Lexical Effects in Phoneme Monitoring: Time-course versus Attentional Accounts

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Under what conditions do lexical factors influence phoneme detection times? Experiment 1 measured subjects' latencies to detect initial phonemes in monosyllabic and disyllabic words that were preceded by a semantically related or unrelated word. One group of subjects was instructed to pay attention to the semantic relations between words, and a second group was asked to focus on acoustic-phonetic information. A significant priming effect was found, only for monosyllabic words, and only in the first group. In Experiment 2, previously observed frequency effects (Dupoux and Mehler, 1990) disappeared when the detection task was biased towards acoustic-phonetic information. In Experiment 3, two student populations were tested with exactly the same instruction set and showed markedly different results: One group showed a consistent lexical superiority effect on monosyllabic items while the other group showed no such effect. Taken together, these results suggest that the presence or absence of lexical effects is extremely sensitive to attentional parameters that can be affected by explicit biasing instructions and/or individual differences. Importantly, these effects cannot be accounted for in terms of mean reaction time differences (where slow reaction times would be expected to lead to stronger lexical influences than fast ones). The results reported here are consistent with the view that phoneme detection can be carried out using either of two quite different routes. Implications for current models of lexical and prelexical processing are discussed.

Introduction

What are the processing levels at which phoneme monitoring responses can be initiated ? This question has been the subject of a considerable research effort during the past decades (Foss, 1969; Newman and Dell, 1978; Foss and Gernsbacher, 1983; Cutler, Mehler, Norris and Segui, 1987; Eimas, Markowitz Hornstein and Payton, 1990; among others), but no clear-cut answer has as yet been found. Yet, phoneme detection or classification is one of the few tasks that are available to explore the first stages of lexical activation in real time. It is crucial to control the different parameters that influence the task if it is to be used to test models of speech processing. Furthermore, a better understanding of the way the task is performed may in itself shed light on speech processing, available linguistic representations, and the decision making system.

Most models of speech processing draw a distinction between two types of information: nonlexical (or *prelexical*) information which is computed whether the speech wave is composed of actual words or not, and lexical information which becomes activated when familiar words are presented. Models disagree about the relationship between these two types of information: Are they extracted in a parallel and autonomous fashion (Klatt, 1980), or do they interact more intimately (McClelland and Elman, 1986)?

The attractive aspect of the phoneme monitoring task is that it has been shown to be sensitive to both prelexical information (vowel length: Foss and Gernsbacher, 1983; Diehl *et al.*, 1987; syllabic complexity: Treiman *et al.*, 1982, among others) and lexical information (lexical status: Rubin *et al.*,

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1976; word frequency: Dupoux and Mehler, 1990; etc.). In principe, therefore, this task can be used to evaluate claims concerning the flow of information during lexical access. To date, however, the theoretical issues remain largely unsettled. The reason for this appears to stem from disagreement about what the task itself reveals about processing. The many contradictory models that have been formulated (Rubin *et al.*, 1976; Foss and Gernsbacher, 1983; Cutler, Mehler, Norris, and Segui, 1987; etc) generally adhere to one or the other of two broad views concerning the nature of phoneme monitoring.

The first view holds that phoneme monitoring provides a rather transparent window on speech processing. During speech perception, all kinds of information are activated online. This first view claims that subjects have no option but to take into account all the relevant information which has accumulated by the time a response is initiated. So when lexical access is completed quickly (say, for short and frequent words), the lexical information that is associated with the entry becomes activated, and inevitably influences the phoneme detection time. If lexical access is not complete when prelexical information becomes available for a response, then only the latter kind of information will come into play. Many researchers have used the metaphor of a race between two processes running in parallel, one which extracts phonemes from the prelexical level and one which recovers them from the lexicon (Foss and Blank, 1980; Newman and Dell, 1978; