Lexical effects in phonemic processing: facilitatory or inhibitory ?

FRAUENFELDER, Ulrich Hans, SEGUI, Juan, DIJKSTRA, Ton

Abstract

This article addresses the questions of how and when lexical information influences phoneme identification in a series of phoneme-monitoring experiments in which conflicting predictions of autonomous and interactive models were evaluated. Strong facilitatory lexical effects (reflected by large differences in detection latencies to targets in words and matched nonwords) were found only when targets came after the uniqueness point of the target-bearing word. Furthermore, no evidence was obtained for lexically mediated inhibition on phoneme identification as predicted by the interactive activation model TRACE. These results taken together point to strong limitations in the way in which lexical information can affect the perception of unambiguous speech.

Reference

FRAUENFELDER, Ulrich Hans, SEGUI, Juan, DIJKSTRA, Ton. Lexical effects in phonemic processing: facilitatory or inhibitory ? *Journal of Experimental Psychology: Human Perception and Performance*, 1990, vol. 16, no. 1, p. 77-91

DOI : 10.1037/0096-1523.16.1.77
PMID : 2137525

Journal of Experimental Psychology:
Human Perception and Performance
1990, Vol. 16, No. 1, 77-91

0096-1523/90/$00.75

Lexical Effects in Phonemic Processing: Facilitatory or Inhibitory?

Uli H. Frauenfelder
Max-Planck Institute for Psycholinguistics, Nijmegen, The Netherlands

Juan Segui
René Descartes University and Centre National de la Recherche Scientifique, Paris, France

Ton Dijkstra
Max-Planck Institute for Psycholinguistics, Nijmegen, The Netherlands

This article addresses the questions of how and when lexical information influences phoneme identification in a series of phoneme-monitoring experiments in which conflicting predictions of autonomous and interactive models were evaluated. Strong facilitatory lexical effects (reflected by large differences in detection latencies to targets in words and matched nonwords) were found only when targets came after the uniqueness point of the target-bearing word. Furthermore, no evidence was obtained for lexically mediated inhibition on phoneme identification as predicted by the interactive activation model TRACE. These results taken together point to strong limitations in the way in which lexical information can affect the perception of unambiguous speech.

No one would dispute the claim that we recognize words on the basis of a *bottom-up* analysis of the speech sounds of which they are composed. Controversial, at least in psycholinguistic circles, is the inverse claim that our lexical knowledge contributes in a direct *top-down* fashion to the analysis of the sensory input such that our perception of speech sounds is influenced by the words they make up. In this article we evaluate these claims about the relative importance of bottom-up and top-down processes mediating between the sublexical and lexical levels of representation.

Two main classes of psycholinguistic models can be distinguished according to the way in which they incorporate bottom-up and top-down processes. In autonomous models (Forster, 1979; Garrett, 1978), bottom-up processes produce their outputs without taking into account information from higher levels. Consequently, top-down processes cannot affect or alter the course of the bottom-up analysis. In contrast, interactive models (Cole & Jakimik, 1980; Marslen-Wilson & Tyler, 1980) allow top-down information to influence bottom-up processing at different levels. In this perspective, language comprehension is assumed to involve the integration of information from different levels of analysis (e.g., sublexical, lexical, syntactic, and semantic) without strong constraints.

The relation between top-down information and bottom-up processing is more complex than this simple contrast between autonomous and interactive models suggests. This is evident in the evolution of the distinction between autonomous and interactive models from a dichotomous toward a more continuous one, with increasingly subtle differences between the two model types (cf. the discussion between Norris, 1982, and Tyler & Marslen-Wilson, 1982). Furthermore, there is a growing awareness that the information flow between any two given levels of processing depends heavily upon the specific properties of the processing and representations at each level. Consequently, it is impossible to generalize from observations about the information flow between two particular levels to global patterns of information exchange within the entire language-processing system.

We restrict ourselves here to the information exchange between the sublexical and lexical levels of processing. The relation between these two levels is of particular interest because it constitutes the parade case of interactive models for both theoretical and empirical reasons. Unlike the relation between other levels (e.g., lexical/syntactic, lexical/semantic, or syntactic/semantic), there is a stable part–whole relation between the sublexical and lexical levels (Tanenhaus & Lucas, 1987). A sequence of segments makes up a word in a more constant fashion than, for example, a sequence of words defines a phrase at the syntactic level. In addition, unlike higher order representations that are computed, lexical representations and their component parts are assumed to be stored, a condition making information exchange between these two levels more feasible and likely.

Indeed, there exists a considerable body of empirical findings that points to lexical effects, that is, effects of lexical context on the bottom-up analysis of the speech input. Subjects' phonetic categorization of ambiguous tokens has been shown to be influenced by the lexical status of the carrier string (Ganong, 1980). More recently, Elman and McClelland (1988) also investigated lexical effects with this procedure. In their study, subjects categorized ambiguous word-initial segments (e.g., lying on a d/g continuum as in [d/g]ates). These ambiguous segments were themselves preceded by ambiguous item-final segments (e.g., s/sh), which had only one lexically appropriate reading (e.g., Engli[s/sh]. Normally, listeners categorize word-initial segments by compensating for the coarticulatory influence of the preceding segments. Listeners in the experiment were shown to compensate in their phonetic

Parts of this research were supported by Grant 837B030 from the CNET (Lanion) to Juan Segui, who thanks the Max-Planck Institute for its generous support during his stays in Nijmegen. Ton Dijkstra is now at NICI, University of Nijmegen. We wish to thank A. Cutler, J. L. Elman, W. D. Marslen-Wilson, D. W. Massaro, B. Repp, and an anonymous reviewer for their helpful comments. We would also like to thank M. Lévéillé and C. Agogué for preparing and running the French experiments. An earlier version of this article was presented at the 11th International Congress of Phonetic Sciences, Tallinn, U.S.S.R., 1987.

Correspondence concerning this article should be addressed to Uli H. Frauenfelder, Max-Planck-Institut für Psycholinguistik, Wundtlaan 1, NL 6525-XD Nijmegen, The Netherlands.

responses to the ambiguous item-initial segments, a result suggesting that the lexical level influenced the categorization of the preceding segment. Research exploiting the phoneme-restoration illusion has also provided evidence for lexical effects. Samuel (1981) used signal detection analysis to compare subjects' discrimination performance on two conditions: noise replacing the target phoneme and noise added to this phoneme. Samuel found poorer discrimination between these two conditions when the affected segment was in a word than when in a nonword, a result suggesting a perceptual influence of the lexical level on phonemic processing.

Although these studies provide evidence for top-down effects on phoneme processing, they are not informative about the time course of the lexical effects,[1] that is, when these effects first arise and how they develop across time. In the present study we used the phoneme-monitoring technique, which has also revealed lexical effects on the phoneme identification process (cf. Cutler, Mehler, Norris, & Segui, 1987; Frauenfelder & Segui, 1989). Subjects in this task (first developed by Foss, 1969) are asked to listen to sentences or lists of words and to detect previously specified phoneme targets as quickly as possible. This task leads subjects to construct a sublexical representation that is generally assumed to be phonemic.[2] Furthermore, detection latencies are generally fast, which ensures a close temporal relation between the perceptual process and the overt detection response and thereby provides information about the time course of the lexical effects.

These lexical effects in phoneme monitoring have been interpreted within both autonomous and interactive frameworks. One autonomous model, the race model (Cutler & Norris, 1979), assumes that there are two independent ways in which a phoneme target can be detected. The first procedure depends upon the computation of a prelexical representation on the basis of the sensory input. In the second, target detection depends upon lexical access that makes available the phonological information associated with the accessed lexical entry. There is a race between these two processes, with the one that reaches completion first providing the phoneme-detection response. The presence or absence of lexical effects is explained in terms of the outcome of the race between these two independent and competing procedures.

Interactive activation models, such as TRACE (McClelland & Elman, 1986), have also provided an explicit account of lexical effects. In TRACE there are several levels of interconnected processing units corresponding to distinctive features, phonemes, and words. These discrete yet interacting processing levels are continuously exchanging excitatory activation. Incoming sensory input provides bottom-up excitation of distinctive feature units, which in turn excite phoneme units. As the phonemes become excited, they alter the level of activation of words. These activated words provide positive feedback to the phoneme units they contain by increasing the level of activation of their constituent phonemes. In addition, a phoneme's activation level also depends upon the amount of inhibition it receives from other activated phoneme units. Hence, the recognition of a phoneme (i.e., attaining a criterial level of activation with respect to other phonemes) depends upon the excitatory activation it receives from the feature level and from the lexical level as well as upon the inhibition from other phonemes.

Stemberger, Elman, and Haden (1985) claimed that subjects responding in the phoneme-monitoring task make direct and exclusive use of activated phoneme units. McClelland and Elman (1986) explained the presence or absence of lexical effects in phoneme monitoring within the TRACE framework by assuming that lexical feedback depends upon the level of activation of the lexical units containing the target; only when there is sufficient lexical activation do lexical effects emerge in phoneme-detection latencies.

