

# 4 Monitoring Sentence Comprehension

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## INTRODUCTION

Psycholinguists have no way of directly observing the sentence-comprehension process. Therefore, they have on the one hand assessed the complexity of sentence processing by means of global measures of comprehension difficulty (paraphrasing, for instance, click location, sentence classification, or other tasks). On the other hand, they have devoted considerable ingenuity to inventing tasks that might be expected to reflect the operations of processing mechanisms during comprehension. The dependent variable in these latter tasks is reaction time (RT); as Pachella (1974) noted: "by default: there simply isn't much else that can be measured [p. 43]." If variations in response latency correlate with experimental manipulations of the sentences being understood, they are assumed to reflect variations in the complexity of processing.

Nearly all on-line studies of auditory comprehension have required subjects to monitor the sentence for a specified target. The targets are of three basic types: part of the sentence itself (a word or a sound), something *wrong* with the sentence (a mispronunciation), or an extraneous signal (e.g., a click) occurring during presentation of the sentence. By far the largest number of studies have involved monitoring for initial sounds of words. In this chapter we will discuss phoneme-monitoring in some detail, review word-monitoring, mispronunciation-monitoring, and tone/click-monitoring results, and conclude with a comparison and evaluation of the monitoring tasks.

## MONITORING FOR PHONEMES

In a phoneme-monitoring experiment,<sup>1</sup> subjects listen for the occurrence of a word beginning with a specified sound in the sentence they are processing. Asked to listen for /b/ as in *boy* in the sentence "The punch barely affected the old man," for instance, they would be expected to press the response button as soon as they had become aware of the initial sound of the word *barely*. Comprehension is usually tested indirectly, by a short recognition test given at the end of the experiment. The technique was developed by Donald Foss.

### Early Phoneme-Monitoring Work

Foss reported that RT was longer after the occurrence of a low-frequency as opposed to a high-frequency word (Foss, 1969), in structurally complex as opposed to structurally simple sentences (Foss & Lynch, 1969), and after a lexically ambiguous as opposed to an unambiguous word (Foss, 1970). Reaction time did not seem to be affected, however, by verb complexity, i.e. whether a verb can take sentence as well as noun phrase objects (Hakes, 1971).

Foss (1969) explained his results in terms of a limited-capacity central-processing mechanism, on which demands are made by all tasks a listener is concurrently performing. Thus, if comprehension is difficult, so that a relatively large amount of the finite processing capacity is taken up by some aspect or other of the comprehension process, such as syntactic analysis or lexical lookup, less capacity will be available for the performance of the phoneme-detection task; hence, this task will be performed relatively slowly. If comprehension is easy, more of the finite processing capacity is available for the detection task, which can then be performed relatively fast.

In the structural complexity experiment, for instance, Foss and Lynch (1969) assumed that the amount of processing necessary to assign the correct structural description to a sentence of relatively simple structure is less than that necessary to process a sentence of complex structure. They found that RT to the /b/ in the word *broke* was longer in the self-embedded sentence "The rioter who the whisky that the store sold intoxicated broke the window" than in the right-branching sentence "The store sold the whisky that intoxicated the rioter who broke the window." This result was confirmed for

<sup>1</sup>Strictly speaking, the term *phoneme-monitoring* may be a misnomer, because there is no indisputable evidence that subjects need to have identified the target at a level as abstract as the phonemic level in order to initiate a response. However, it is difficult to devise another name appropriate for a task in which subjects given the target specification /b/ as in *boy* can correctly detect the target in words as phonetically diverse as *big*, *badger*, or *blend*.

relative clauses by Hakes, Evans, and Brannon (1976). Other research (Hakes, 1972; Hakes & Cairns, 1970; Hakes & Foss, 1970) showed that if self-embedded or complement sentences contained relative pronouns (as in the example above), RT was faster than if they did not ("The rioter the whisky the store sold intoxicated broke the window"). Hakes and his colleagues concluded that the presence of relative pronouns facilitated the assignment of the appropriate structural description, thereby freeing more of the processing mechanism for performance of the monitoring task.

A similar interpretation was given for word frequency. Foss (1969) found that RT was lengthened when the word bearing the phoneme target was immediately preceded by a low-frequency word rather than a word of higher frequency (e.g., "itinerant bassoon player" vs. "travelling bassoon player"). Foss hypothesized that the accessing of a low-frequency word from the mental lexicon was an operation making greater demands on the finite processing capacity than the accessing of a more familiar word. Cairns and Foss (1971) subsequently presented evidence indicating that, under certain circumstances, sentential context can remove the frequency effect, although later work (reported in Foss, 1975) casts some doubt on these findings.

We discuss later the interpretation of these experiments. In the next section, however, we examine the fortunes of what was once held to be a basic fact: the effect of lexical ambiguity on phoneme-monitoring RT.

### The Ambiguity Effect

Foss (1970) first reported that the presence of an ambiguous word immediately before the target-bearing item (as in the sentence "The punch barely affected the old man") led to longer RTs than those produced for the same sentence with the ambiguous word replaced by an unambiguous word ("The cocktail barely affected the old man"). Foss hypothesized that the entire set of readings of the ambiguous item is accessed from the mental lexicon, thus taking up more processing capacity. Further work (Cutler & Foss, 1974; Foss & Jenkins, 1973) showed that this effect did not disappear even if preceding sentential context was sufficient to determine which reading should be assigned to the ambiguous word, i.e., to disambiguate it (e.g., "The wine punch barely affected the old man"). Although common sense tells us that ambiguous lexical items are not recognized as ambiguous in context, phoneme-monitoring results appeared to show that contextual disambiguation does not remove the added complexity of processing resulting from the presence of an ambiguous word.

