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Monitoring around the Relative Clause

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This article reports two experiments which examined the utility of the phoneme monitoring technique for studying syntactic processing of sentences. In French, by using self-embedded relative clauses, it is possible to isolate and examine the effect of a syntactic cue while controlling the factors known to effect phoneme detection times. Monitoring within and after the relative clause led to significant differences in phoneme detection times for reversible subject and object relatives only after the clause boundary. These results demonstrate the sensitivity of the phoneme monitoring task to syntactic processing and are taken to reflect structural calculations of the underlying grammatical relations for the reversible object relatives. When lexical information was introduced with nonreversible relatives, there was no longer a difference between the detection times for subject and object relatives after the clause boundary. Thus, it appears that lexical information can be used in the attribution of underlying grammatical roles.

Progress in the study of how and when sentences are understood has been hampered by the lack of reliable on-line procedures. Foss developed one on-line technique, phoneme monitoring, with the expectancy that it indicated the momentary fluctuations in processing difficulty. It was assumed that phoneme monitoring could be used to measure difficulty in syntactic processing (Foss & Lynch, 1969; Hakes & Cairns, 1970; Hakes, Evans, & Brannon, 1976), in lexical processing of ambiguous words (Foss, 1970; Foss & Jenkins, 1973) and of complex verbs (Hakes, 1971). However, the discovery by investigators that other parameters affect the phoneme detection times now underscores the necessity to reexamine more closely some of these assumptions. Such factors as the frequency of the "critical" word, the word preceding the target (Foss, 1975), the length of the critical word (Mehler, Segui, & Carey, 1978, Newman & Dell, 1978), the phonological similarity between the critical and the target phoneme (Newman & Dell, 1978), the transitional probability of the critical word (Blank & Foss, 1978) and of the target word (Morton & Long, 1976), and prosody (Cutler, 1976) have all been shown to affect detection times of the target phoneme. Since phoneme monitoring's sensitivity to most of these factors now seems established (Cutler & Norris, Note 1), no conclusive evidence for its sensitivity to syntactic variables exists. Indeed, most

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of the early studies which investigated syntactic and lexical processing did not control for many of these recently discovered factors.

It thus is important to ascertain whether phoneme monitoring is a useful tool for studying on-line syntactic processing and if so, what aspects. We have chosen to focus on self-embedded relative clauses (subject and object) for which structural differences have rather consistently yielded different processing difficulties; subject relatives have been shown to be easier than object relatives to comprehend (Fodor, Bever, & Garrett, 1974; Wanner & Maratsos, 1978; Holmes, Note 3).

In French, studies on subject and object relatives have furnished essentially similar results (Amy & Vion, 1976, Segui & Léveillé, 1977). However, in French, self-embedded relatives have some interesting properties not found in English. Both the subject and object relatives can be identical in all details except for the last phoneme of the relative pronoun: qu*i* versus qu*e*.[1] Thus, for the reversible relatives shown in Table 1 (a and b), the only cue available for determining the underlying grammatical relations comes from the relative pronoun. Hence, an isolated syntactic cue can be studied without other confounding factors such as lexical information or prosody.[2] In addition, the strict control of the immediate context around the target, not feasible for English but necessary for phoneme monitoring, is possible.

However, it is possible to introduce lexical information by using nonreversible relatives of the type shown in Table 1 (c and d) while maintaining the necessary controls on the words preceding the target. Specification of the role of lexical information (selectional restrictions and pragmatic cues) is required to elaborate a theory of sentence comprehension. For nonreversible relatives, such information, together with syntactic cues (word order, functors, inflections, etc.) may be used to determine the underlying grammatical relations. Inversely, processing based on syntactic cues may only proceed without regard for lexical information. Thus, it can be concluded that if the nonreversible relatives behave differently than the reversible ones, then word meaning decisions and syntactic calculations apparently interact in sentence processing.

Following the original hypothesis of Foss, the phoneme monitoring task reflects the moment to moment demands on short-term memory. Thus, since maximum memory demands could be expected within the relative clause where information such as the head noun is stored (Wanner & Maratsos 1978), it would be of interest to monitor within the relative clause. Furthermore, the phoneme monitoring task may also reflect other activities such as structural decisions or calculations. Phoneme detection times would accordingly be most affected at those points (possibly the clause boundary) where there are decisions concerning the grammatical roles of the major elements in the relative clause such as the subject and the object. In order to better understand the notion of processing difficulty and its relationship to the phoneme monitoring task, it is necessary to monitor within and at the end of the relative clauses.