The essential difference in the explanation that interactive and autonomous models provide for lexical effects resides in the way they assume that the lexical level contributes to phoneme identification. In interactive models, phoneme-detection responses are derived exclusively from the phonemic level of representation, which is affected directly by the lexical level. In contrast, in an autonomous model, phoneme detection is based either on a prelexical representation computed from the signal or on a lexically stored description. Although these two basic model types differ radically in their architecture, they appear to be consistent with much of the data found in the phoneme-monitoring literature. Given this state of affairs, it is critical to collect additional performance data that will allow us to evaluate these two model types. In particular, we address here the questions of when and how lexical and segmental information sources are brought together.

In the first section of this article, we attempt to trace the time course of lexical effects by examining when these effects first arise and how they evolve across time. In the second section, we explore how the lexical level influences phoneme identification. More specifically, we investigate the possibility that lexical information can inhibit phoneme detection. Such inhibition is predicted by TRACE but excluded by the race model. In the final section, we analyze the implications of the results obtained for models of speech perception and lexical processing.

Time Course of Lexical Effects

To characterize the time course of lexical effects, we must determine when lexical information first exerts an influence on the phoneme-identification process and how this influence evolves over time. Although the two classes of models distinguished above make roughly the same predictions concerning facilitatory lexical effects, there are some subtle but important differences in the predicted time course of these effects.

---

[1] Fox (1984) conducted a speeded phonetic categorization experiment with stimuli like those used by Ganong (1980). He found lexical effects for slow responses (RT > 800 ms) but not for fast ones (RT < 500 ms).

[2] The true nature of this sublexical representation and its relation to the representation(s) computed in normal language understanding must still be determined. For the purposes of this article, we assume that a phonemic representation drives the phoneme-monitoring response, but we remain neutral with respect to how closely this phoneme-detection process matches normal comprehension.

According to the race model, the lexical level can begin to influence phoneme detection only after the phonological code associated with the target-bearing word has been recovered. Consequently, lexical effects are expected to emerge rather abruptly because they are contingent upon the discrete moment in time at which the target-bearing item has been recognized. In contrast, for TRACE, the lexical level is involved from the beginning of the perceptual process, but its effect on the phonemic level builds up gradually and continuously as the lexical units themselves receive more and more activation. The strength of the lexical feedback is proportional to the level of activation of the lexical units containing the target phoneme, and hence a lexical unit can provide its phonemes with excitatory feedback before it has been recognized. In summary, according to a race model, lexical effects arise at a discrete moment in time—after word recognition, that is, postrecognition—whereas in TRACE they emerge more gradually, first appearing before the recognition of the target-bearing word, that is, prerecognition.

To evaluate these predictions about the time course of lexical effects, we must be able to establish the moment at which a word can be recognized. The cohort model (Marslen-Wilson, 1984; Marslen-Wilson & Welsh, 1978) represents an important attempt at determining the time course of word recognition. According to this model, the sensory input corresponding to the initial sounds of a word activates the set or cohort of those words compatible with this information. This cohort is then successively reduced in membership, as the word candidates that mismatch later arriving sensory information drop out. This process continues until only one word remains compatible with the input, and it is at this moment that the word is recognized. Within this framework, it is possible, with additional assumptions (e.g., about the units of analysis—features, phonemes, or syllables—and about the required goodness of fit), to specify the recognition point[3] of any given word.

The recognition point has been shown in several studies (Grosjean, 1980; Tyler & Wessels, 1983) to be a good predictor of the moment at which a word is effectively recognized. Most relevant for the discussion here is a phoneme-monitoring study conducted by Marslen-Wilson (1984). This research contrasted the performance of two groups of subjects on the detection of phonemes located in different positions within words or nonwords. In the experiment containing lists of only nonwords, detection times (measured from target phoneme onset) did not vary as a function of target position. In the experiment with word lists, the detection times decreased as the targets were located later within the target-bearing words. The detection latencies to these targets were strongly correlated with the temporal distance separating the targets from the recognition point of those words, and this was true even for the targets in word-initial position. For this position, an inverse lexical effect was found, with word-initial targets being detected more slowly than nonword-initial targets. This inverse lexical effect suggests that subjects detecting word-initial targets waited until they recovered the lexical code despite the fact that they could have responded more quickly with the prelexical information, as the faster results for the comparable nonwords attest.

These results show that the recognition point provides a good indicator of the moment at which word recognition takes place, and they suggest that subjects adopt two mutually exclusive strategies, depending upon the lexical status of the experimental items. They detect phoneme targets in words on the basis of lexical information and targets in nonwords by using prelexical information. If the information source used in the detection response is determined by the lexical status of the target-bearing item, phoneme monitoring is more appropriate for studying the time course of word recognition than for examining the relative contribution of lexical and prelexical information sources to phoneme detection in words.

However, we want to show here that the results obtained by Marslen-Wilson (1984) were conditioned by the nature of the experimental lists he used. Homogeneous lists (only words or nonwords) led his subjects to rely on a specific type of information (lexical or prelexical). Because our objective is to study the relative contribution of lexical and prelexical information to phoneme identification, we must prevent subjects from relying on a particular information type and allow both to contribute to the phoneme-detection response. To do so, we propose to use mixed experimental lists that are made up of both words and nonwords. Under these experimental conditions, subjects cannot know which information source is most useful for making their phoneme-detection response, and they should therefore rely more equally on both.

---

[3] We can distinguish at least two different ways of operationalizing the recognition point. Unfortunately, both depend upon a number of difficult and somewhat arbitrary decisions. The first, the dictionary recognition point, or what we prefer to call the *uniqueness point*, is defined by using a phonetic dictionary. This is the point at which a word's initial sequence of phonemes is shared by no other word listed in a phonetic dictionary. Clearly crucial in determining the uniqueness point is deciding what constitutes an entry in the dictionary. First, we are confronted by the morphological question of whether derivationally or even inflectionally related words should be included in the computation of the uniqueness point. Generally, morphologically related words are not included in the computation of the uniqueness point. Thus, the uniqueness point can better be viewed as the "family uniqueness point," that point at which only the members of the morphological family remain in the cohort. Second, we must deal with word frequency, that is, how frequent or familiar the words must be to be included in the uniqueness point computation. It is common practice to exclude extremely rare words. Finally, once the phoneme defining the uniqueness point is established, we must determine where this phoneme begins. Coarticulation between this phoneme and the preceding phoneme complicates locating the uniqueness point precisely.

The recognition point can also be determined empirically with the gating procedure (Grosjean, 1980) producing the *gating recognition point*. In this procedure, subjects hear increasingly large fragments of each word (e.g., increases of 50 ms of signal per gate) and must report which word they thought they were hearing, along with a confidence rating. This procedure gives an estimation of the amount of stimulus information subjects needed to correctly identify the word. Again, several arbitrary decisions must be made for the determination of this point: whether confidence ratings should be included and which percentage of subjects must have correctly identified the word.

Experiment 1

To trace the time course of lexical effects, we placed phoneme targets in different positions with respect to the recognition point of the target-bearing word. We took the recognition point to correspond to the uniqueness point (UP), which was defined as that point in a word at which its initial part is shared by no other morphologically unrelated word in a phonetic dictionary. Two target positions were selected before the uniqueness point (at word onset and before the uniqueness point); two target positions, after this position (after the uniqueness point and at word offset). A nonword was derived from each of the target-bearing words, with the target and its local environment kept constant. We assumed that the difference in the detection times to the same targets in matched words and nonwords for the different target positions provides a measure of the lexical contribution and its evolution across time. Thus, we intended to determine how lexical effects evolve across time and particularly whether they emerge before or after the uniqueness point as TRACE and race models, respectively, predict.

Method

Subjects. Thirty-eight undergraduates at the University of Nijmegen, all native speakers of Dutch, were paid for their participation in the 1-hr experiment.

Materials. The test stimuli (shown in the Appendix) consisted of 120 Dutch words and 120 matched nonwords that were all at least bisyllabic. The nonwords were derived from the words by replacing two to four phonemes by phonemes that differed from the original ones by one distinctive feature. The local environment of the phoneme target in the words and nonwords was kept similar, because other studies (Cutler, Butterfield, & Williams, 1987; Foss & Gernsbacher, 1983; Treiman, Salasoo, Slowiaczek, & Pisoni, 1982) have shown that a target's local environment affects its detection time. Every nonword also had the same stress pattern as its matched word.

The target phonemes, the voiceless stops (/p/, /t/, or /k/), were located in four different positions with respect to the uniqueness point (UP) of target-bearing words: at word onset, before the uniqueness point, after the uniqueness point, and at word offset. The uniqueness point was taken to correspond to that point in a word at which its initial part is shared by no other morphologically unrelated word in a phonetic dictionary. Targets in nonwords were located in the same serial position as in the matched words but were identified with respect to the nonword point: at nonword onset, before the nonword point, after the nonword point, and at the nonword offset. The nonword point (NWP) was defined as that point moving from onset to offset at which the item becomes a nonword. Table 1 shows examples of the test stimuli containing /p/ targets as well as the average distance for all stimuli (measured in phonemes) separating the targets from the uniqueness point in words and from the nonword point in nonwords.

In addition to the 240 target-bearing test stimuli, another 120 target-bearing words and nonwords were included as filler items. These monosyllabic and bisyllabic items had their targets located in initial or final position. An additional 380 words and nonwords (of different lengths) that did not contain the phoneme target were also used. These fillers without targets were placed, along with the target-bearing items, in 12 different lists (4 lists for each of the three phoneme targets). Each list was made up of 60 items (20 test items, 10 target-bearing filler items, and 30 filler items not containing the target). The 12 lists were divided into two blocks; each block contained two lists for each of the three phoneme targets. The test words and matched

Table 1
Examples of Stimuli for Experiment 1

Target Position	Word	Distance	Nonword	Distance
Item onset	Pagina	−3.9	Pafime	−3.1
Before UP/NWP	oPeratie	−2.5	oPelakoe	−1.6
After UP/NWP	olymPiade	+2.3	arimPiako	+2.3
Item offset	bioscooP	+2.7	deoftooP	+3.6

Note. UP = uniqueness point; NWP = nonword point.

nonwords were assigned to experimental lists such that their order of presentation was counterbalanced across the two blocks. Finally, a practice list with the target /s/ was also created. This list contained 20 items similar in structure to the experimental lists.

The practice and experimental lists were recorded in a soundproof room by a male native speaker of Dutch at a rate of one item every 4 s. A 1000-Hz warning tone preceded each item by 2 s.

Procedure. Subjects were tested in groups of 4. They were told they would hear lists of words and nonwords and were asked to make a speeded detection response (with their preferred hand) to target phonemes, which could occur in any position in the target-bearing items (see Frauenfelder & Segui, 1989, for further discussion of this technique). Targets were specified to the subjects both auditorily before each list (by including phrases like "listen now to the sound /p/ as in Paul") and visually by means of a booklet of index cards that subjects had in front of them.

Pulses, inaudible to the subjects, were placed electronically on the second track of the tape at the onset of every target-bearing item. The temporal distance separating pulses from the closure and burst of the target phonemes was determined visually on the screen of an oscilloscope and used to correct the measured reaction times. These pulses triggered a clock in a minicomputer, which was stopped by the subjects' response.

Results

Mean reaction times (measured from the burst of item-initial targets and from the beginning of closure for the targets in the remaining three positions) were computed for each subject and each experimental item. All responses less than 100 ms or greater than 1,000 ms were replaced by the means of the item and subject means for the relevant condition. Three subjects with more than 15% errors were excluded from the analysis, as was one experimental item that had been mispronounced. Figure 1 shows the results for words and nonwords broken down according to target position with respect to the uniqueness point.

The mean reaction times (RTs) were submitted to an analysis of variance, with the lexical status (word vs. nonword) of the target-bearing item and the target position (Positions 1 to 4) as the principal factors. There were significant main effects in the by-subject (F_1) and the by-item (F_2) analyses of both lexical status, $F_1(1, 34) = 371$, $p < .001$ and $F_2(1, 29) = 94$, $p < .001$ and target position, $F_1(3, 102) = 136$, $p < .001$ and $F_2(3, 87) = 88$, $p < .001$. The interaction between these two factors was also highly significant, $F_1(3, 102) = 168$, $p < .001$ and $F_2(3, ,87) = 39$, $p < .001$. Planned comparisons for the effect of lexical status for targets located in the two positions before the uniqueness point showed a significant effect by subject, $F_1(1, 34) = 5.03$, $p < .05$ but not by item ($F_2 < 1$) whereas the lexical effect was highly significant for the targets placed in the two positions after the uniqueness point both by subject, $F_1(1, 34) = 430$, $p < .001$ and by item,

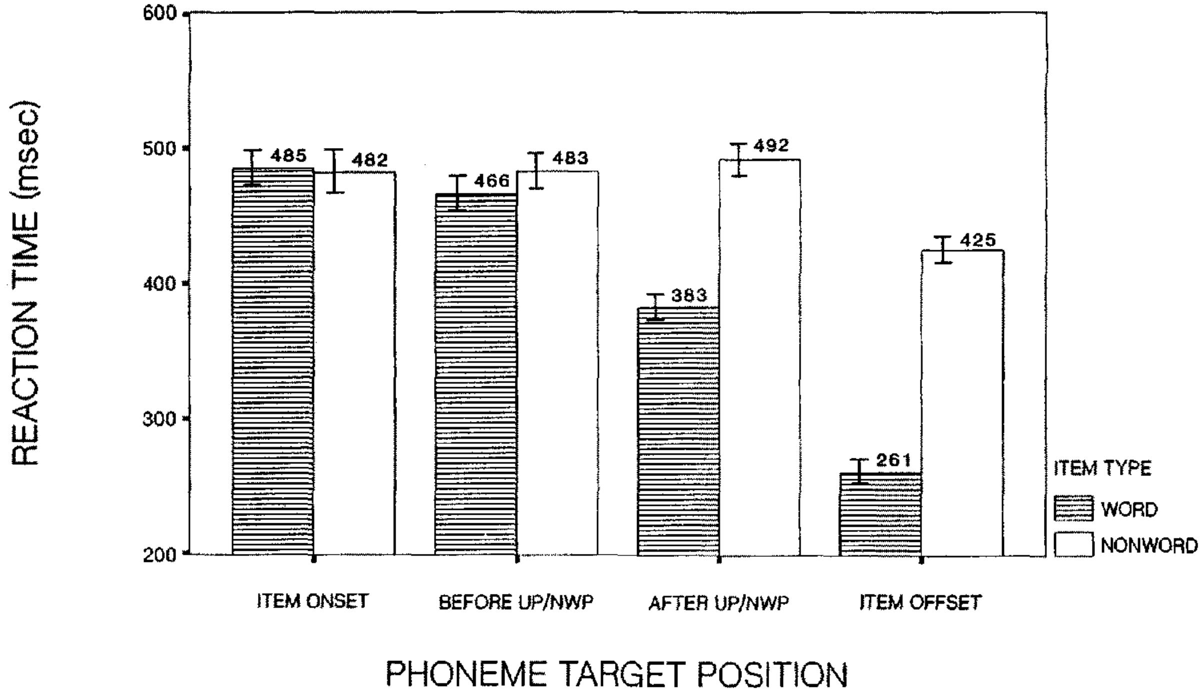

Figure 1. Mean reaction time for phoneme targets in words and matched nonwords as a function of their position: item onset, before UP/NWP, after UP/NWP, and item offset. (The vertical lines show *SE*. UP = uniqueness point; NWP = nonword point.)

$F_2(1, 19) = 119$, $p < .001$. Finally, more detailed planned comparisons for each separate target position revealed no effect for the first position ($F < 1$), a marginally significant effect for the second position, $F_1(1, 34) = 19.7$, $p < .001$ and $F_2(1, 29) = 2.2$, $p = .15$, and strong effects for the third position, $F_1(1, 34) = 214$, $p < .001$ and $F_2(1, 29) = 71$, $p < .001$ and the fourth position, $F_1(1, 34) = 415$, $p < .001$ and $F_2(1, 29) = 102$, $p < .001$.

Discussion

In this experiment we have taken the difference in the detection times of phoneme targets in matched words and nonwords as a measure of the lexical contribution to the phoneme-detection process and have examined the evolution of this contribution as a function of target position. The general pattern of results revealed that the uniqueness point played a pivotal role in the determination of the lexical effect, with extremely robust effects for the targets located after the uniqueness point and no or only weak effects for the targets before the uniqueness point. This overall pattern is globally consistent with the predictions of both the race and the interactive activation models. For the former, the lexical level contributes to the phoneme-detection response only after the phonological code of the target-bearing word becomes available. In TRACE, the level of activation of the target-bearing word should increase after the uniqueness point, and consequently so does the lexical feedback to the constituent phonemes. As McClelland and Elman (1986, p. 32) put it, "In TRACE things are not quite so discrete. However, it will still generally be the case in TRACE that the size of the lexical effect will vary with the location of the 'unique point'."

A position-by-position analysis revealed a somewhat more complicated pattern in the evolution of the lexical effects across time. In particular, there was a weak lexical effect for the targets located before the uniqueness point (i.e., the second position). Such an effect is inconsistent with the race model but is predicted by TRACE for which the activated lexical units can begin to excite their constituent phonemes before a single lexical unit has been recognized.[4] Furthermore, TRACE predicts these effects to be relatively weak compared with those after word recognition for which lexical activation and the resulting feedback are much stronger.

Because the predictions of the two models we are contrasting diverge most clearly concerning the existence of lexical effects before the uniqueness point, it is crucial to establish the validity and reliability of these small effects. Unfortu-

[4] It should be noted that the versions of the race model and TRACE model presented here are not the only ones possible. Although these results are inconsistent with the version of the race model sketched above that exclude lexical effects before word recognition, there exist variants that could predict such early effects. Such models arrange processes not in discrete stages but rather in a cascade fashion (McClelland, 1979). Each process is continuously supplying its partial outputs to the next higher level of processing. Norris (1982, 1986) developed an autonomous model with this feature to explain the effects of sentential context on word recognition. This model could be extended to allow the activated lexical candidates to influence the phoneme-detection process. One can also imagine alternative versions of the TRACE model in which top-down feedback is slow to exert its influence, and consequently lexical effects emerge only after the UP. Nonetheless, we would maintain that the versions of the TRACE and race models presented here are the most representative of the two respective model types.

nately, however, the interpretation of these results is complicated by the difficulty encountered in determining a psychologically valid definition of the uniqueness point. Indeed, this definition depends upon a series of assumptions about the subject's lexicon. As the size of the lexicon is bound to vary across subjects, the uniqueness point moves earlier or later in the word, depending upon whether the subjects know certain words. This variation in the uniqueness point across subjects could contribute to the small lexical effects observed for the second position.[5]

To determine more precisely whether the small difference in the detection times of phonemes located in the second position in words and nonwords actually reflects lexical involvement before word recognition, we conducted some additional analyses. These analyses were based on a new definition of UP, which we hoped was psychologically more reliable. Three native Dutch speakers were first asked to determine the phoneme at which each target-bearing test word became unique. Subsequently, a trained listener located the physical onsets and offsets of these phonemes in the speech signal of the experimental items. Finally, we examined the relation between phoneme-detection latencies for targets located in the second position and the distances separating these targets from the refined UP. These analyses did not reveal any significant correlations between these two measures. The absence of significant correlation in these analyses suggests that the detection responses to the targets in the second position are not affected by lexical information.

Finally, we found no difference in the detection times to targets in the initial position of words and nonwords. The absence of a lexical effect here suggests that the detection of these phonemes is not influenced by lexical information. These results are consistent with those obtained previously by other researchers (Foss & Blank, 1980; Segui, Frauenfelder, & Mehler, 1981), who failed to obtain effects of lexical status for item-initial targets in polysyllabic items. They are also compatible with the predictions of both autonomous and interactive models. In the former, the prelexical code should win the race and trigger the response, and for TRACE, the phoneme unit corresponding to the target should trigger a detection response before sufficient lexical activation has accumulated to provide it with feedback.

It should be noted, however, that the absence of a lexical effect for the first position contrasts with the inverse lexical effect obtained by Marslen-Wilson (1984) for the same position. The conflict between these two experimental findings can be resolved if the experimental list is assumed to play a role in determining the type of information subjects use in detecting phonemes. Subjects confronted with homogeneous word lists, as was the case in the study by Marslen-Wilson, are led to adopt a purely lexical strategy for every target position. Consequently, even for word-initial targets, subjects wait to recover the lexical information and respond more slowly than if they were responding on the basis of prelexical information. The situation is quite different when subjects receive heterogeneous lists of words and nonwords. Here, the contribution of prelexical or lexical information is conditioned by the availability of each when the target phoneme arrives. For the targets in the first position, no lexical information is yet available to influence the detection times, and hence there is no lexical effect.

The strong influence of list structure on the pattern of results obtained for these two experiments indicates that phoneme identification is not invariant. Variability in the subjects' performance as a function of task demands has been explained recently by appeals to attentional processes not only for phoneme monitoring (Cutler, Mehler, Norris, & Segui, 1987; Segui & Frauenfelder, 1986) but also for other related tasks such as phoneme restoration (Nusbaum, Walley, Carrell, & Ressler, 1982; Samuel & Ressler, 1986). Thus, for instance, Cutler, Mehler, Norris, and Segui (1987) proposed an extended version of their race model in which they include mechanisms of attention switching to account for the presence or absence of lexical effects. Listeners are assumed to shift their attention between the lexical and prelexical codes as a function of task demands. The detection response is derived from the code the listener is paying attention to.

Cutler, Mehler, Norris, and Segui (1987) argued that serial autonomous models provide a more natural account of the variability in the lexical contribution to phoneme monitoring than the interactive models. In particular, they claimed that their race model with two response "outlets" straightforwardly allows attentional shifts caused by the specific properties of the experimental situation to control the outcome of the race. In contrast, interactive models, such as the one proposed by Stemberger et al. (1985) with a single response "outlet" at the phonemic level, cannot appeal to shifts between outlets. Such connectionist models can account for the variability in lexicality effects by modifying the weightings of bottom-up and top-down connections as a function of the task demands. This solution has the negative consequence of multiplying the number of additional parameters in the model to make it even more powerful and less testable. In the absence of clear empirical results favoring one model over the other, Cutler, Mehler, Norris, and Segui based their preference for autonomous models on arguments concerning the naturalness or elegance with which such models can account for the experimental results. Whereas similar arguments might be made on the basis of the differential effect of list structure on item-initial phoneme detection, it is clearly preferable to obtain further empirical results that provide a more direct test of these models.

In the following section we examine more closely how lexical information affects phoneme identification. In particular, we explore whether in addition to a facilitatory effect shown in the preceding experiment, the lexical level can also exert an indirect inhibitory effect on the phoneme detection. This is especially interesting because the two models described

[5] When a given subject does not know words that were included in the definition of the target-bearing word's uniqueness point, the uniqueness point will be moved earlier in the word. This shift in the uniqueness point decreases the distance between the target in second position and the uniqueness point and may even lead to cases in which the target follows the assumed uniqueness point.

above make different predictions about the existence of such effects.

Inhibitory Lexical Effects

The original interactive activation model developed for visual word recognition (Rumelhart & McClelland, 1982; McClelland & Rumelhart, 1981) included excitatory and inhibitory connections between nodes at different levels. Subsequent models constrained the information flow by having only excitatory connections between units at different levels and inhibitory connections between units at the same level; for example, TRACE allows the lexical level to excite but not to inhibit the phoneme level, whereas it allows phoneme units to inhibit other phoneme units but not to excite them. It is important to note, nonetheless, that this model predicts indirect inhibition from the lexical level to the phoneme level through the combined effects of positive lexical feedback to the phoneme level and within-level inhibition between phoneme units. The race model, in contrast, does not allow for inhibitory effects. The two competing detection procedures function completely independently so that the lexical code can never affect the computation of the prelexical code.

We tested for the existence of such inhibition by making the lexical information incompatible with the bottom-up evidence for the target. French[6] subjects were asked to detect a target phoneme that appeared in the place of a lexically appropriate phoneme; for example, we replaced the phoneme /l/ in *vocabulaire* by the target phoneme /t/ producing *vocabutaire.* Because the original target phoneme /l/ was located after the uniqueness point of the target-bearing item, TRACE predicts that it receives excitatory feedback from the lexical level by the time the uniqueness point has been reached. It should be recalled that the previous experiment demonstrated the existence of strong lexical effects for targets in this position. This lexically activated but physically absent phoneme should begin to inhibit other phonemes, including the substituted target phoneme /t/ that actually occurs at its place in the nonword sequence. When the target phoneme arrives, it is already inhibited by the lexically activated phoneme /l/. This lexically incompatible phoneme target should be less activated than the same phoneme /t/ with the same local environment "/ytE/" in a control nonword such as *socabutaire* in which the target presumably receives neither top-down excitation nor lateral inhibition. If there is lexically mediated inhibition as predicted by TRACE, then one would expect slower phoneme-detection latencies to the lexically incompatible targets than to targets in control nonwords. Actual TRACE simulations (Peeters, Frauenfelder, & Wittenburg, 1989) confirmed these predictions.

The race model predicts no inhibition in the specific instance of our experiment. The lexical code of the word *vocabulaire* cannot contribute at all to the detection of the target /t/ in *vocabutaire*, because this lexical code does not contain the target phoneme in question. The targets in both types of nonwords must be detected solely on the basis of the prelexical code, and thus the race model predicts no difference between the detection times for targets in the two nonword conditions.

Experiment 2

Method

Subjects. Sixteen students of the University of Paris V, all native speakers of French, participated in the experiment voluntarily.

Materials. Twelve matched pairs of inhibiting (INW) and control (CNW) nonwords were constructed in the following fashion (see Appendix). Each inhibiting nonword was created by replacing a phoneme located after the uniqueness point of three- or four-syllable words by the target phoneme. The resulting sequence was a nonword with its nonword point at the target phoneme; for example, the phoneme, /l/, in the word *vocabulaire* was replaced by the target phoneme, /t/ to make the target-bearing nonword *vocabutaire.* The phonological distance between the original and the substituted target phoneme was always at least two distinctive features. The target phonemes, /p/, /t/, and /k/ were substituted for /l/ or /r/, /n/ or /z/, and /r/ or /z/, respectively.

A control nonword was derived from each inhibiting nonword by replacing the initial phoneme of the inhibiting nonword by another phoneme, which generally came from the same broad phonological class as the original phoneme (e.g., stops replaced stops) but differed in place of articulation and/or voicing. The nonword point of the resulting control nonwords came well before the target phoneme, generally at the end of the first syllable. Thus, for example, from the inhibiting nonword *vocabutaire*, we derived the matched control nonword *socabutaire* whose nonword point is at its fourth phoneme.

Three experimental lists, one for each of the target phonemes, were constructed. Each list consisted of 45 words and 45 nonwords. In addition to the 8 test target-bearing items (4 inhibiting nonwords and 4 control nonwords) in each list, there were also 20 target-bearing fillers (10 words and 10 nonwords). Eight of these distractors had their target phoneme in roughly the same position as the test items, whereas targets occupied either the first or last position of the remaining items. The other 62 filler items in each list did not contain a target phoneme. Each list was so constructed that the order of presentation of matched test items was counterbalanced and that matched target-bearing nonwords were always separated by at least 15 intervening items.

The three experimental lists were recorded in a soundproof room by a female speaker of French at a rate of one item every 2 s. A practice set of 15 items of similar composition was also recorded. Timing pulses were aligned at the beginning of the burst of every target phoneme of the experimental items by means of a digital oscilloscope.

Procedure. The practice list and the three experimental lists were presented in counterbalanced order to individual subjects over stereo headphones. Subjects received written instructions informing them that they would hear lists of words and nonwords and that their task was to detect a previously specified phoneme target as quickly as possible. Targets were specified before each list on the tape by using sequences like /p/ as in *Paris* or *piloffe.* A timing pulse, inaudible to the subject, triggered an electronic clock in a minicomputer. The clock was stopped by the subject's keypress response.