Cairns and Kamerman (1975) also found that lexical ambiguity produced an RT decrement that disappeared if the target-bearing word did not immediately follow the ambiguous word. Swinney and Hakes (1976) found

that it was, after all, possible to construct contexts that would determine the choice between readings during rather than after lexical access; what was necessary was a context so strongly related to one reading of the ambiguous word that it virtually predicted it (e.g., *baseball* for *bat*).

These experiments have recently been called into question by the results of a study by Mehler, Segui, and Carey (1978), in which it was shown that longer words preceding the target-bearing word led to faster RTs than did shorter words. Mehler et al. explained this result as follows: long words generally require no more higher-level processing than do short words, but they take up more input time, thus delaying the arrival of the next item to be processed. At the end of a long word, therefore, processing has progressed further than at the end of a short word, so that more attentional capacity has been freed for phoneme detection.

In the five ambiguity experiments described above, the unambiguous control words were usually longer than the ambiguous words (e.g., *cocktail* as a control for *punch* in the example cited). Therefore, it is possible that all the supposed demonstrations of an ambiguity effect were in fact demonstrations of an effect of preceding word length. Indeed, Mehler et al. showed that ambiguous words paired with controls of the same length produced no RT decrement; ambiguous words that were longer than their control words actually produced faster RTs than did the controls.

Swinney (personal communication, 1976) has since claimed that those ambiguous words in the materials of Swinney and Hakes (1976) that are equal in length to their controls nevertheless exhibit the ambiguity effect; the same is said to be true of the materials used by Cairns and Kamerman (Cairns & Hsu, 1977). However, no new demonstration of an ambiguity effect with length controlled has yet been reported. A pilot study in our own laboratory, using ambiguous words very carefully matched for length and frequency with their controls, failed to show a significant difference due to ambiguity. It seems doubtful whether there ever was an ambiguity effect on phoneme-monitoring latencies.

Swinney (1976) has recently presented other evidence that, he claims indicates that the entire set of readings of an ambiguous word is accessed from the mental lexicon regardless of contextual disambiguation. Swinney required subjects to make a word-nonword judgment about a visually presented word while simultaneously listening to a sentence. When the sentence contained an ambiguous word (e.g., *bug*) that occurred immediately before the visual stimulus appeared, RT was faster to words connected with *both* readings of the ambiguity (*ant*, *spy*) than to control words, whereas when the sentence contained an unambiguous control word (e.g., *insect*), only the word related to that meaning was facilitated in comparison with the control. Furthermore, in the ambiguity case both related words were facilitated even with disambiguating prior sentence context.

This result may only indicate, however, an associative effect of accessing one lexical entry upon other entries: Occurrence of the word *bug* automatically primes the lexical entries of words associated with it, including both *ant* and *spy*, and this priming is reflected in faster word-nonword decision times. It does not necessarily show that both these interpretations of *bug* are read out of the lexical entry in the ordinary course of sentence comprehension.

Investigators have also claimed (Holmes, Arwas, & Garrett, 1977; Mistler-Lachman, 1975) that the time subjects take to classify a sentence as meaningful is increased by the presence of a lexical ambiguity. If this finding proves statistically reliable, it provides an interesting counterpoint to the failure to detect an increase in processing complexity due to lexical access of ambiguous words. It would indicate that the fact that a word has more than one lexical reading does not increase the time needed for lexical access, but may increase the time needed to comprehend the sentence. Whatever extra analysis is required to determine the appropriate reading of a sentence containing an ambiguous word need not have any local effect measurable with existing on-line techniques.

### Characteristics of the Target-Bearing Word

Reaction time to targets on stressed syllables is faster than RT to targets on unstressed syllables (Shields, McHugh, & Martin, 1974). Stress on words also leads to faster RTs, and both open-class words (e.g., nouns and verbs) and closed-class words (e.g., conjunctions and prepositions) are similarly affected by stress (Cutler & Foss, 1977).

The acoustic correlates of stress are responsible for part of this effect, but not all of it, as is demonstrated by an experiment (Cutler, 1976) in which the target item in two conditions to be compared was acoustically identical and occurred in an invariant syntactic context in each condition; but the intonation contour imposed on the sequence preceding the target item was such that in one condition a high level of stress would be expected to occur at target position, whereas in the other condition the target would be expected to be relatively unstressed. Although the item was acoustically identical, RT in the first condition (high stress expected) was faster. This result indicates that the intonation contour of a sentence can direct attention during comprehension to the points at which high stress will fall. The value of this operation to the process of comprehension seems to be that the semantically most central (i.e. the focused) portions of the sentence are thereby located; in a further experiment, Cutler and Fodor (1979) showed that varying the focus of a sentence by means of preposed questions also resulted in focused targets consistently producing faster RTs than did nonfocused targets, despite the

fact that the sentence containing the target remained acoustically constant, with only the preceding question being changed.

The nature of phoneme-monitoring targets was examined in detail in a series of experiments in which the materials were not sentences but lists of various kinds. Initially, the topic at issue seemed to be the "units of perception." Savin and Bever (1970) discovered that monitoring for an initial phoneme in a list of nonsense monosyllables produced RTs that were *longer* than those produced for the same list when the specified target was an entire syllable. On the basis of this result, they challenged Foss's (1969) explanation of phoneme-monitoring results in terms of a limited-capacity central-analyzing mechanism. Instead, they claimed, phoneme identification could only be performed after syllable identification, syllables being the primary units of perception. The slowing of phoneme-identification latencies around syntactically or lexically difficult portions of a sentence must be due to an increase in the time needed to perform operations that *necessarily precede* phoneme identification rather than an increase in the processing capacity required by *concurrent* operations.<sup>2</sup>

A reply to Savin and Bever's (1970) article was offered by Foss and Swinney (1973), who reported an experiment in which not only was syllable-monitoring RT faster than was phoneme-monitoring RT, but monitoring for words in a list of words produced even faster RTs than did monitoring for syllables in a list of syllables. Furthermore, Foss and Swinney drew attention to an experiment by Bever, Savin, and Hurtig (cited in Bever, 1970), in which they found that monitoring in a list of short sentences was performed faster if subjects knew the entire target sentence than if they knew just the initial word. By analogy to the Savin and Bever argument, then, the primary "unit of perception" should be the clause. Foss and Swinney proposed, however, a way out of this awkward situation: If a distinction were to be drawn between the perception of a linguistic unit and its identification, one could still hold that lower level units were perceived, as common sense would tell us, prior to higher level units, whereas the order in which units of the signal could be identified (i.e., brought to awareness) and, hence, responded to in a monitoring task, could be, up to a point, reversed; higher level units might be sooner accessed to consciousness.

A simpler explanation of these results, however, was offered by McNeill and Lindig (1973), who pointed out that in Savin and Bever's (1970) and Foss and Swinney's (1973) work, the fastest RTs had always been collected when

<sup>2</sup>Savin and Bever (1970) did not dispute the sensitivity of the phoneme-monitoring task to variables affecting comprehension difficulty, i.e., the usefulness of the task as a measure of comprehension difficulty, but merely Foss's (1969) explanation of this sensitivity. Moreover, their explanation of the effects of syntactic and lexical variables on monitoring RT was neither necessitated by their findings nor inapplicable to previous phoneme-monitoring findings.

the level of the target (phoneme, syllable, word) matched the level of the list in which the search was undertaken. McNeill and Lindig found that either upward (e.g., looking for a phoneme in a list of words) or downward (e.g., searching for a word in a list of syllables) mismatches produced longer latencies, and explained their result in terms of focus of attention: If the list contains syllables then the subject's attention will be focused at the syllabic level, and a syllable target will be easiest to respond to, and so on. In normal language use, they proposed, the focus of attention would be on the meaning of an utterance. Thus, the experiments on lists of items, which allow the focus of attention to be altered at will, tell us nothing about the "units of perception" in normal comprehension.

In a later experiment, Healy and Cutting (1976) found that a match between target and response item also facilitated RT when the search list was not homogeneous but was composed of some items that matched the level of the target and some which did not. This, result, therefore, cast doubt on McNeill and Lindig's (1973) focus explanation; Healy and Cutting preferred to conclude that simple physical identity of target and response item facilitated response latency, a known effect in visual tasks (cf. Posner & Mitchell, 1967). They also discovered that intrinsic ease of recognition of phonemes can determine whether phonemes or syllables are recognized faster when the matching variable is controlled; phonemes that produce faster naming latencies are recognized faster than are syllables, but syllables can generally be identified faster than can phonemes that produce slow naming latencies. This result would imply that phoneme identification is accomplished at a fairly low level of analysis.

Other findings from phoneme-monitoring in lists of items concern the linguistic naturalness of the material. Rubin, Turvey, and van Gelder (1976) found that RT to phoneme targets on words was faster than was RT to targets on nonwords. Cutler and Cooper (1978) reported that RT to targets embedded in lists that conformed to certain syllable-structure constraints of English was faster than was RT to targets in lists that defied these constraints.

None of the findings in this series of experiments reflected upon the usefulness of phoneme-monitoring as a measure of comprehension difficulty. In the typical phoneme-monitoring experiment, RT is compared to the *same* target under different conditions, preceded by different words, for instance, or different intonation contours. Thus, the relative difficulty of the particular target is controlled. Nevertheless, these studies concerned the level at which a phoneme can be identified, and recent work has indicated that the conclusions drawn from monitoring in lists may also hold for monitoring in sentences. Healy and Cutting's (1976) description of phoneme identification as a low-level prelexical process, in other words, may also be correct for sentence comprehension. The next section addresses this question in detail.

## Phoneme-Monitoring and Lexical Access

Foss, Harwood, and Blank (Foss, personal communication, 1977) have recently demonstrated that although RT to a phoneme target is sensitive to the frequency of the immediately preceding word in the sentence, it is *not* sensitive to the frequency of the word bearing the target. Moreover, Foss and Blank (Blank, personal communication) have found that although RT to targets *following* nonwords is slower than is RT to targets following real words, there is no RT difference between targets beginning words and beginning nonwords.

On the basis of these results, Foss and his colleagues claim that phoneme targets can be detected before the word they are part of is looked up in the mental lexicon. Once the *preceding* word has been identified, only low-level phonological analysis of the target-bearing word is necessary: If the target phoneme is in the first position in the string, it is in the required word-initial position and a response can be made. Phoneme monitoring responses, in other words, precede lexical access.

This claim is in conflict with other results. First, there is the experiment by Rubin, Turvey, and van Gelder (1976) referred to previously; in that experiment RT to targets *on words* was faster than was RT to targets on nonwords. On the surface, the only difference between Foss's word-nonword experiment (Blank, personal communication) and that of Rubin et al. was that in the former the materials were sentences; in the latter, lists: both lists of either words or nonwords alone and mixed lists consisting of both monosyllabic words and nonsense syllables.

Second, Morton and Long (1976) found that high contextual probability of the word bearing the target led to faster RTs than did low probability. They interpreted this result as a reflection of more rapid lexical access of more probable words. The phoneme-monitoring response was made, according to Morton and Long's account, *after* lexical access.

Current research on the relation of phoneme detection to lexical access seems, therefore, to be in disarray. On the one hand, Foss's results (Foss & Blank, personal communications) indicate that the detection response can be initiated before lexical access; on the other hand, Morton and Long's (1976) and Rubin et al.'s (1976) results indicate that the detection response is made after lexical access.

An initially appealing resolution of this contradiction invokes the precise task specifications. Because subjects in a phoneme-monitoring experiment are performing two concurrent tasks, detection and comprehension, some scope exists for altering the relative task payoffs. In the typical phoneme-monitoring experiment, subjects are aware that their comprehension—strictly speaking, their recall of the sentences—will be tested, but not until the



end of the experiment. Meanwhile, the detection task must be performed on each new sentence, and a reminder of it is given in the form of the target specification preceding each sentence. Perhaps relatively more attention might be devoted to the detection than to the comprehension task, and the priority assigned to phoneme detection might encourage initiation of the response at the earliest possible moment. If the instructions emphasized the comprehension rather than the detection task, however, phoneme identification might be performed after lexical access simply because it had been assigned less attention than had the components of comprehension. In fact, Morton and Long (1976) required their subjects to recall each sentence verbatim immediately following its presentation.

This suggestion does not, however, provide a sufficient explanation of the contradictory results; high transitional probability of the target-bearing word leads to faster RTs even when comprehension is only tested afterwards by the usual brief recognition test (Foss, personal communication).

The apparent contradiction can be resolved, however, if one rejects the assumption that detection of the phoneme target must necessarily either precede or follow lexical access of the target-bearing word. Suppose, instead, that after an initial phonological analysis the two processes, looking up the phonologically analyzed string in the mental lexicon and determining whether the initial component of the string is the specified target, go on in parallel, and, other things being equal, the target identification process will be completed first. In this case, RT to the target will show no effect of lexical characteristics of the target-bearing word.

If lexical access is speeded up, however, it may be completed before the target-detection process has finished. In this case, the identification of the word may facilitate the monitoring process. There are two ways in which this may happen: on the one hand, it may be possible to respond on the basis of the phonological information in the lexical entry *instead of* awaiting completion of the target-detection process. On the other hand, lexical information may interact with the target-detection process to facilitate phoneme identification. Note that the effect of speeded lexical access can only be facilitative: Slower lexical access will simply not affect the target-identification process.

One factor that may speed up lexical access is preceding context that is highly predictive of a particular word. Another is intonation or context indicating that focal stress will fall on a certain word. Phoneme-monitoring RTs are sensitive to transitional probability of the target-bearing word (Morton & Long, 1976), to the prior occurrence of a related word (Rubin, 1975), and to cues to focus on the target-bearing word (Cutler, 1976; Cutler & Fodor, 1979).

Characteristics of the lexical entry of the target-bearing word will be unlikely to affect RT. Factors internal to the lexical entry of *the preceding*

word, however (e.g., word frequency or simply whether the word is real) can affect RT.<sup>3</sup> In contrast to the effect of context, these effects can also be inhibitory. Words of low frequency and nonwords take longer to identify because the process of looking for them in the lexicon takes longer. To detect a *word-initial* target, it is necessary to have processed the preceding word; hence, slower target detection will be the result of slower lexical access of the previous word.

Of course, contextual effects that speed up lexical access should therefore facilitate RT to a target on the following word. They do, as was shown in an experiment by Blank and Foss (1977).

The effect of word length is interesting. As Mehler et al. (1978) showed, longer words are associated with faster detection of targets on the following word. The target-bearing word itself, however, should be associated with faster RTs when it is short.<sup>4</sup> This is because very short words may be retrieved quite quickly from the mental lexicon; the opportunity exists for lexical access to facilitate target detection. Long words, however, are often to a certain extent redundant and do not pose a proportionately greater identification problem than do short words. But because of the extra duration of a long word—at least the duration of one syllable, which in English averages 180 msec (Huggins, 1964)—more time is available for processing it. Thus, by the time the target on the following word arrives, processing has progressed further for a long word than for a short word. This reduction in processing *load* may itself lead to faster monitoring latencies, as Mehler et al. claim. However, it may also be the case that the result is due simply to the time at which the end of the word is identified. Because subjects are listening for word-initial targets only, a target cannot be detected until the end of the previous word has been identified. The end of a longer, more redundant, word may be identified as it occurs, whereas the decision that a short word has

<sup>3</sup>Lexical ambiguity does not appear to affect phoneme-monitoring RTs, as we have shown. However, the internal complexity of lexical entries may vary in other ways than in number of readings for the word. Kintsch (1974) reported finding no effect of derivational complexity on phoneme-monitoring RTs; but the materials he used differed in many ways other than in derivational complexity of the word preceding the target; in particular, the critical variables of word length and sentence length were quite uncontrolled.

<sup>4</sup>It might be expected that studies using predominantly monosyllabic target-bearing words would be more likely to find effects of characteristics of the target-bearing word itself, whereas studies in which the target-bearing words were predominantly polysyllabic would be more likely to find effects of the preceding word only. This is in fact the case. In Morton and Long's (1976) study, in which contextual plausibility of the target-bearing word led to faster RTs, approximately three-quarters of the target words were monosyllabic, one quarter polysyllabic. Studies from Foss's laboratory have, on the other hand characteristically used more polysyllabic than monosyllabic target words. In the unpublished study by Blank and Foss (1977) referred to previously, in which word-nonword status was found to affect RT to targets on the following word but not to targets on the critically varied word, three-quarters of the target words were polysyllabic, one quarter monosyllabic.