In the first experiment, reversible subject and object relative clauses were studied since for these sentences there are minimal structural differences and no lexical cues. The target was the initial phoneme of the main verb which came immediately after the relative clause boundary.

[1] This structure is a stylistic variant of another form of the object relative which is similar to the object relative in English. This stylistic variant is less common in oral than in written form, but it represented about 40% of the subjects' productions in a study by Noizet, Deyts, & Deyts (1972).

[2] Both the intonational contours and the length of the pause at the relative clause boundary were identical for subject and object relatives.

TABLE 1
EXAMPLES OF SENTENCES WITH TARGETS USED IN EXPERIMENTS I AND II

Reversible relatives
(a) Le savant qui connait le docteur *travaille* dans une université moderne. The scientist who knows the doctor works in a modern university.
(b) Le savant que connait le docteur *travaille* dans une université moderne. The scientist who the doctor knows works in a modern university.
Experiment I
The target "t" in the main verb (in italics) follows the relative clause boundary.
Experiment II
The target "d" in the noun (underlined) precedes the relative clause boundary.
Nonreversible relatives
(c) L'éditeur qui publie la revue demande beaucoup de rigueur dans les articles. The editor who publishes the journal requires much precision in the articles.
(d) Les articles que publie la revue demandent une lecture attentive. The articles that the journal publishes require attentive reading.
Experiment II
The target "d" in the main verb (underlined) follows the relative clause boundary.

EXPERIMENT I

Method

Design and materials. Eight pairs of sentences containing reversible self-embedded relatives were constructed. An example of a pair (one sentence containing the subject relative pronoun "qui" and the other the object relative pronoun "que") is presented and translated in Table 1 (a and b) with the target word in italics. These sentences were made up of animate nouns (generally human) such as "docteur" and "savant" in the examples. In addition, 30 filler sentences were constructed in order to vary the target position (beginning, end of the sentence as well as no target) and the sentence structures (right branching relatives and sentences of other syntactic construction) and thus to prevent the subjects from adopting ad hoc strategies for dealing with the relatives.

Two lists of experimental sentences were prepared (L1 and L2). Each list contained one of the sentences in each pair such that both lists contained an equal number of subject and object relatives as well as the same fillers. The experimental lists were recorder in a random order by a female native speaker of French in normal intonation using a two-track Ampex AG 440B tape recorder at 15 ips with 30 seconds between sentences. Each sentence was preceded by a specification of the phoneme to be detected in that sentence. In order to indicate which of the 4 phonemes /p, b, t, d,/ was to be monitored, a French city whose name begins with the phoneme was pronounced: /p/ as in Paris, /b/ as in Bordeaux, /t/ as in Toulouse, and /d/ as in Dunkerque.

The instructions indicated that the subject was to respond as rapidly as possible to the word beginning with the target phoneme by pressing on the response button. The subject was also told to pay careful attention to the meaning of the sentences so that he could answer questions which immediately followed certain sentences. Thus eight questions concerning the grammatical relations (of the form "who did what to whom?") were included on both experimental lists to insure that the subjects paid attention to the meaning and did not just concentrate on the phoneme detection part of the task. Cutler and Norris, (Note 1) have suggested that differences in the results obtained with phoneme monitoring in the same kind of linguistic materials may be attributable to the amount of attention paid by the subjects to comprehension which is, in part, determined by the nature of the comprehension task (recall after each sentence or at the end of the experiment). In this experiment, it was especially critical that subjects pay close attention to the sentence since the meaning hinges on a single word, the relative pronoun.

Subjects were presented the list binaurily. When responding, subjects pressed a response button that stopped an electronic clock in a PDP12 computer (maximum error: ±1 millisecond). The clock was triggered by a click placed on the inaudible channel of the tape. Clicks were aligned with the beginning of the phonemes manually by running the tape slowly across the playback heads. Subsequently, by means of a two-channel oscilloscope, a correction was measured and edited into the program for the data collection.

Subjects. Thirty adults in the Parisian university community served as subjects. Fifteen subjects received the first list (L1); the remaining 15 subjects received the second list (L2). Each subject was paid for his participation in the experiment which lasted about 30 minutes.