Results

Mean RTs for each experimental item and each subject were computed; responses shorter than 100 ms or longer than

[6] The switch from Dutch to French was based on convenience and not on any expectations of language-processing differences. Indeed, we did not expect the nature of lexical effects to differ across these two languages.

1,000 ms were omitted. The omitted responses (3.3% of the total data) were equally distributed over inhibiting and control nonwords. The mean RTs were 451 ms for inhibiting nonwords and 449 ms for control nonwords. An analysis of variance, with the factors nonword type (inhibiting nonword vs. control nonword) and phoneme target (/p/, /t/, /k/), showed no statistically significant main effects. The interaction between these two effects was also not significant ($F <$ 1).

Discussion

The absence of RT (and error) differences between the two nonword types suggests that there is no measurable lexically mediated inhibition on the target phoneme. Although the phoneme target was incompatible with the information provided by the lexical context, there was no delay in the detection times relative to the control nonword condition. These results are inconsistent with the prediction of TRACE, which allows lexically mediated inhibition of target phonemes, but they are consistent with the race model in which the detection response for both types of nonwords is based exclusively on the prelexical code.

Before rejecting lexically mediated inhibitory effects on the basis of this null result, we must exclude two alternative explanations. According to the first, we obtained no RT difference because subjects adopted a purely prelexical response strategy for both nonword types despite the presence of target-bearing words in the experimental list. According to the second, we obtained no difference because the control nonwords produced inhibition of approximately the same magnitude as that for the inhibiting nonwords. Because the control nonwords were quite similar to the original words, they might have activated these words to produce lexically mediated inhibition. Indeed, in constructing the matched nonword stimulus pairs, we changed only the initial phoneme of the inhibiting nonwords to derive the control nonwords. We kept the item pairs and especially the local environment of the phoneme targets as similar as possible to be sure that any RT difference obtained would be attributable to lexically mediated effects and not to some other contaminating factor.

According to the cohort model, even a small difference in the item-initial phoneme between the two nonword conditions is sufficient to guarantee that they are processed differently. Control nonwords that mismatch the original lexical item in their initial phoneme are assumed never to enter into contention for recognition. This assumption is not shared by all models of word recognition. TRACE, for example, allows words that mismatch the input in their initial parts to be activated and to compete for recognition. However, even for TRACE, the control nonwords would receive less activation than the inhibiting nonwords, so that detection latency differences are predicted.

In order to reject the second explanation for the null result and at the same time to show that subjects are processing the stimuli lexically, we conducted a further experiment. In this experiment we introduced another condition in which we compared the detection times to targets located after the uniqueness point in words and after the nonword point in matched nonwords. The items differed in the same way as the nonwords in Experiment 2, that is, only in their initial phoneme (e.g., the /t/ target in *gladiateur* vs. *bladiateur*). If we obtain a difference in phoneme detection times between these words and nonwords and simultaneously no inhibition for the inhibiting nonwords, we can reject these two alternative explanations. A lexical effect would not only confirm that subjects are processing the items at the lexical level but also would show that the minimal phonological deviation in the initial phoneme of the nonword prevents it from activating the word from which it is derived. By extension, we could conclude that the control nonword also does not activate the lexical entry from which it is constructed and thus provides a good control for evaluating lexically mediated inhibition.

Experiment 3

Method

Subjects. Twenty students of the University of Paris V, all native speakers of French, participated voluntarily in this experiment.

Materials. The experimental materials were identical to those used in the previous experiment with the exception that the 24 target-bearing distractors were replaced by 24 matched test items (four words and four nonwords per experimental list) that constituted the lexical condition (see Appendix). The target phonemes (/p/, /t/, /k/) were located after the uniqueness point of the words (e.g., the target phoneme /t/ in the word *gladiateur*). The matched nonwords were derived from these words by replacing the initial phoneme of each word by another phoneme differing in three distinctive features or less. The nonword points of the resultant matched nonwords came well before the target phoneme (e.g., at the /d/ in the nonword *bladiateur*). Table 2 shows examples of the test stimuli with /t/ targets in the inhibition and lexical conditions.

Procedure. The experimental procedure was identical to that used in Experiment 2.

Results

As in the previous experiment, mean RTs for each subject and each item of the four experimental conditions were

Table 2
Examples of Stimuli for Experiments 3 and 4

Condition	Stimulus
Experiment 3	
Inhibition	
Inhibiting nonword	vocabuTaire
Control nonword	socabuTaire
Lexical	
Word	gladiaTeur
Matched nonword	bladiaTeur
Experiment 4	
Inhibition	
Inhibiting nonword	simpliciDé
Control nonword	fimpliciDé
Lexical	
Word before UP	profiTable
Word after UP	ouverTure

Note. UP = uniqueness point.

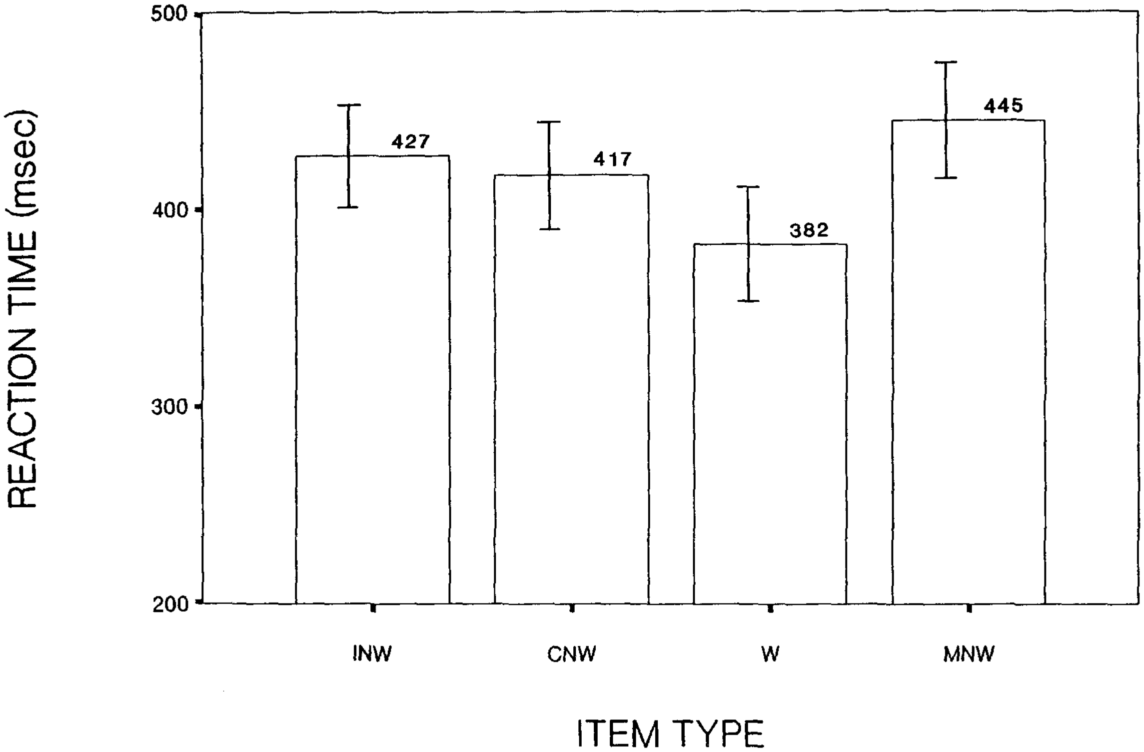

Figure 2. Mean reaction time for phoneme targets in inhibiting nonwords (INW) and control nonwords (CNW) and for targets in words (W) and matching nonwords (MNW). (The vertical lines show *SE*).

computed, with responses shorter than 100 ms or longer than 1,000 ms omitted. The omitted responses for the inhibition condition were less than 2% of the total data and were equally distributed over the two nonword types. For the lexical condition, a similar pattern of error data was obtained. The results for the inhibition and lexical conditions are summarized in Figure 2.

A two-way analysis of variance, with item type (inhibiting nonword and control nonword) and type of target phoneme (/p/, /t/,/k/) as within-subjects factors, revealed no significant main effect. The interaction between these two factors was not significant either. A two-way analysis of variance for the lexical condition, with item type (word item and matched nonword) and target phoneme type, was also conducted. The factor, item type, introduced significant differences, $F_1(1, 19) = 20.05$, $p < .005$ and $F_2(1, 9) = 8.80$, $p < .02$, whereas target phoneme type was significant in the subject analysis only, $F_1(2, 38) = 12.06$, $p < .005$.[7] The interaction between these factors was not significant, $F(2, 38) = 1.13$.

Discussion

The results for the inhibition condition replicate those obtained in the second experiment and confirm the absence of lexically mediated inhibition. This finding cannot be attributed to subjects not processing the items lexically because the lexical condition of the same experiment revealed a strong facilitatory lexical effect. Furthermore, because this lexical effect was obtained for words and nonwords differing only in their initial phoneme, we can conclude that the small modification that produced the nonword was sufficient to prevent this nonword from activating the word from which it was derived. This result suggests that the absence of a difference in detection latencies to targets in the inhibition condition cannot be attributed to comparable inhibition in both inhibiting and control nonwords but must be due to the absence of inhibition in both.

