probe Type | Sentential Bias | | | | | | | | | | | |
|-------------|--------------|----------------------|----|------|------------------------|----|------|----------------------|----|------|------------------------|----|------|
| | | Primary Meaning | | | | | | Secondary Meaning | | | | | |
| | | Presentation Point 0 | | | Presentation Point 1.5 | | | Presentation Point 0 | | | Presentation Point 1.5 | | |
| RT | E | P | RT | E | P | RT | E | P | RT | E | P | | |
| Primary | Experimental | 693.5 | 7 | 33.9 | 685.7 | 14 | 28.8 | 705.3 | 12 | 25.4 | 723.0 | 10 | -1.1 |
| | Control | 727.4 | 8 | | 714.5 | 7 | | 730.7 | 7 | | 721.8 | 6 | |
| Secondary | Experimental | 726.1 | 11 | 34.3 | 746.3 | 18 | -2.7 | 713.8 | 5 | 71.7 | 695.4 | 7 | 51.9 |
| | Control | 760.4 | 12 | | 743.6 | 16 | | 785.5 | 14 | | 747.3 | 13 | |

Note -- RT = mean lexical decision latency; E = number of errors in each cell; P = priming score.

that does not directly reflect the immediate access of words. Rather, their technique appears to reflect processes involving a more conscious manipulation of words that occurs following lexical access. (See Yates, 1978, for a similar argument based on data obtained in a nonsentential processing situation.) The present data also suggest that we should reject a similar self-terminating ordered search model of lexical access, which was proposed by Forster (1976). Forster's model was built on data derived from isolated lexical decision experiments, and, while it may hold for the recognition of isolated words, the current data do not support thus as a model of lexical access in sentence comprehension situations. (It may be, however, that in an isolated test, the most frequent meanings precede the less frequent meanings in being brought to consciousness.) Finally, the present experiments also provide confirmation of the somewhat more indirect support given to the exhaustive access model by Cairns and Hsu (1980), Holmes et al. (1977), Lackner and Garrett (1972), Swinney (1979), and Tanenhaus et al. (1979).² Further, the results of the examination of the time course of lexical meaning activation provide verification of a number of additional facts that have been posited concerning the lexical processing system.

In summary, lexical access appears to be an exhaustive and autonomous subroutine of the sentence comprehension process (autonomous in the sense that it does not appear to be driven or guided by previously occurring semantic information). It also appears that lexical access is an automatic process (in the sense of Posner & Snyder, 1975) that is driven solely by the acoustic/phonetic form of the word. The present experiment clearly does not allow us to determine the exact stimulus properties that will be sufficient to provide such access, but, once this stimulus criterion is met, all information that is directly related to a word appears to be made available to the comprehension device. At present, there appears to be little critical evidence that could help determine whether such access occurs in serial or in parallel during sentence comprehension. However, there is a great deal of evidence concerning frequency effects on unambiguous words tested in isolation (see, e.g., Forster, 1976) that suggests serial processing may be the rule.

Further, the second experiment demonstrates that a postaccess process operates to evaluate accessed entries in terms of frequency of meaning and contextual information. This results in a single unambiguous interpretation for the word, an interpretation that can be integrated into the ongoing structural/semantic interpretation of an utterance (see Swinney, in press, for a more detailed description of some properties of this and related sentential processes). The time course of this process is clearly complete at least by 1.5 sec following occurrence of the word. It is likely, however, that this figure considerably underestimates the time course of the decision. In fact, results of a recent study by Simpson

(1981) suggest that the process may be over by 150 msec following the ambiguity. In this work Simpson used priming in a situation similar to that used in this and the Tanenhaus et al. (1979) papers, but Simpson presented the visual word 150 msec after the ambiguity (at the end of a sentence). Simpson found no priming for the secondary meaning of ambiguities when the context biased the ambiguity toward its primary meaning. He suggested that this result supports a serial terminating access model but, as argued previously, the 150-msec delay in test point most likely resulted in the tasks' measuring output of the postaccess decision process, not immediate access. Thus, Simpson's results are quite in accord with the exhaustive access hypothesis. In addition, the fact that priming was found only for the contextually relevant interpretation of the word in the delayed test position by both the present study and that of Simpson suggests that the effects of context rapidly overwhelm any bias provided by relative frequency of meaning. In fact, given exhaustive access, frequency apparently has an effect only in the total absence of disambiguating cues.