Results

The mean reaction times for each subject and for each item were computed. Reaction times which were longer than 1000 milliseconds and shorter than 100 milliseconds were omitted from the calculation of the means. These errors made up less than 3% of the data and were evenly distributed across lists. Table 2 shows the overall reaction times (for both lists) to detect the target phoneme after reversible subject and object relative clauses.

TABLE 2
MEAN REACTION TIMES FOR THE SUBJECT AND OBJECT RELATIVE SENTENCES (FOR LISTS L1 AND L2)

	Subject QUI	Object QUE
	Reaction time (msec)	
List 1	423	474
List 2	423	499
Mean	423	487

An analysis of variance showed that the only significant effect was the main effect (type of relative clause structure) $F(1,28) = 16.4\ p < .001$. The interaction between lists and relative clause type was not significant ($F < 1$).

A t test taking the sentences as a random variable also gave significant differences ($t(7)) = 2.86\ p < .05$) between the means for subject and object relatives.

Discussion

The results of the first experiment revealed significant differences in the detection times between phonemes immediately following reversible subject relative clauses and those following object relative clauses. Since the factors known to affect phoneme detection times were controlled in this experiment, the differences in the reaction times must be attributed to differences in processing difficulties for the two structures. Thus, it appears that the phoneme monitoring technique can be used in studying syntactic processing. The longer detection times for reversible object relatives are taken to reflect additional mental work which could correspond to the computation of the basic grammatical relationships for the relative clause. Some part of this computation apparently takes place when all the important elements of the object relative clause (the nouns and verb) have been received. Thus, the clausal unit apparently plays an important role in the processing of the object relative clause.

It could, however, be that the differences in processing between the two types of reversible relative clauses also exist within the relative clause. A second experiment in which the phoneme to be monitored was located within the relative clause was conducted to examine this possibility. In addition, another set of sentences containing nonreversible relative clauses was used to study the effect of lexical information on sentence processing. If the processing of syntactic information to determine the grammatical relations is done independently of lexical information, results similar to the ones obtained in the first experiment could be expected. If, on the other hand, lexical information contributes to the process of determining the underlying grammatical relations, then the differences in detection times found after the relative clause boundary for reversible subject and object relatives should be reduced or even eliminated for nonreversible relatives.

EXPERIMENT II

Method

Design and materials. Eight pairs of sentences containing reversible self-embedded relatives were constructed. An example of a pair of reversible relatives is presented in Table 1. The target was the initial phoneme in the noun just *before* the relative clause boundary: such as the /d/ in "docteur" for *a* and *b* in Table 1.

Another eight pairs of sentences containing nonreversible self-embedded relatives were also constructed. As can be seen in *c* and *d* of Table 1, the target (underlined) comes *after* the relative clause boundary: /d/ in "demande."[3] While the second noun was the same for both subject and object relatives ("la revue"), the first noun was generally animate (editeur) for the subject relatives, inanimate for the object relatives. Finally 29 filler sentences were also prepared. All these sentences were compiled on to two lists (with some questions to insure comprehension) such that both lists contained an equal number of reversible and nonreversible subject and object relatives. The rest of the procedure was the same as in the first experiment.

Subjects. Forty-two adults in the Parisian university community served as subjects. Twenty-one subjects were assigned to the first list (L1) and the remaining 21 subjects were assigned to the second (L2). Each subject was paid for his participation in the experiment which lasted about 30 minutes.

Results

The mean reaction times in milliseconds for both the reversible and the nonreversible relatives were computed without the responses that were shorter than 100 milliseconds and longer than 1000 milliseconds (les than 3%). These means are presented in Table 3.[4] As can be seen, there is little difference between the mean reaction times for subject and object relatives for both reversibles and nonreversibles. An analysis of variance showed that the main effect (type of relative clause structure) was not significant for either the reversible relatives ($F_{(1,40)}$ = 1.77) or nonreversible relatives ($F_{(1,40}$ = 0.29). For the two types of relatives, reversible and nonreversible, neither the effect of the list (L1 or L2) nor the interaction between the main factor and the list was significant (Fs $<$ 1).