The results of the lexical condition are interesting in their own right because they are informative about the effect of mismatching information on lexical activation. They lend support to the cohort model, which makes strong assumptions about the importance of word onsets in generating word candidates and of mismatching information in eliminating these candidates from the cohort. It appears that a mismatch in the initial segment of an item is sufficient to prevent that sequence from being recognized as a word. These findings are consistent with other results recently obtained (Marslen-Wilson & Zwitserlood, 1989) with the cross-modal priming pro-

[7] It is interesting to note that the effect of phoneme type is essentially due to the slower detection of the phoneme /k/ in words, compared with the other target phonemes (448 ms for /k/ vs. 354 ms for /p/ and 343 ms for /t/). The phoneme /k/ is realized orthographically in French by the letters c, k, or qu. The RT difference between this phoneme and the others has not been observed for the nonword items. This suggests that the responses given to word items are influenced by the corresponding orthographic representations of the words.

cedure. Those experimenters compared the amount of priming in lexical decision latencies produced by a rhyme prime (a prime differing only in its first phoneme from the word that is semantically associated with the visual probe) with that generated by the original word itself. The results showed that the rhyming items (both words and nonwords) were much less effective primes than the original word and that they did not allow access to the original word.

As we pointed out above, the absence of lexical inhibition effects runs counter to the predictions of TRACE. However, as simulations confirm (Peeters et al., 1989), TRACE also predicts that the recognition of a phoneme target should vary as a function of the phonological distance separating it from the original lexically appropriate phoneme; the more similar the two are, the more difficult it should be to discriminate between them. It is possible that inhibitory lexical effects did not emerge in the preceding two experiments because the phonological distance between the original and the substituted target phonemes (more than two distinctive features) was too large, and as a consequence the lexically activated phoneme did not have a strong enough influence on the target phoneme to be measured. In the next experiment, we investigated this possibility by decreasing the phonological distance between targets and lexically activated phonemes to one distinctive feature—that of voicing.

Experiment 4

Method

Subjects. Eighteen students of the University of Paris V, all native speakers of French, participated voluntarily in this experiment.

Materials and procedure. Twelve matched pairs of inhibiting nonwords and control nonwords (four pairs for each of the three targets, /d/, /t/, /k/) for the inhibition condition were constructed by the procedure used in the preceding experiments with the exception that the phonological distance between the replaced and target phonemes was reduced to the single distinctive feature of voicing (see Appendix). Thus, for example, the inhibiting nonword *simplicidé* was derived from the word *simplicité* by replacing the original phoneme /t/ by the target phoneme /d/.

Matching control nonwords again were derived from each inhibiting nonword by replacing the initial phoneme of the inhibiting nonword by another phoneme of the same manner of articulation (e.g., the control nonword *fimplicidé* was created from the inhibiting nonword *simplicidé*). All nonword points of the control nonwords were located close to the end of the second syllable, well before the target phoneme.

Eighteen target-bearing words (6 for each target type) were also included in the experiment to confirm the existence of lexical effects. In half of these words, the target phoneme was located before the uniqueness point (e.g., the target phoneme /t/ in *profitable*), and in the other half the target came after the uniqueness point (e.g., the target phoneme /t/ in *ouverture*). Table 2 also gives examples of the test stimuli used in this experiment with targets /d/ and /t/ in the inhibition and lexical conditions, respectively. These target-bearing words and nonwords were embedded in one of three experimental lists of 64 items each (32 words and 32 nonwords). In addition to the 21 words and 21 nonword filler items that did not contain a phoneme target, 3 words and 3 nonwords with targets in initial positions were included to vary the position of the target.

The experimental procedure was identical to that used in Experiment 2.

Results

In computing the mean RTs for the inhibition and lexical conditions, we eliminated latencies shorter than 100 ms or longer than 1,000 ms. For the inhibition condition, the omitted responses (approximately 5% of total data) were equally distributed across the two conditions. For the lexical condition, less than 3% of the data were eliminated. Figure 3 summarizes the overall results for both the inhibition and lexical conditions.

An analysis of variance performed on data from the inhibition condition indicated that neither the factor nonword type (inhibiting nonword vs. control nonword) nor the type of target phoneme (/d/, /t/, /k/) introduced significant effects ($F < 1$ in both cases). The interaction between these factors was also not significant, $F(2, 34) = 2.16$, $p > .10$. Furthermore, there was no difference in the percentage of errors or omissions for the two nonword conditions. An analysis of variance for the lexical condition, however, showed that the difference between the two conditions (before and after uniqueness point) was highly significant, $F_1(1, 17) = 55.40$, $p < .005$. A Student's t test (two-tailed) indicated that the difference was also significant by item, $t(10) = 4.56$, $p < .01$.

Discussion

The results obtained in this experiment show that even in cases in which the phonological distance between the lexically supported phoneme and the target phoneme is small, no evidence for inhibition is found. In the same experiment, however, we found evidence for lexical effects with faster detection latencies to target phonemes located after the uniqueness point than those to targets placed before the uniqueness point. We discuss the implications of the asymmetry between lexical facilitation and inhibition in the following section.

General Discussion

In this article we have addressed the questions of how and when lexical information influences phoneme identification. Our objective was to contrast interactive and autonomous models of speech processing, because they provide different answers to these questions. In the first experiment, we traced the time course of lexical effects by comparing the detection times to phoneme targets located in different positions in matched words and nonwords. The results revealed a strong facilitatory lexical influence that emerged after the uniqueness point, as predicted by both the race and the interactive activation models. The small RT difference observed for phonemes placed immediately before the uniqueness point is predicted by TRACE but not by the race model. According to the latter, lexical effects should arise only after the word has been recognized and its lexical code recovered. However, as we noted above, because the lexical effects for the second position are at best weak and open to different interpretations, they are not very useful in evaluating the two models.

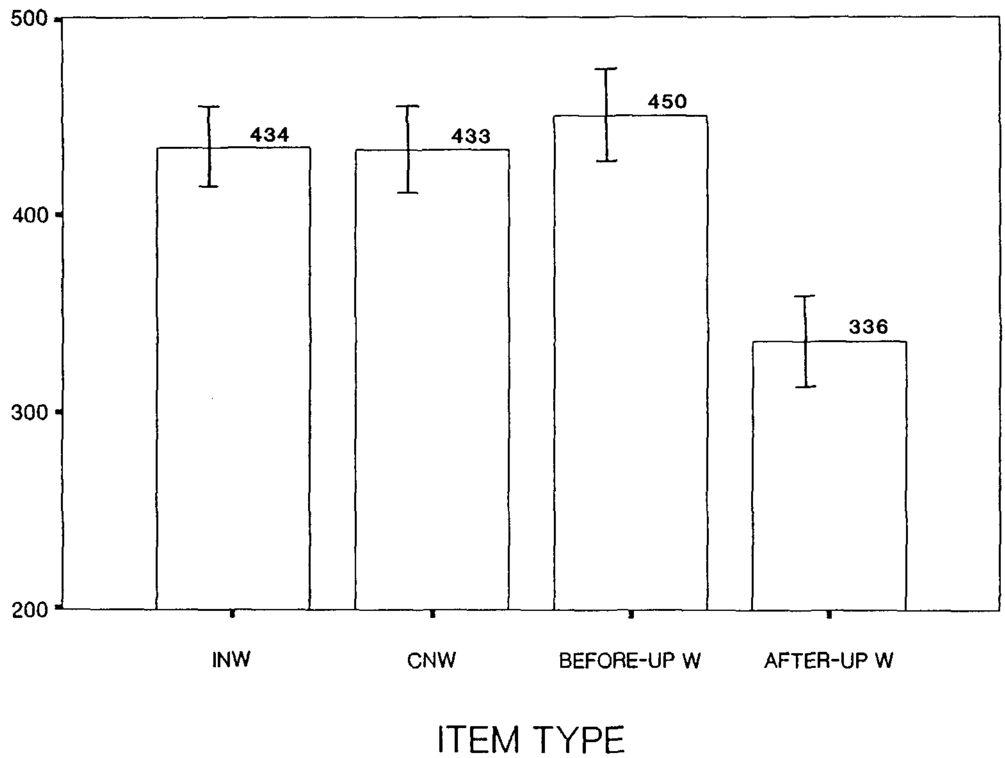

Figure 3. Mean reaction time for phoneme targets in inhibiting nonwords (INW) and control nonwords (CNW) and for targets before (Before-UP) and after (After-UP) uniqueness point in words. (The vertical lines show *SE*.)