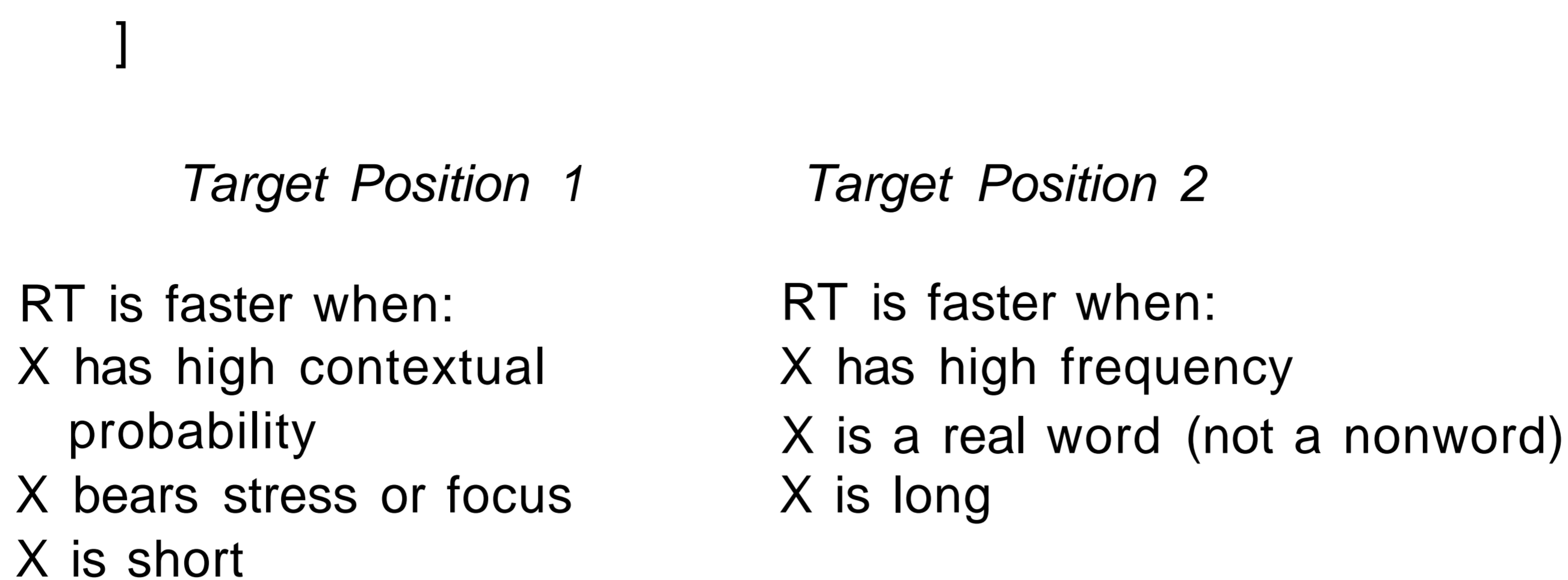


FIG. 4.1. A schematic representation of a sentence. X marks the word position in which the independent variable is manipulated; possible phoneme-monitoring positions with respect to X are represented by asterisks.

ended may not be arrived at until *after* it has ended, i.e., after the target has occurred; thus, the monitoring response would be delayed.

Figure 4.1 summarizes the effects that are crucial to our argument. We have claimed that there is a target detection process that neither precedes nor follows lexical access of the target-bearing word, but runs parallel to it. Target detection cannot be accomplished until the preceding word has been identified; therefore, the target-detection process is sensitive to lexical characteristics of the preceding word. Longer words allow more time for processing before arrival of the target; therefore, greater length of the preceding word results in faster target detection.

In unusual circumstances, lexical access of the target-bearing word can be speeded up to such an extent that target detection is facilitated by completed lexical access. Factors internal to the lexical entry of the target-bearing word do not have this effect, but contextual ("top-down") factors do: Cues to focus direct more attention to the focused word's lexical access; context that makes a particular word highly predictable has the effect of priming the lexical entry.<sup>5</sup> Also, very short words can be accessed more quickly.

Two concluding points remain to be made. First, our explanation of the effect on target-detection time of lexical characteristics of the preceding word assumes that target identification cannot succeed until the preceding word has been processed. This may only be true when subjects are monitoring for *word-initial* targets, as is usually the case in phoneme-monitoring experiments. Indeed, we would predict that subjects who were listening for *any* occurrence of the target sound would respond faster to the same word-initial targets than would subjects who were listening for initial sounds only.

Second, all that we have said in the foregoing discussion applies to sentences, but we would expect the same effects to show up in monitoring

<sup>5</sup>Very effective priming of the lexical entry is achieved by giving the word itself as target. This is one reason why word-monitoring times are faster than phoneme-monitoring times.

performed on lists of items,<sup>6</sup> with the obvious exception that context effects do not exist in lists. Rubin, Turvey, and van Gelder's (1976) finding that targets on words are detected faster than are targets on nonwords in mixed word-nonword lists seems to be a contradiction to this claim, because in sentences there is *no* RT difference between targets on words and nonwords. Closer inspection reveals, however, that this is not a counterexample at all. On the one hand, the stimuli in this experiment were all consonant-verb-consonant (CVC) syllables; we would expect such short words to be accessed extremely quickly and completed lexical access of the *words* to facilitate target detection. On the other hand, the monitoring task was disjunctive: The subjects were looking for one of two targets. Phoneme-monitoring RTs are slower if more than one target is being listened for both in lists (Foss & Dowell, 1971; Steinheiser & Burrows, 1973) and in sentences (Treisman & Squire, 1974). Therefore, if the target-identification process is slowed down by the added target, it is more likely that the lexical-access process will be completed first.