A comparison of the results for the reversible relatives in experiments I and II was legitimately undertaken, since the majority of the reversible sentences in experiment II were almost identical to those used in experiment I. The results were analysed for the five out of eight sentence pairs in which the noun inside the relative clause was changed in experiment II in order to have a plosive target. The means for these sentence pairs (subject and object relatives) in both experiments I (435, 496 milliseconds)

[3] Two clarifying remarks concerning the French in the linguistic materials should be made: (1) Although the orthography of the targets for the nonreversible sentences (c and d) differs, their pronunciations is identical. (2) In contrast to English where the verb *know* can take either a direct object or a verbal complement, the verb *connaitre* in *a* and *b* takes only a direct object. Thus, a reading of sentence *a*, "The scientist who known (*that*) the doctor works. . . ," is not possible for *connaitre* in French.

[4] An analysis of the recorded responses to the comprehension questions showed that the majority of the sentences were understood correctly. In fact, there were no recorded errors for the nonreversible relatives. The error rate for the questions concerning the reversible relatives was approximately 15%, with a slightly better performance for the subject relatives. For both types of reversible relatives, more errors were made in response to questions about the grammatical relations in the relative clause than in the main clause. These results, taken together, indicate that the subjects were able to perform simultaneously on both tasks: comprehension and phoneme detection.

TABLE 3
MEAN REACTION TIME FOR THE SUBJECT AND OBJECT RELATIVE SENTENCES (REVERSIBLES AND NONREVERSIBLES)

	Subject QUI	Object QUE
	Reaction time (msec)	
Reversible (before clause boundary)	430	422
Nonreversible (after clause boundary)	457	449

and II (421, 418 milliseconds) as well as the difference between the sentence pairs (60 milliseconds in experiment I and 3 milliseconds in experiment II) were comparable to those obtained for all the test sentences in both experiments.

Thus, an analysis of variance (VAR3-structure S ⟨G⟩ × T, Note 4) was performed on the results of experiments I and II using target position as the intersubject factor and the type of relative clause structure as the intrasubject factor. This analysis showed that the former factor did not introduce significant differences ($F_{(1,70)} = 1.53$) while the latter did ($F_{(1,70)} = 3.67$) $p < .05$. More importantly, the analysis revealed a very significant interaction between these two factors ($F_{(1,70)} = 16.71$) $p < .0005$ (see Fig. 1). The specific comparisons confirmed the results of the preceding analyses.

A similar comparison for reversible and nonreversible relatives in experiments I and II was also conducted. The results of this analysis must be interpreted with caution since neither the subjects nor the sentences were the same in the two experiments. While the difference in sentences was unavoidable, the same subjects might have been used. However, including both types of relatives on the same list would imply too many sentences with the same target position and the risk of target anticipation. In addition it must be recalled that the difficulty of these structures makes it undesir-

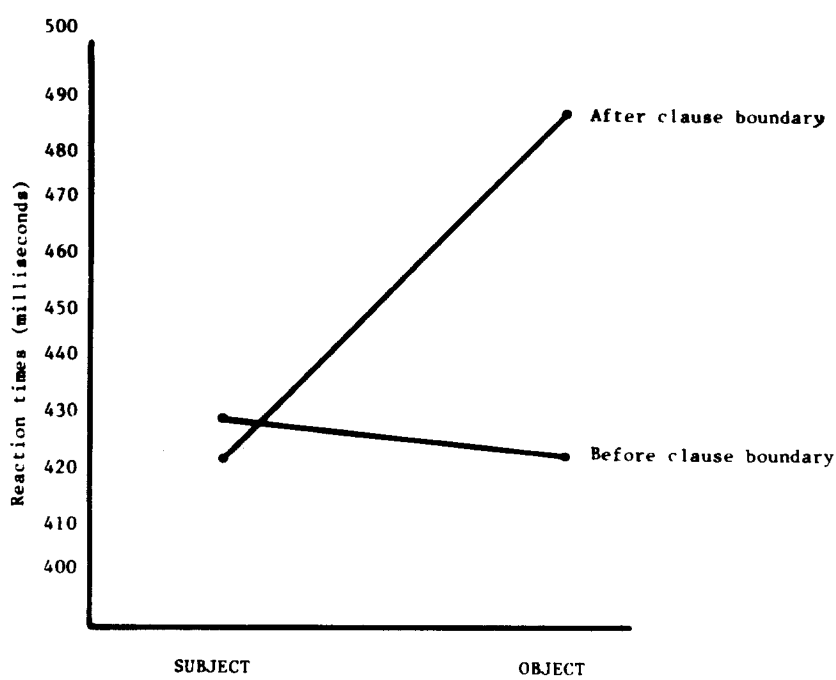

FIG. 1. Phoneme detection times before and after the relative clause boundary of reversible relatives according to their clause structure (subject, object).