Additional experiments are required to determine whether the lexical level can really influence the phonemic processing before the target-bearing word has been recognized. The demonstration of a prerecognition locus of lexical effects is particularly important from the connectionist perspective, because it would mean that top-down lexical feedback actually contributes to the activation process leading to word recognition. If, however, lexical feedback comes into play only after the lexical unit has been recognized, then this feedback, of course, can no longer influence the word recognition process.[8]

The contrast between the results observed for item-initial targets in this experiment (no lexical effect) and that of Marslen-Wilson (inverse lexical effect; 1984) indicates that the phoneme detection process is not invariant but depends upon the experimental situation. This variability suggests that listeners have some control over the sublexical and lexical levels of processing and can exploit the level that is most useful for performing the task. Nusbaum and Schwab (1986) related these control processes to attentional mechanisms whose role in speech perception, they claimed, has largely been ignored. Nonetheless, more recent research on both phoneme restoration (Nusbaum, Walley, Carrell, & Ressler, 1982; Samuel & Ressler, 1986) and phoneme detection (Cutler, Mehler, Norris & Segui, 1987; Frauenfelder & Segui, 1989) is investigating the way in which attention influences speech perception. This research suggests that it is not sufficient simply to characterize the information flow within the processing system but that it is also necessary to determine the nature of control structures responsible for handling this information. Unfortunately, there has been very little discussion of these issues within the connectionist perspective. In particular, models such as TRACE do not yet include a control structure that can account for the variability in subjects' performance as a function of task demands.

In the second section of this article, we discussed whether the lexical influence, observed to be highly facilitatory after the uniqueness point in the first experiment, can also be inhibitory when the lexical information is incompatible with the phonemic information corresponding to the target to be detected. There exist some experimental findings by the mispronunciation-detection task (Cole, 1973; Cole & Jakimik, 1980) and shadowing (Marslen-Wilson & Welsh, 1978) that may be taken to suggest the existence of inhibitory lexical effects. These results—fewer mispronunciation detections and more fluent restorations when the mispronunciation was in the second syllable than in the first—can be interpreted as showing that the mispronounced, but nonetheless accessed, word inhibits the intrusive phoneme. Although this interpretation in terms of inhibition can account for the decreased probability of detecting or repeating the mispronounced item,

[8] Simulations (Peeters et al., 1989) with stimuli that matched those of Experiment 1 showed that lexical to phoneme feedback does accelerate word recognition. When we compared the time it took TRACE to recognize words with and without lexical feedback, we found a difference of approximately three cycles (75 ms).

it is inconsistent with the RT results for the mispronunciations actually detected. An inhibitory account would incorrectly predict slower rather than faster responses for mispronunciations occurring later in the word.[9]

More important, we want to argue that data obtained with these tasks cannot provide an adequate test for lexical inhibition. For an experimental procedure to reveal whether lexical information influences (either facilitates or inhibits) sublexical processing, subjects should be able, in principle, to focus their attention on the sublexical level and to respond by using the information available at this level. In this way, any systematic modification in their responses, not explainable at this level, must be attributed to the contribution of higher levels. Unfortunately, neither shadowing nor mispronunciation detection have these required properties. Indeed, the shadowing task focuses the subject's attention on higher levels of representation. Although the mispronunciation-detection task does force subjects to attend to the sound structure of the utterance, it requires them to use the lexical representation to detect faulty pronunciations. In contrast, the phoneme-monitoring task satisfies these two requirements and thus provides a better test for the existence of lexical influences on phonemic processing.

The results of our three phoneme-monitoring experiments in which the bottom-up information conflicted with the lexical information provided no evidence for such inhibitory lexical effects. The absence of inhibition is problematic for TRACE because it predicts inhibition through the combined effect of lexical feedback and lateral inhibition between phoneme units. In contrast, the race model predicts no inhibition because it includes two competing detection procedures that operate autonomously. Consequently, lexical information cannot inhibit the computation of the prelexical code.

TRACE could, nonetheless, account for the absence of inhibition by adjusting the parameters that define the strength of the different connections. This adjustment could take several different forms: an increase in the strength of the bottom-up activation of phonemes or a decrease in the top-down activation of phonemes or, finally, a decrease in the strength of lateral inhibition between phonemes. As a result of such adjustments, the inhibitory influence exerted on the target phoneme by the lexically activated but absent phoneme would be weakened or even eliminated. Adjustments like these are possible, but not desirable, as pointed out by McClelland and Elman (1986), who consistently used the same parameters for their simulations. Ultimately, modifications of parameter sets that are required to account for the absence of inhibition or for variability in lexical effects as a function of task demands should probably be determined in a systematic fashion by some higher level control structure of the type alluded to above.

The phoneme-monitoring experiments presented here made exclusive use of unambiguous stimuli, unlike the phonetic categorization studies mentioned above, which included both ambiguous and unambiguous stimuli. In the latter studies, the largest lexical effects were obtained for tokens in the ambiguous phonetic boundary region. We cannot exclude the possibility that lexical inhibition in phoneme monitoring would emerge with ambiguous stimuli. More generally, we need a better understanding of the relation between the quality of the sensory input and lexical effects. Ganong (1980) interpreted his findings of larger lexical effects for ambiguous tokens than for endpoints of the continua as evidence against a postperceptual locus of lexical effects. Similarly, McClelland and Elman (1986) claimed that this inverse relation between stimulus quality and the size of top-down effects is indicative of interactions between the phoneme and lexical levels. However, Massaro and Oden (1980) described the results of Ganong (1980) quantitatively with a fuzzy logic model making the assumption that these two information sources do not interact but make independent contributions to the categorization process. These conflicting interpretations of the same pattern of results illustrate the subtle differences between models and the increasing difficulty of distinguishing between them empirically.

In conclusion, we have uncovered a strong asymmetry between facilitatory and inhibitory effects. Although lexical information accelerates phoneme detection for phonemes after the uniqueness point of the target-bearing words, it cannot override conflicting bottom-up information and inhibit phoneme-detection times. The facilitatory effects are compatible with the predictions of both interactive and autonomous models, even though they appeal to different mechanisms in explaining these effects. In contrast, the absence of inhibitory effects is explicitly predicted by the autonomous model but poses serious problems for TRACE. These results show the existence of strong limitations in the way in which lexical information can affect speech processing as reflected by the phoneme-detection task.

[9] The cooccurrence of faster RTs and fewer detections/restorations has a more widely accepted explanation that does not appeal to inhibition. Here, listeners are assumed to recognize words by their first syllable and to access their stored phonological representations. As a consequence, they pay less attention to the subsequent syllables and are less likely to notice discrepancies between the input and the phonological representation of the intended word. However, when listeners are able to attend to the sound structure of the input and confront it with the activated phonological representation, then they can efficiently detect discrepancies that occur late in the mispronounced word.

References

Cole, R. A. (1973). Listening for mispronunciation: A measure for what we hear during speech. *Perception & Psychophysics, 13*, 153–156.

Cole, R. A., & Jakimik, J. (1980). A model of speech perception. In R. A. Cole (Ed.), *Perception and production of fluent speech* (pp. 133–163). Hillsdale, NJ: Erlbaum.

Cutler, A., Butterfield, S., & Williams, J. N. (1987). The perceptual integrity of syllabic onsets. *Journal of Memory and Language, 26*, 406–418.

Cutler, A., Mehler, J., Norris, D., & Segui, J. (1987). Phoneme identification and the lexicon. *Cognitive Psychology, 19*, 141–177.

Cutler, A., & Norris, D. (1979). Monitoring sentence comprehension. In W. E. Cooper & E. C. T. Walker (Eds.). *Sentence processing: Psycholinguistic studies presented to Merrill Garrett* (pp. 113–134). Hillsdale, NJ: Erlbaum.

Elman, J. L., & McClelland, J. L. (1988). Cognitive penetration of the mechanisms of perception: Compensation for coarticulation of lexically restored phonemes. *Journal of Memory and Language, 27*, 143-165.

Forster, K. I. (1979). Levels of processing and the structure of the language processor. In W. E. Cooper & E. C. T. Walker (Eds.), *Sentence processing: Psycholinguistic studies presented to Merrill Garrett* (pp. 27-86). Hillsdale, NJ: Erlbaum.

Foss, D. J. (1969). Decision processes during sentence comprehension: Effects of lexical item difficulty and position upon decision times. *Journal of Verbal Learning and Verbal Behavior, 8*, 457-462.

Foss, D. J., & Blank, M. A. (1980). Identifying the speech codes. *Cognitive Psychology, 12*, 1-31.

Foss, D. J., & Gernsbacher M. A. (1983). Cracking the Dual Code: Toward a unitary model of phoneme identification. *Journal of Verbal Learning and Verbal Behavior, 22*, 609-632.

Fox, R. A. (1984). Effect of lexical status on phonetic categorization. *Journal of Experimental Psychology: Human Perception and Performance, 10*, 526-540.

Frauenfelder, U. H., & Segui, J. (1989). Phoneme monitoring and lexical processing: Evidence for associative context effects. *Memory & Cognition, 17*, 134-140.

Ganong, W. F. III. (1980). Phonetic categorization in auditory word perception. *Journal of Experimental Psychology: Human Perception and Performance, 6*, 110-125.

Garrett, M. F. (1978). Word and sentence perception. In R. Held, H. W. Leibowitz, & H. L. Teuber (Eds.), *Handbook of sensory physiology: Perception* (Vol. 8, pp. 611-625). Berlin: Springer-Verlag.

Grosjean, F. (1980). Spoken word recognition processes and the gating paradigm. *Perception & Psychophysics, 28*, 267-283.

Marslen-Wilson, W. D. (1984). Function and process in spoken word recognition. In H. Bouma & D. G. Bouwhuis (Eds.), *Attention and performance X: Control of language processes* (pp. 125-149). Hillsdale, NJ: Erlbaum.

Marslen-Wilson, W. D., & Tyler, L. K. (1980). The temporal structure of spoken language understanding. *Cognition, 8*, 1-71.