### MONITORING FOR WORDS

Word targets can be detected faster than can lower level targets in lists of words (Foss & Swinney, 1973). This result was explained by McNeill and Lindig (1973) and Healy and Cutting (1976) as due to congruence of the target with the response item. Their explanation would hold as well for sentences as for lists of unrelated words, so that it comes as no surprise to find that detection of word targets is faster than is detection of phoneme targets in sentences also (Treisman & Squire, 1974).

Different types of word monitoring have been compared by Marslen-Wilson and Tyler (1975). In a normal sentence no difference was found between time to detect a word that rhymed with the specified target and time to detect a word belonging to the semantic category specified by the target. In anomalous or ungrammatical sentences, however, category monitoring produced longer RTs than did rhyme monitoring. Marslen-Wilson and Tyler claimed that this result indicated that during processing of a normal sentence construction of the semantic representation interacts with construction of representations at other levels in such a manner that the results of all levels of analysis are available in parallel. This interpretation, however, assumes that the results of different levels of analysis (phonological, lexical, semantic) are

<sup>6</sup>No direct investigation has been carried out of the effect of word frequency in lists. However, there is some evidence that frequency of the target-bearing word, which Foss, Harwood, and Blank (personal communication, 1977) found did not affect RT in sentences, also does not affect RT in lists. Results of a study in which the materials were lists of unrelated words showed no correlation between speed of response and frequency of the target-bearing word ( $r_s = -.06$ ).

equally available as the basis for the monitoring response. But as we comprehend a sentence, we are not generally aware of the result of phonological analysis. Extra processing may well be needed before the output of such analysis can become accessible to the decision mechanism that makes the monitoring response. Therefore, a lack of RT difference between rhyme- and category-monitoring in normal prose may not directly reflect the temporal relation between processing stages. Normal processing may still proceed serially, with phonological analysis being completed before higher level analysis.

More recently, Marslen-Wilson, Tyler, and Seidenberg (1978) have again used rhyme- and category-monitoring tasks to investigate the interaction of semantic and syntactic processes in comprehension. The targets in this experiment occurred either immediately before or immediately after clause boundaries. Response latencies were not determined solely by the position of the target relative to the syntactic boundary, however—as would be expected on a purely syntactic account of clausal structuring—but were also influenced by the "completeness" of the semantic representation of the clause; when semantic completeness was high, RTs were significantly faster before the boundary than after, but when the clause was less semantically complete, there was no significant difference between before-boundary and after-boundary monitoring times. Marslen-Wilson et al. interpreted this finding as further evidence that comprehension is an interactive process, in which the listener constructs a representation of the sentence word-by-word, drawing on both syntactic and semantic information in the input.

### MONITORING FOR MISPRONUNCIATIONS

The technique of measuring latency to detect deliberate mispronunciations in a sentence was devised by Cole (1973), who found that changes in the later part of words produced faster detection latencies than did changes in initial sounds and that the more distinctive features had been altered the faster the alteration was detected; thus, a mispronunciation of /p/ as /b/, for example (a change involving only the feature voicing) produced longer detection times than did a mispronunciation of /p/ as /z/, a four-feature change. (Cole also reported that the fewer the features altered, the less likely the mispronunciation was to be detected at all, a finding corroborated by Marslen-Wilson and Welsh [1978]).

Recently, however, Cole has measured RT to detect mispronunciations during sentence comprehension and has found that large RT variations can be produced by manipulations of contextual factors. For instance, mispronunciation of the initial segment of the second syllable of *cargo* or *address* is detected faster if the preceding context determines that those two

syllables comprise one word rather than two (*car go; a dress*). Similarly, if the mispronounced word has a high probability of occurrence in the context, is implied by the preceding context, or is closely connected with the main theme of the material being processed, reaction is speeded. (These experiments are summarized in Cole and Jakimik [in press]).

Monitoring for mispronunciations is, therefore, obviously a measure that is sensitive to many factors affecting sentence comprehension. Results from mispronunciation-monitoring experiments, however, although interesting in themselves, are not directly comparable with results from experiments in which the monitor target was part of an undegraded input signal. Cole and his coworkers are fairly scrupulous in constructing sentences that allow subjects only one option for an appropriate alternative to a nonsensical item, and their results indicate that subjects are locating this alternative, that is, not simply reacting with a positive detection response on encountering a nonword (a conceivable strategy in a mispronunciation-monitoring task), but are reacting to identification of the word *appropriate* for the sentence context, the word that has been mispronounced. Latency to detect a mispronunciation reflects, therefore, not simply word recognition but word *reconstruction*. Thus, it would necessarily be a more indirect measure of, for example, lexical access than is phoneme monitoring. For this reason, investigation of, for instance, the nature of lexical entries is less well served by the mispronunciation-monitoring task than by other monitoring techniques. Mispronunciation monitoring, on the other hand, lends itself well to the study of exactly *how* words can be reconstructed, i.e., the manner in which a "context" is created.

### MONITORING FOR EXTRANEOUS SIGNALS

Lights, clicks, and tones have been employed as sentence-extraneous monitor targets. Monitoring for a visual signal, a flash of light, appears not to be sensitive to factors affecting complexity of sentence processing (Foss, personal communication). This may indicate that variations in comprehension difficulty are best reflected by tasks that involve the mechanisms engaged by the comprehension process; if the target is nonlinguistic, therefore, it should, in the case of auditory sentence comprehension, be auditory. Interestingly, Geers (1978) has shown that performance of deaf subjects on a flash-location task while lip-reading (i.e., while processing in the visual modality) is remarkably similar to the performance of hearing subjects on click-location during auditory comprehension.