Finally, although the current investigation, as well as a growing body of related work (for a review, see Swinney, in press; Tanenhaus et al., 1979), demonstrates the exhaustive nature of the lexical access routine, little else is known about the microstructure of the routines themselves. An optimistic outlook foresees a continuation of the current trend toward the development of increasingly sensitive methodologies for investigating ongoing language comprehension, so that questions about this microstructure will become accessible to experimental attack.

REFERENCE NOTES

1. Cutler, A., & Foss, D. J. *Comprehension of ambiguous sentences. The locus of context effects*. Paper presented at the meeting of the Midwestern Psychological Association, Chicago, May 1974.
2. Hogaboam, T. *Lexical ambiguity and sentence processing*. Paper presented at the meeting of the Midwestern Psychological Association, Chicago, 1977.
3. Hogaboam, T. *Comprehension times for ambiguous words in natural language contexts*. Paper presented at the annual meeting of the Psychonomic Society, San Antonio, Tex., November 1978.

REFERENCES

- CAIRNS, H. S., & HSU, J. R. Effects of prior context upon lexical access during sentence comprehension: A replication and reinterpretation. *Journal of Psycholinguistic Research*, 1980, 9, 1-8.
- CAIRNS, H. S., & KAMLRMAN, J. Lexical information processing during sentence comprehension. *Journal of Verbal Learning and Verbal Behavior*, 1973, 14, 170-179.
- CHOOOROW, M. Time compressed speech and the study of lexical and syntactic processing. In W. Cooper & E. C. T. Walker (Eds.), *Sentence processing: Psycholinguistic studies presented to Merrill Garrett*, Hillsdale, N.J.: Erlbaum, 1979.
- CLARK, H. H. The language-as-fixed-effect fallacy: A critique of language statistics in psychological research. *Journal of Verbal Learning and Verbal Behavior*, 1973, 12, 335-359.