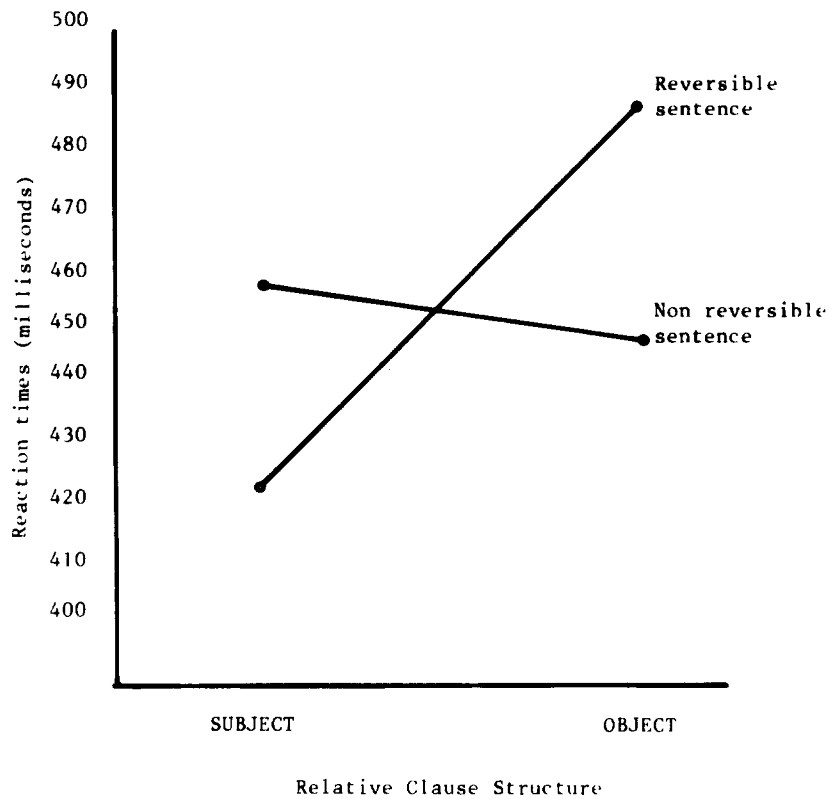

FIG. 2. Phoneme detection times after the relative clause boundary of reversible and nonreversible relatives according to their clause structure (subject, object).

able to include too many relatives (distractors or test items) since the subject's attentional level could be decreased.

The analysis (VAR3) using reversibility as the intersubject factor and type of relative clause structure as the intrasubject factor showed that the main effect, reversibility, did not introduce significant differences ($F_{(1,70)} = .06$), whereas the factor, type of relative clause structure, did ($F_{(1,70)} = 6.23$) $p < .05$. The interaction between the two factors was highly significant ($F_{(1,70)} = 14.03$) $p < .0005$) (Fig. 2). The specific comparisons confirmed the results of the preceding analyses.

Discussion

While the results from experiment I showed that the detection times for targets immediately following the relative clause boundary, are significantly longer for reversible object relatives, experiment II failed to yield significant differences between subject and object reversibles within the relative clause. The contrast between the results obtained within and after the reversible object relative clause suggests that the major structural computation to which the phoneme monitoring task is apparently sensitive is localized at the clause boundary. No evidence for such a computation was found within the relative clause. The similar within clause detection times for subject and object reversible relatives may imply similar overall or total processing difficulty. However, this does not allow us to infer that the nature of the processing for the two structures is identical at this point.

The absence of a difference after the clause boundary for nonreversible relatives suggests that the structural decisions, reflected by phoneme monitoring, were facilitated or even short circuited by the lexical information present in the nonreversibles. It appears that decisions concerning the grammatical roles in the relative clause are based both on syntactic and lexical information.