Abrams and Bever (1969) and Holmes and Forster (1970) measured RT to detect the occurrence of a click as a function of processing load at various points in the syntactic structure of a sentence. Abrams and Bever found end-of-clause RT to be slower than beginning-of-clause RT, from which they concluded that processing load at the end of a clause was comparatively heavy. Both Abrams and Bever and Holmes and Forster found that RT

declined across the sentence; however, Holmes and Forster reported RTs to clicks located in a major syntactic boundary to be faster than RTs to clicks not in a boundary, whereas Abrams and Bever found that this effect was obscured by the overall sentence-position effect.

Reaction time to a short tone was measured by Green (1977), who found that the task specifications strongly affected it: Those subjects who were required merely to memorize and repeat a sentence responded to the signal faster than did subjects who were required to provide an appropriate continuation for the same sentence.

Monitoring for a sentence-extraneous auditory signal possesses at least one technical advantage in comparison with monitoring for a target that forms part of the sentence being processed: Fewer constraints are imposed on the construction of experimental sentences. Materials for phoneme-monitoring studies, for example, have become increasingly more difficult to construct. Early studies used a variety of different initial sounds: obstruents, resonants, and vowels (see, e.g., Hakes, 1972). Researchers later noted, however, that RT varied as a function of the particular phoneme target, with stops, for example, producing generally faster RTs than did fricatives (Foss & Swinney, 1973; Morton & Long, 1976; Rubin et al, 1976; Savin & Bever, 1970). This result is probably due to the custom of aligning the signal that starts the timer in phoneme-monitoring experiments with the onset of the target phoneme, in conjunction with the longer intrinsic duration of fricatives in comparison with stops. Nonetheless, Rubin et al. (1976) found that their word-nonword difference held for the target /b/ but not for the target /s/. Most recent phoneme-monitoring research has used only stop consonants, which, although dependent upon the surrounding context for their unambiguous identification (Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967), do not appear to introduce variation as a result of differing among themselves: A separate analysis of the results presented by Cutler (1976) revealed no effects due to differences between the three phoneme targets /b/, /d/, and /k/. Also, Martin (1977) reported that the six stop consonants do not appear to differ in detectability. No research has been carried out on whether RTs are affected by the number of different targets used in an experiment (a unique target is always specified in phoneme monitoring for each sentence); current practice usually involves three or four stop-consonant targets. Even given all six stop consonants as potential targets, however, the construction of phoneme-monitoring materials can be a formidable task, as any phoneme-monitoring researcher will testify. For instance, in an experiment in which the target is the initial phoneme of the critically varied word (e.g., Morton & Long, 1976) pairs of words must be selected that vary on the critical dimension under study but are both matched on such variables as length and word frequency *and* each begin with a stop consonant. Word-monitoring tasks, in which such factors as memorability of the target item might well play a role, can involve similar difficulties.

However, it appears that monitoring for sentence-extraneous signals does not reflect, or does not reflect in the same manner, the variables that affect monitoring for targets within the sentence. Three striking inconsistencies can be observed among results from the very few studies available using nonlinguistic auditory signals and results from phoneme-monitoring studies. The first difference concerns word frequency. Whereas the effect of increasing word frequency is to speed phoneme-monitoring RTs (Foss, 1969), Green (1977) reported that when subjects were required to provide a continuation for the experimental sentence, sentences containing noun phrases constructed of high-frequency words were associated with slower RTs to end-of-the-sentence tones than were sentences with low-frequency noun phrases. This difference was only evident when subjects were required to produce continuations from the experimental sentences. When the subjects' task was simply to memorize the experimental sentence for immediate recall, there was no significant effect of noun-phrase frequency. As Green pointed out, latencies in the continuation condition of his experiment may have reflected response variables (construction of the continuation) as well as processing variables, so that the increased RT in this instance could well be explained as a function of the difficulty of choosing between the larger number of possible continuations appropriate for a sentence containing high- as opposed to low-frequency words. Support for this conjecture is provided by MacKay's (1970) finding that sentence-completion times for sentence fragments containing lexical ambiguities are longer than are completion times for unambiguous fragments; there are presumably more possible continuations for ambiguous than for unambiguous fragments. Nevertheless, Green's failure to find any significant effect of word frequency in the noncontinuation condition of his experiment is clearly inconsistent with the phoneme-monitoring results.

The second inconsistency between monitoring for sentence-internal and for sentence-external targets concerns position in the sentence. Reaction time in phoneme-monitoring studies generally decreases across the sentence or clause (Cutler & Foss, 1977; Foss, 1969; Shields, McHugh & Martin, 1974), the only reported exception being the complex self-embedded sentences used by Foss and Lynch (1969). Word-monitoring RT also decreases across the clause (Marslen-Wilson et al., 1978). Reaction time to clicks, however, does not show such a consistent pattern. Holmes and Forster (1970) found that click-detection time decreased across the sentence and, to a small extent, across the clause. Abrams and Bever (1969) also found an RT decrease across the sentence. Analyzed with respect to clause boundaries, however, their results show that RTs at the end of the first clause are slower than are RTs at the beginning of the second clause. Finally, Bond (1972) found that RT to clicks became increasingly slower as the click occurred further into the phonological phrase ("any sequence that was demarcated by a clear intonation contour [p. 137]"), a finding in direct conflict with the phoneme-monitoring results.



The third inconsistency involves stress and again arises from the Bond study (1972). Whereas phoneme-monitoring RT is faster on stressed than on unstressed syllables (Cutler, 1976; Cutler & Foss, 1977; Shields et al., 1974), the reverse is true for click monitoring: Bond found that clicks in stressed syllables are detected slower than are clicks in unstressed syllables.