- CONRAD, C. Context effects in sentence comprehension: A study of the subjective lexicon. *Memory & Cognition*, 1974, 2, 130-138.
- CUTLER, A., & NORRIS, D. Monitoring sentence comprehension. In W. E. Cooper & E. C. T. Walker (Eds.), *Sentence processing: Psycholinguistic studies presented to Merrill Garrett*. Hillsdale, N.J.: Erlbaum, 1979.
- FORSTER, K. I. Accessing the mental lexicon. In R. J. Wales & E. Walker (Eds.), *New Approaches to language mechanisms*. Amsterdam: North Holland, 1976.
- FORSTER, K. Levels of processing and the structure of the language processor. In W. Cooper & E. Walker (Eds.), *Sentence Processing Psycholinguistics studies presented to Merrill Garrett*. Hillsdale, N.J.: Erlbaum, 1979.
- FOSS, D. J. Some effects of ambiguity upon sentence comprehension. *Journal of Verbal Learning and Verbal Behavior*, 1970, 9, 699-706.
- FOSS, D. J., & JENKINS, C. Some effects of context on the comprehension of ambiguous sentences. *Journal of Verbal Learning and Verbal Behavior*, 1973, 12, 577-389.
- FOSS, D. J., & SWINNEY, D. On the psychological reality of the phoneme: Perception, identification and consciousness. *Journal of Verbal Learning and Verbal Behavior*, 1973, 12, 246-257.
- GARRETT, M. Does ambiguity complicate the perception of sentences? In G. B. D'Arcais & W. J. Levelt (Eds.), *Advances in psycholinguistics*. Amsterdam: North Holland, 1970.
- HOGAROM, T., & PERFETTI, C. Lexical ambiguity and sentence comprehension. *Journal of Verbal Learning and Verbal Behavior*, 1975, 14, 265-274.
- HOLLEY-WILCOX, P., & BLANK, M. Evidence for multiple access in the processing of isolated words. *Journal of Experimental Psychology: Human Perception and Performance*, 1980, 6, 75-94.
- HOLMES, V. M., Accessing ambiguous words during sentence comprehension. *Quarterly Journal of Experimental Psychology*, 1979, 44, 13-35.
- HOLMES, V. M., ARWAS, R., & GARRETT, M. F. Prior context and the perception of lexically ambiguous sentences. *Memory & Cognition*, 1977, 5, 103-110.
- KIRK, R. E. *Experimental design*. Monterey, Calif: Brooks/Cole, 1968.
- KUCERA, H., & FRANCIS, W. *Computational Analysis of present-day American English*, Providence, R. I: Brown University Press, 1967.
- LACKNER, J. R., & GARRETT, M. F. Resolving ambiguity: Effects of biasing context in the unattended car. *Cognition*, 1972, 1, 359-372.
- MEHLER, J., SEGUI, J., & CAREY, P. Tails of words: Monitoring ambiguity. *Journal of Verbal Learning and Verbal Behavior*, 1978, 17, 29-35.
- NEWMAN, J. E., & DELL, G. S. The phonological nature of phoneme monitoring: A critique of acme ambiguity studies. *Journal of Verbal Learning and Verbal Behavior*, 1978, 17, 359-374.
- ONIFER, W., HIRSHKOWITZ, M., & SWINNEY, D. A miniprocessor PDP8/e-based system for investigations of on-line language processing: Automated program for psycholinguistic experiments (APPLE). *Behavior Research Methods & Instrumentation*, 1978, 10, 307-308.
- POSNER, M. I., & SNYDER, C. R. Attention and cognitive control. In R. Solso (Ed.), *Information processing and cognition*. Hillsdale, N.J: Erlbaum, 1975.
- SHIFFRIN, R. M., & SCHNEIDER, W. Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review*, 1979, 84, 127-190.
- SIMPSON, G. Meaning dominance and semantic context in the processing of lexical ambiguity. *Journal of Verbal Learning and Verbal Behavior*, 1981, 20, 120-136.
- SWINNEY, D. Lexical access during sentence comprehension: (Re)consideration of context effects. *Journal of Verbal Learning and Verbal Behavior*, 1979, 18, 645-660.
- SWINNEY, D. Lexical processing during sentence comprehension: Effects of higher order constraints and implications for representation. In T. Myers, J. Laver, & J. Anderson (Eds.), *The cognitive representation of speech*. Amsterdam: North Holland, in press.
- SWINNEY, D., ONIFER, W., PRATHER, P., & HIRSHKOWITZ, M. Semantic facilitation across sensory modalities in the processing of individual words and sentences. *Memory & Cognition*, 1979, 7, 159-165.
- TANENHAUS, M. K., LEIMAN, J. M., & SEIDENBERG, M. S. Evidence for multiple stages in the processing of ambiguous words on syntactic contexts. *Journal of Verbal Learning and Verbal Behavior*, 1979, 18, 427-440.
- TWEEDY, J., LAPINSKI, R. H., & SCHVANEVEKDT, R. W. Semantic context effects on word recognition: Influence of varying proportion of items presented in an appropriate context. *Memory & Cognition*, 1977, 5, 84-89.
- YATES, J. Priming dominant and unusual senses of ambiguous words. *Memory & Cognition*, 1978, 6, 636-643.

NOTES

1. These comparisons were also made under a more conservative analysis, the Bonferroni t (Kirk, 1968). The critical value of "d" for $\alpha = .01$ was .083. As can be seen by inspection, all comparisons were also significant under this analysis (particularly the critical case involving activation of the secondary meaning in the primary-bias condition), with the exception of the condition involving facilitation of the primary meaning in a secondary-meaning bias condition (which was marginally significant at $p < .1$). There were also no significant differences (chi-square analysis applied to relevant pairs) in the number of errors made in different experimental cells (see Table 1).

2. Cairns and Hsu (1980) specifically examined the effects of contexts that were biased toward the more and less probable meanings of ambiguities on a phoneme monitoring task. They reported increased phoneme monitoring times for ambiguities (compared with controls) in both conditions. Thus they, also, argued against Hogaboam and Perfetti's (1975) ordered search model and for a multiple-access model. However, there is some uncertainty in interpreting the Cairns and Hsu results, due to a possible confounding of the phonetic properties of the materials that preceded their monitoring targets. This confounding in the phoneme monitoring studies has been discussed by Newman and Dell (1978). The present experiment not only supports the Cairns and Hsu interpretation of lexical access but also specifically demonstrates the activation of each meaning of an ambiguity, regardless of its frequency of occurrence or its contextual bias.

APPENDIX A

EXPERIMENTAL MATERIALS FOR EXPERIMENT 1

Listed below are the sentences biased toward primary (P) and secondary (S) meanings of the ambiguity, along with the visual words associated with primary and secondary meanings and their controls.