Marslen-Wilson, W. D., & Welsh, A. (1978). Processing interactions and lexical access during word recognition in continuous speech. *Cognitive Psychology, 10*, 29-63.

Marslen-Wilson, W., & Zwitserlood, P. (1989). Accessing spoken words: The importance of word onsets. *Journal of Experimental Psychology: Human Perception and Performance, 15*, 576-585.

Massaro, D. W., & Oden, G. C. (1980). Speech perception: A framework for research and theory. In N. J. Lass (Ed.), *Speech and Language: Advances in basic research and practice* (Vol. 3, pp. 129-165). New York: Academic Press.

McClelland, J. L. (1979). On the time relations of mental processes: An examination of systems of processes in cascade. *Psychological Review, 86*, 287-330.

McClelland, J. L., & Elman, J. L. (1986). The TRACE model of speech perception. *Cognitive Psychology, 18*, 1-86.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part 1. An account of basic findings. *Psychological Review, 88*, 375-407.

Norris, D. G. (1982). Autonomous processes in comprehension: A reply to Marslen-Wilson and Tyler. *Cognition, 11*, 97-101.

Norris, D. G. (1986). Word recognition: Context effects without priming. *Cognition, 22*, 93-136.

Nusbaum, H. C., & Schwab, E. C. (1986). The role of attention and active processing in speech perception. In E. C. Schwab & H. C. Nusbaum (Eds.), *Pattern recognition by humans and machines: Speech perception VI* (pp. 113-157). New York: Academic Press.

Nusbaum, H. C., Walley, A. C., Carrell, T. D., & Ressler, W. H. (1982). Controlled perceptual strategies in phonemic restoration (Progress Rep. No. 8, pp. 83-103). Indiana University, Speech Research Laboratory.

Peeters, G., Frauenfelder, U. H., & Wittenburg, P. (1989). Psychological constraints upon connectionist models of word recognition: Exploring TRACE and alternatives. In R. Pfeifer, Z. Schreter, F. Fogelman-Soulié, & L. Steels (Eds.), *Connectionism in perspective* (pp. 395-402). Amsterdam: North-Holland.

Rumelhart, D. E., & McClelland, J. L. (1982). An interactive model of context effects in letter perception: Part 2. The contextual enhancement effect and some tests and extensions of the model. *Psychological Review, 89*, 60-94.

Samuel, A. G. (1981). Phonemic restoration: Insights from a new methodology. *Journal of Experimental Psychology: General, 110*, 474-494.

Samuel, A. G., & Ressler, W. H. (1986). Attention within auditory word perception: Insights from the phonemic restoration illusion. *Journal of Experimental Psychology: Human Perception and Performance, 12*, 70-79.

Segui, J., & Frauenfelder, U. (1986). The effect of lexical constraints upon speech perception. In F. Klix & H. Hagendorf (Eds.), *Human Memory and Cognitive Abilities: Symposium in Memoriam Hermann Ebbinghaus* (pp. 795-808). Amsterdam: North Holland.

Segui, J., Frauenfelder, U., & Mehler, J. (1981). Phoneme monitoring, syllable monitoring and lexical access. *British Journal of Psychology, 72*, 471-477.

Stemberger, J. P., Elman, J. L., & Haden, P. (1985). Interference between phonemes during phoneme monitoring: Evidence for an interactive activation model of speech perception. *Journal of Experimental Psychology: Human Perception and Performance, 11*, 475-489.

Tanenhaus, M. K., & Lucas, M. M. (1987). Context effects in lexical processing. *Cognition, 25*, 213-234.

Treiman, R., Salasoo, A., Slowiaczek, L. M., & Pisoni, D. B. (1982). Effects of syllable structure on adults' phoneme monitoring performance (Progress Rep. No. 8, pp. 63-81). Indiana University, Speech Research Laboratory.

Tyler, L. K., & Marslen-Wilson, W. D. (1982). Conjectures and refutations: A reply to Norris. *Cognition, 11*, 103-107.

Tyler, L. K., & Wessels, J. (1983). Quantifying contextual contributions to word-recognition processes. *Perception & Psychophysics, 34*, 409-420.

(*Appendix follows on next page*)

Appendix

Table A1
Test stimuli for Experiment I: Lexical Condition

	Target: |p|		Target: |t|		Target: |k|	
Position	Word	Nonword	Word	Nonword	Word	Nonword
Onset	pagina	pafime	tafereel	tageleer	kanselier	kamzeriel
	parallel	palarrer	technologie	tefmorozjie	karamel	kalaner
	parochie	palossie	telefoon	terezoom	karnaval	kalmawar
	personeel	pelfomeer	theologie	tearozie	kazerne	kafelme
	pessimisme	peffonisne	theorie	tejeloe	keizerin	keiveling
	piano	puamu	timmeren	tinnelen	kalender	karembel
	porselein	polfereim	tirannie	tilammie	kardinaal	kalbimaar
	professor	plogeffol	toerisme	toelifne	kolonel	koromer
	programma	ploslanga	tunesië	tumefio	koningin	komining
	paviljoen	pawirgoem	twijfelen	twiegeren	kolibrie	korietsie
Before UP	opera	opelo	interesse	omteluffe	microfoon	niklosoos
	japanner	jopammel	liturgie	ratulfie	eskimo	efkinu
	oplossing	eproffim	artillerie	altierolie	academie	akaboongie
	apparaat	appalaak	astroloog	aftraroos	vakantie	zakampee
	diploma	biprona	atelier	atteroel	doctrine	bokpliengе
	epidemie	epubonie	materiaal	nateliaar	etiket	epikup
	episode	apozabe	motivering	notizelink	rekening	lekemim
	kapelaan	taporaam	categorie	patefolee	alcohol	arkogor
	operatie	opelakoe	kastelein	pasteriem	economie	ekomeengie
	speculaas	sputeraaf	notaris	motalif	macaroni	nakalumi
After UP	sinaasappel	zimaafopper	garantie	zalantzou	logica	rezika
	maatschappij	nookfrappie	schrijfster	fleifstel	marokko	naiokku
	chimpansee	zjanpamfoe	suggestie	fuzzestei	mirakel	nilaker
	envelop	emferop	minister	nimistal	musicus	nufikug
	europa	uilepa	resolutie	lewaluutseu	fabrikant	sablikamp
	manuscript	namestlipt	kabouter	padoutel	historicus	jiftolikug
	olympiade	arimpiako	evolutie	ewaruutseu	paprika	tatliko
	utopie	akopee	informatie	imzolnaatsje	risico	lifika
	antilope	amdirepe	augustus	uivoftus	vaticaan	zopikaan
	ethiopië	akiëpië	commentaar	ponnemtaal	inbreker	implekel
Offset	bioscoop	deoftoop	sigaret	fiwalet	mozaiek	nofioek
	handicap	santitep	journalist	zjoelmerist	apotheek	atapeek
	wetenschap	vedemsgop	element	eronent	atletiek	aplepoek
	filantroop	ziramdloop	argument	alvunent	basiliek	daziriek
	isotoop	ifokoop	alfabet	arsadet	bibliotheek	didriopeek
	hennep	jemmep	bajonet	dojomet	dramatiek	blanapiek
	aartsbisschop	eerksdifgop	celibaat	zeripaat	gymnastiek	funmagpiek
	galop	farop	olifant	arigant	huwelijk	juzeruk
	klimop	trinop	acrobaat	aploboot	limerick	rinnelik
	ketjap	tekjop	favoriet	vowaliet	pittoresk	tipolask

Note. The nonwords are given in an orthographic representation that corresponds to the way in which they were pronounced. UP = uniqueness point.

Table A2
Test Stimuli for Experiments 2–4

Experiments 2 and 3: Inhibition condition					
Target: |p|		Target: |t|		Target: |k|	
INW	CNW	INW	CNW	INW	CNW
barbitupique	garbitupique	vocabutaire	socabutaire	paratokère	garatokère
consécrapion	lonsécrapion	margatine	nargatine	preposikion	breposikion
vétéripaire	sétéripaire	kangoutou	mangoutou	tribulakion	trabulakion
congrégapion	dongrégapion	binocutaire	finocutaire	protagokiste	brotagokiste
Experiment 3: Lexical condition					
Target: |p|		Target: |t|		Target: |k|	
Word	Nonword	Word	Nonword	Word	Nonword
estampille	istampille	piédestal	liédestal	remarquer	lemarquer
municipalité	runicipalité	principauté	frincipauté	oscilloscope	escilloscope
olympique	ilympique	gladiateur	bladiateur	odalisque	idalisque
nécropole	nacropole	nomen-clature	domen-clature	péllicule	déllicule
Experiment 4: Inhibition condition					
Target: |d|		Target: |t|		Target: |k|	
INW	CNW	INW	CNW	INW	CNW
tonalidé	ponalidé	abécetaire	ibécetaire	plantikrade	blantikrade
tortuosidé	mortuosidé	debandate	pebandate	tobokan	mobokan
simplicidé	fimplicidé	dissoutre	missoutre	proloke	troloke
crusdacé	trusdacé	roucoulate	poucoulate	mistikri	vistikri

Note. UP = uniqueness point; INW = inhibiting word; CNW = control nonword. The nonwords are given in an orthographic representation that corresponds to the way in which they were pronounced.

Received August 15, 1988
Revision received December 13, 1988
Accepted February 27, 1989 ■