The lesson from these results appears to be that sentence processing affects RT to sentence-internal and sentence-external targets in different ways. With respect to stress, it appears plausible that this should be so. The faster phoneme-monitoring RT to targets on stressed words appears to reflect the direction of attention towards such items in order that the semantically more central items in the sentence might be identified (Cutler & Fodor, 1979). If attention is focused on the stressed word in this manner, then it could be considered to be as a consequence diverted from sentence-extraneous occurrences such as a click. Or, at a simpler level, the difference may simply result from competition between the input signals: The stressed syllables, being louder, mask the click more than do the unstressed syllables. Both these arguments can also be extended to the clause-position problem, because the highest stress in a clause tends to fall, *ceteris paribus*, at the end.

The failure of tone-monitoring RT to exhibit an effect of word frequency, however, indicates that lexical access processes may not affect RT to nonlinguistic signals either directly or indirectly. In any event, it seems that reaction to extraneous signals is a less direct measure of sentence comprehension than is reaction to sentence-internal targets. Before monitoring for nonlinguistic targets can be considered a useful measure, more information is required about exactly what processing operations it reflects and in what manner it reflects them. Comparative studies in which monitoring latencies for sentence-internal and sentence-external targets were collected and compared for the same materials would be particularly valuable.

## CONCLUSION

Although not the only on-line measures of sentence comprehension,<sup>7</sup> monitoring tasks are certainly the most widely used. They are similar to each

<sup>7</sup>Other on-line tasks include word-by-word reading (Aaronson & Scarborough, 1976), shadowing latency (Marslen-Wilson & Welsh, 1978), lexical decision during comprehension (Swinney, 1976), naming latency during comprehension (Tyler & Marslen-Wilson, 1977). Postcomprehension RT measures, such as sentence-reading time (Garrod & Sanford, 1977; Haviland & Clark, 1974) sentence-classification time (e.g., Moore, 1972), or RT to a probe of various kinds (e.g., Green, 1975; Suci, Amnion, & Gamlin, 1967; Walker, 1976), which give a global index of the time required for completion of a large number of processes, necessarily obscure the individual contribution of each particular process. Therefore, they are of little value in investigating such topics as the role of lexical access in comprehension; but they can often provide a useful check on the persistence of observed on-line effects.

other in many important ways. First, they are all, technically speaking, divided attention tasks, because subjects are required to monitor for the target while at the same time comprehending the sentence. Thus, it is possible that one or both tasks could be performed less well under these conditions than in isolation. Indeed, it is likely that the target detection task is interfered with by concurrent sentence comprehension (Ball, Wood, & Smith, 1975; Martin, 1977). The subject of interest in monitoring experiments, however, is not the RT task per se, but how it can illuminate the sentence-comprehension process. Accordingly, a constant performance decrement due to concurrent comprehension should not confound the results. (The number of errors—missed targets—in phoneme-monitoring experiments is usually below 10%, few enough to leave adequate data if sufficient subjects and items are tested). The comprehension process itself seems unlikely to be adversely affected by the detection task;<sup>8</sup> overlearned tasks are generally resistant to interference from concurrent tasks (Moray, 1969), and sentence comprehension is about as overlearned a task as any that one could ask a subject to perform.

Second, all monitoring tasks are RT measures. Thus, they require a certain investment in equipment; they force the experimenter to consider such problems as the tradeoff between speed and accuracy of response; and the variability of baseline RT across subjects makes it very difficult to measure between-subjects variables. (For further discussion of these issues see Pachella[1974]).

In this paper, however, we have concentrated on the differences between the various forms of monitoring. We have suggested that the phoneme-monitoring task, for instance, is sensitive to contextual factors and to lexical factors, but in different ways. We have posited a target-identification process that goes on in parallel with the lexical-access process and that, other things being equal, will be finished before lexical access is completed. Top-down processing of predictive context or intonation can have the effect of speeding up lexical access so that it is completed before the target has been identified; this facilitates RT. Thus, the phoneme-monitoring task can be used as a measure of, for example, contextual predictability of the target-bearing word.

Factors internal to a word's lexical entry, however, affect RT to targets on the following word only; when lexical access is slowed down, the detection of a target on the next word is slowed down because a target in the specified word-initial position cannot be identified until the preceding word has been satisfactorily recognized. Thus, phoneme monitoring can also be used as a measure of lexical factors; in this case, manipulations of the independent variable would be effected in the word that preceded the target-bearing word. Of course, all the other factors that affect RT to phoneme targets must be

<sup>8</sup>However, Hakes and Foss (1970) found that paraphrasing was significantly less accurate when the monitor target occurred later in the sentence rather than earlier.

rigorously controlled, including word length. Phoneme-monitoring materials are not easy to construct. Nonetheless, there is probably considerable scope for future investigation of the internal characteristics of the mental lexicon using this task.

There is not, so far, sufficient evidence on which to base such detailed conclusions about the other monitoring tasks. We have suggested, however, that mispronunciation monitoring, because it requires subjects to reconstruct the mispronounced words, is suitable for the investigation of how effectively different types of context enable word reconstruction. Word monitoring of different kinds requires subjects to monitor for the target at different levels (e.g., the phonological level of a rhyme or the semantic level of category membership [Marslen-Wilson et al., 1978]) and is therefore suitable for investigating the speed with which decisions at various levels can be made. Monitoring for extraneous signals may, as we have pointed out, be sensitive to overall processing load due to comprehension at the time at which the target occurs; but because confounding acoustic factors have not been controlled in the very few relevant experiments, this is as yet far from certain.

Foss (1969) originally claimed that phoneme-monitoring RTs reflected total load on a limited-capacity processing mechanism shared by any and all tasks a listener might be performing. This conception has not proved correct. In fact, it may be the case that no monitoring task gives a global measure of total processing load at a particular point in sentence comprehension. However, what we have may be preferable: different tasks that measure different specific aspects of the comprehension process.

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