1. (P) The postal clerk put the package on a postal *scale* to see if it had enough postage. (S) The dinner guests really enjoyed the specially prepared rivet *bass*, although one guest did get a *scale* caught in his throat.

WEIGHT SOURCE FISH COAL

2. (P) The housewife's face literally lit up as the plumber extracted her lost wedding *ring* from the sink trap. (S) The office walls were so thin that they could hear the *ring* of their neighbor's phone whenever a call came in.

FINGER TALENT BELL WHIP

3. (P) The team came out of the locker-room with fire in their eyes after the *coach* delivered what was perhaps the best speech of his life. (S) A perfectly matched pair of black stallions pulled the Queen's *coach* up to the base of the marble stairway.

FOOTBALL OUTLOOK CARRIAGE COMPOUND

4. (P) Each of the pre-fabricated apartment units was hoisted into position by a *crane*, itself over two stories tall. (S) The listeners brought their binoculars on their trip into the everglades, and saw a small flock of herons and a *crane* which rarely came to that area of the country.

CONSTRUCTION CONSIDERABLE BIRD HORN

5. (P) In the 4th round the challenger for the middleweight boxing title went down for a *count* of 9, but was saved by the end of the round. (S) The man's great-grandfather had held the title of *count* in late 18th century Germany.

TALLY FAIRY DUKE RAKE

6. (P) For several weeks following the exterminator's visit they did not find a single *bug* anywhere in the apartment. (S) For several months following the discovery that they were being watched by the C.I.A. they kept checking the phone for a *bug* or phone tap.

INSECT CUSTOM SPY TAN

7. (P) Summer became far more enjoyable after the family had a large outdoor *pool* installed in their backyard. (S) After dinner, often both father and son would adjourn to the game room to shoot *pool* and smoke cigars.

WATER THINK BILLIARDS TADPOLES

8. (P) John sat down to make out checks for the monthly bills, but could not find a single working *pen* anywhere in the house. (S) All of the animals escaped when the gate to the *pen* had been left slightly ajar.

INK ROT PIG PAD

9. (P) For the office waiting room she bought a small green *plant* that was supposed to do well in low light. (S) The Ford Motor Company has an assembly *plant* just outside of metropolitan Boston.

FLOWER PLASTER FACTORY VIOLENT

10. (P) The burglar threw his full weight against the door, but the *lock* simply would not yield. (S) To enable cargo ships to ascend the 20 foot differential between the two lakes a single mammoth *lock* has been built on the west side of the dam.

KEY OIL CANAL PEACH

11. (P) When he paid the dinner check he would always pick up a toothpick and an after dinner *mint* for later in the evening. (S) The thieves were planning to rip off a shipment of silver being taken to the Denver *mint* to be made into new currency.

CANDY ALARM COIN SCAR

12. (P) At the arctic observation station it became so *cold* that the kerosene for the stove froze solid. (S) He had been kept home in bed for the past two days by a persistent *cold* he just couldn't seem to shake.

HOT AID FLU ROT

13. (P) The old man was regarded by the townspeople as a *sage* and was therefore consulted on all matters of major importance. (S) The unusual taste in her thanksgiving stuffing came from the addition of a touch of *sage* and a sprinkling of taragon.

WISE HOST SPICE DIARY

14. (P) The church choir was accompanied by a one hundred and fifty year old *organ* which stood impressively in the real balcony of the church. (S) The bullet must have hit a vital *organ* because by the time they reached him, he was already dead.

PIANO MAYOR KIDNEY OYSTER

15. (P) The businessman took the checks and receipts to the first national city *bank* on his way to the board meeting. (S) The rudderless boat reached the edge of the water and ran onto the gently sloped *bank* without as much as scratching the paint on the hull.

MONEY FIELD RIVER BASIC

16. (P) They drove out to a private airport to catch a *plane* which connected with the regular commercial carriers (S) In order to fix the sticking door, the cabinetmaker reached into his toolbox and pulled out a hand *plane* to trim down the bottom edge

PROPELLER MONASTERY WOOD TALL

APPENDIX B

EXPERIMENTAL MATERIALS FOR EXPERIMENT 2

Listed below are the sentences biased toward primary (P) and secondary (S) meanings of the ambiguity, along with the visual words associated with primary and secondary meanings and their controls.

1. (P) Her favorite flavor of lifesavers is *mint* because they have red and white stripes and a fresh tingling taste (S) Once the armored truck was filled with the new currency, it left the *mint* and headed for the Federal Reserve in Washington where it had to make its delivery.