General Discussion

The major aim of this paper has been to test the validity of the phoneme monitoring technique as a measure of the complexity of syntactic processing. In order to do this, it was necessary to control rigorously all the other nonsyntactic variables known to play a role in the determination of phoneme detection times. For center-embedded relatives in French, such controls are feasible. The results obtained in the first experiment have shown that the time to detect the initial phoneme of the main verb was significantly longer for reversible object relatives than for reversible subject relatives. These results seem to confirm the sensitivity of the phoneme monitoring technique to syntactic processing. However, this technique is perhaps only of limited utility since the controls that are necessary contrain to a large degree the types of structures that can be studied.

The longer phoneme detection times after the reversible object relative can be interpreted in many different ways depending upon one's theory of sentence processing. These theories can generally be classified according to the amount of discontinuity in the syntactic and semantic processing that is assumed (Marslen-Wilson, Tyler, & Seidenberg, 1978). According to an extreme discontinuous processing theory (Bever & Hurtig, 1975), the subject accumulates lexical and syntactic information during the clause and only at the end of the clause computes the underlying grammatical relations. For sentences containing reversible subject relatives, the assignment at the clause boundary of grammatical relations to the accumulated information would be rather straightforward. However, for the object relatives, an additional computation at the clause boundary is necessary perhaps due to the mismatch between the surface (O-V-S) order and the cannonic (S-V-O) order. If, on the other hand, one assumes that sentences are processed in a continuous on-line fashion (Marslen-Wilson & Tyler, 1975) the phoneme detection times could be interpreted somewhat differently. For subject relatives, the grammatical roles would be assigned to the nouns as they are heard with a check at the clause boundary that the correct relational assignments have been made. For object relatives the subject would be misled into assigning an incorrect S-V-O interpretation on the basis of the first animate noun (taken as a subject) and the word order. At the clause boundary the check would reveal the incompatability between the roles assigned and the "que" functor. The calculation necessary to rectify the incorrect structural assignments (Kimball, 1973) would thus be reflected in the longer phoneme detection times.

Unfortunately, neither of the two explanations is entirely satisfactory or complete. In the case of the discontinuous explanation, the nature of the calculation for object relatives needs to be more clearly specified. For the on-line interpretation, it remains unclear why the unambiguous information provided by the relative pronoun "que" was not available or used as it was received to determine the grammatical relations. However, for both these explanations as well as any other possible account of these results, the longer detection times for object relatives would probably be taken to reflect structural decisions concerning the underlying grammatical relations. The difficulty involved in making these structural decisions relates to the complex nature of this kind of object relative. For such structures, the syntactic information in the word order (N-V-N) is, in some sense, contradictory to the information contained in the "que" functor and the available lexical information is not useful for determining the grammatical relations.

Such an interpretaiton is consistent with the results of the second experiment for which there were no differences in the phoneme detection times between the nonreversible relatives. Such a finding suggests that the attribution of the grammatical roles is facilitated by the lexical information in the nonreversible relatives. This information according to a on-line theory, could prevent the subject from incorrectly attributing an S-V-O structure to the object relatives. So, the inanimate character of the first noun could bias the subject towards attributing the role of object rather than subject to this noun. In addition, the meaning of the verb would serve to further confirm this assignment. Since the correct structure could already have been found before the clause boundary, there would be no reason to expect additional mental computations at the clause boundary. The results from the first and the second experiment taken together seem to provide evidence for the influence of semantic constraints upon the extraction of grammatical relations. In the case of such a difficult structure as this kind of object relative, this conclusion is not so surprising. Indeed it is likely that the reliance on semantic cues increases as the syntactic complexity increases (Forster, Note 2).

Finally, it may be instructive to consider the results obtained when the target phoneme was contained within the reversible relative clause. The absence of a difference between the phoneme monitoring times for these two structures suggest that the global processing complexity may be roughly the same. It is, however, premature to infer that the same kind of syntactic processing is going on for both structures. In fact, it has recently been questioned whether phoneme monitoring times are actually a global measure of the total processing difficulty at a given point in the sentence (Cutler & Norris, Note 1). Perhaps this task provides a measure of specific aspects of sentence comprehension. Thus, for example, phoneme monitoring is now especially being used to study the effects of contextual and lexical factors on the lexical access to both the critical and target words. However, in this study, syntactic processing has also been shown to affect phoneme detection times. Future research will hopefully help determine the limits of phoneme monitoring's sensitivity to syntactic factors and clarify the interaction between the higher level syntactic processes and the lexical factors in the determination of phoneme detection times.

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