SPICE GRAVY COINS JEEP

2. (P) Their pet has very fluffy *grey fur* all over him except on his two front paws and his tail which are white with spots of black and brown. (S) All year long the green needles stay on the branches of the *fir* because it is an evergreen, which never loses all its leaves, even in the winter.

COAT ROOF PINE BRANDY

3. (P) The worker had a large tattoo across his *chest* and several smaller tattoos on his back and down both arms (S) Her wedding dress had been kept in an old *chest* which had been up in the attic for the last forty years.

BODY HALF STORAGE REMOVAL

4. (P) The doctor put the man's broken leg in a *cast* and explained that he would have to wear it for at least five weeks before it could come off. (S) The movie was good because its *cast* included great people like Elizabeth Taylor, Marlon Brando, and John Wayne.

PLASTER PROTEST ACTORS SPREAD

5. (P) The ultraviolet rays that come from the *sun* can burn your skin so you must be careful outside during the summer. (S) The father had many children but his *son* was his favorite because he reminded him of himself when he was a child

LIGHT POWER DAUGHTER BITTER

6. (P) After the bee pollinates the *flower* it flies back to its hive and uses the nectar it has collected to make honey. (S) The pastry chef uses extra fine sugar, and *flour* to make homemade pastries for restaurants and pastry chefs all over the city.

PETALS SKIRTS BAKING SQUIRT

7. (P) When Peter joined the military he had no idea that in 6 months he would be driving a *tank* as part of the European defense forces and would actually be enjoying his job. (S) It took half the morning to fill the farmers huge irrigation *tank* which would be used in the wheat fields which had been suffering from drought since early in the summer.

WAR SET CONTAINER BATHROOMS

8. (P) When he looked at cars he carefully studied their fuel efficiency so he could *choose* a car which would take him where he wanted to go for the least gas. (S) The little girl loves bubble gum so much that the *chews* it all the time, even at school were she knows she is not supposed to.

SELECT TEXT TEETH HAPPY

9. (P) The little boy tied his wagon to his bicycle with a *cord* so that he could pretend to be a conductor with his wagon following him wherever he went. (S) He would often pick up his guitar and play a *chord* or two just to hear how it would sound in the new song that he was writing.

ROPE FORK MUSIC FRONT

10. (P) The wind that blew down from the north pole was so *cold* that you had to be covered in warm clothing to avoid frost-bite. (S) To get rid of the fever and pain that go along with a

cold, doctors often prescribe aspirin, rest, and plenty to drink.

CHILL DEEP SICK REAR

11. (P) The church choir was accompanied by a one hundred year old *organ* which stood impressively in the rear balcony of the main chapel. (S) The heart is a vital *organ* which pumps about six quarts of blood at a rate of approximately 80 beats per second.

PIANO TRACK KIDNEY BUCKLE

12. (P) The door was closed with a strong *lock* to prevent burglars from breaking into the house and stealing everything inside. (S) As the barge passed through the *lock* the bridge was raised and all the people on shore smiled and cheered.

KEY ARM CANAL GRATE

13. (P) We used insecticide to kill the *bug* we found crawling on the floor because they scare me and I don't like having them in the house. (S) In order to find out what was going on in the secret talks the F.B.I. put a *bug* under the coffee table and monitored the conversation.

SPIDER STORY SPY TAN

14. (P) The photographer developed the *film* that he had used to take pictures at his friend's wedding reception the week before. (S) The oil formed a thin *film* on top of the water which hurt the wildlife living in the lake.

CAMERA SHADOW LAYER HARSH

15. (P) The leaves and stem of the *plant* had turned brown because no one had watered it over the two weeks they were on vacation. (S) The workers who made shoes at the Boston *plant* refused to work because they didn't feel they were being paid enough for their hard work.

SHRUB SNAIL FACTORY SMOKE

16. (P) He struck the unlit *match* against a rock and started a cheery blaze so that they could keep warm until morning. (S) There are three teams competing in the *match* and the team with the most points will go on to the national championships in New York.

FIRE DIRT CONTEST CLIMATE

17. (P) Hamburger is chopped up *steak* which is formed into patties, broiled, and eaten on a hamburger bun with ketchup or mustard. (S) The camper used a hammer to drive the metal *stake* into the ground so that the tent would stay up even in the wind and rain of the thunderstorm.

MEAT WAVE PEG HEM

18. (P) It was the judge's first time in *court* and he was extremely nervous about making the important choices that from now on would decide people's futures. (S) The new owners of the hotel decided to improve its outdoor recreational facilities and drew up plans to resurface the existing outdoor *court* which had fallen into disrepair under the previous management.

LEGAL SHARP TENNIS RUBBER

19. (P) The telescope was fixed on a distant *star* which is in a galaxy being investigated by scientists for possible forms of life. (S) John Wayne was a movie *star* known for his cowboy portrayals in which he always ends up being the "good guy."

PLANET MELODY CELEBRITY PARTNER

20. (P) Jack's new three piece suit needed a plain *tie* so as not to clash with the many colored plaid design which was now the utmost in men's fashion. (S) Even though the playoffs ended in a *tie* it seemed that the Canadians had played much better than the Boston team.

NECK TRIP EQUAL ABOVE

21. (P) Before he started his diet he had been afraid to get on a *scale* but now he was pleased to see that dieting had been worth it and he was thinner. (S) The bass's *scales* of blue and gold shimmered as it passed through the water below us.

WEIGH WEAVE FISH TAPE

22. (P) Instead of painting the room we put up a big oak *panel* which not only covered the room but gave it a nice warm feeling. (S) Our questions were answered by a *panel* made up of experts in the area of energy research from all over the country.

WALL FACT GROUP YOUNG

23. (P) The blossom of the magnolia gives a sweet *scent* from the beautiful pink blossoms it gets between May and early June. (S) From her purse, the little girl took a nickle and a *cent* and handed them to the man at the drugstore to pay for the red licorice she was buying.

SMELL DRILL PENNY MOUTH

24. (P) Because we were so hot we put a *fan* at one end of the room to lower the stifling temperature in the room (S) As the performer was leaving his dressing room an admiring *fan* came up to him to say hello, get his autograph, and ask a few simple questions.

COOL TEA FOLLOWER ESTIMATE

25. (P) The housewife was overjoyed when the plumber extracted her lost wedding *ring* from the trap of the kitchen sink where it must have been lodged for over a year. (2) Luckily the alarm had a loud *ring* which woke up the family so that the) could escape before the house was destroyed by flames

FINGER TALENT BELL SCORE

26. (P) lie wrote the memo using a gold *pen* and white stationary that he had received as a present from his employer the year before. The farmhand left the gate to the *pen* open which allowed all the animals to get loose and run all over the farm.

INK TALL PIG PET

27. (P) The passengers at the airport all got onto the *plane* and took off to a vacation of fun and relaxation in Europe (S) The carpenter smoothed the surface using a *plane* so that the door could be opened and closed without catching on the rug

JET HAT TOOL FOOL

28. (P) There was so much chlorine in the *pool* that the water made your skin itch and made you sneeze (S) The player chalked-up his cue stick and ended the *pool* game by sinking a very tricky shot into the corner pocket.

SWIM TONI BILLIARDS THIMBLI

29. (P) In order to put the floor of the new building in place it was necessary to use a *crane* to lift the heavy beams which could not be lifted without machinery. (S) Its beautiful feathers and huge wing span make the *crane* an unusual and beautiful sight which everyone should get to see.

CONSTRUCTION PROFESSIONAL BIRD OLDER

30. (P) Because his team had not been able to advance, the *coach* called a tone-out so that he could advise the team on the next strategy. (S) In last week's parade the Queen rode in a golden *coach* driven by a man in traditional costume.

FOOTBALL SLEEPING CARRIAGE THIMBLE

31. (P) All the cash that was kept in the safe at the *bank* was stolen last week when two masked men broke in. (S) A large piece of driftwood that had been washed up onto the *bank* by the last storm stood as a reminder of how high the water had actually risen.

MONEY STUDY RIVER TWELVE

32. (P) This morning for breakfast I had two pieces of *toast*, scrambled eggs, a big glass of juice, and a black cup of coffee. (S) The father of the bride stood to offer a *toast* to the newly married couple, wishing them luck and success in their life together.

BREAD HAZARD GLASSES SKILLED

33. (P) The company president decided who would get raises this year, but it was the vice-president who had the *duty* of telling the employees who would get raises and who wouldn't. (S) The customs officer said that we must pay a *duty* on everything we brought into the country that was worth more than one hundred dollars.

TASK FADE IMPORT SKETCH

34. (P) Warm weather and salt water make the *beach* a really fun place to go with your friends to cool off on a hot, sunny day in July. (S) Whenever he wanted to be alone to think he would sit under the branches of a large *beech* which provided a quiet cool retreat from the pressures of the outside world

SAND SELF TREE CELL

35. (P) Whenever we have a family reunion, with all the relatives present, my *aunt* Jane takes charge of doing the cooking, which insures that the meal will be very good. (S) At the picnic one of the children found an *ant* in his peanut butter and jelly sandwich and refused to eat anything else until he came home.

UNCLE WIDE INSECT PRETTY

36. (P) The grade school teacher put the children's pictures up on the bulletin board with thumb *tacks* so that their parents could see examples of the children's work when they came to the school. (S) The congress has imposed a new gas *tax* which will make the cost of gasoline climb by at least ten percent.

NAILS EAST INCOME PRETTY

37. (P) The kite rose in the *air* steadily but the string suddenly broke and it looked as if the brand new kite might be lost forever. (S) The young playboy was the sole *heir* to his father's fortune which was estimated to be worth at least five million dollars.

BREATHE ORANGE INHERIT AUCTION

38. (P) An acorn is a kind of *nut* which squirrels collect so that they will have something to eat during the long winter. (S) The auto mechanic used a wrench to tighten the *nut* up securely so it could not vibrate loose and possibly become a safety hazard.

FOOD FALL BOLT BITE

39. (P) To accommodate the guests who were coming to dinner she put an extra leaf in the dining room *table* and got out the good china and silverware that was only used on special occasions. (S) In order to help consumers buy gasoline efficient automobiles the department of transportation published a *table* which gives the miles per gallon of every major type of automobile available in America.

CHAIR MAID LIST STEP

40. (P) In England the Queen is the head of *state* even though it is the prime minister who is responsible for running the government. (S) Even though the outside of the car appeared new, the motor was actually in a very bad *state* and the mechanic said it would need a complete overhaul to work again.

COUNTRY COMPANY CONDITION STRUCTURE

41. (P) The young man stopped by the barber shop to get his *hair* cut before he went to meet his fiance's parents for the first time. (S) The father returned from an afternoon of hunting small game with a pheasant and a fat *hare* both of which he had hit on his first shot at each.

HEAD WIRE RABBIT TRUCK

42. (P) We couldn't wait to get out on the lake so we immediately started hoisting the *sail* but found that somehow the material had been torn into two separate pieces. (S) The clothes had been reduced for a special end of the season *sale* which was held annually during the last two weeks of September

BOAT WINE PRICE DAIRY

43. (P) When she finished folding the blankets and started to fold the *sheets* she noticed that the stains on them supply had not come out in the wash. (S) When you apply for a job you have to fill out many forms and *sheets* so that the employer will know where you've worked before and will be able to decide if you're right for the job.

BED LOT PAPER CHAMP

44. (P) We opened the old jar of jelly expecting it to be spoiled and after finding *mold* covering the contents we decided to look for something more appetizing in the refrigerator. (S) She formed the clay using a *mold* because she wanted the bowl she was making to be perfectly round.

DECAY UPSET SHAPE TRAIN

45. (P) After he got arrested his wife came to *bail* him out and take him home, just as she does every time he gets arrested. (S) The canoe was filling up with water so he started to *bail* very quickly because he was afraid he would sink.

JAIL NEAT BUCKET CRADLE

46. (P) Everything she cooks is delicious but her *carrot* cake is the best because she serves it warm with whipped cream. (S) The size of the stone in her bracelet is one *carat* and it sparkles in its beautiful setting of golden cues.

VEGETABLE PAVEMENT DIAMOND PATIENT

47. (P) You have to separate the egg *yolk* from the egg white when you make meringue for the top of a dessert such as a lemon meringue pie. (S) The oxen were each held in a *yoke* which allowed the earliest farmers to till the barren land and make it fertile enough for growing crops.

YELLOW METHOD HARNESS LUGGAGE

48. (P) After you sat an avocado, you can place the *pit* in some loose soil and soon have your own fast growing avocado. (S) The prisoner had been thrown down into a *pit* where he survived on berries and water for 3 months until he was finally rescued.

SEED HALL HOLE SAFE

(Received for publication September 15, 1980.
revision accepted October 20, 1980.)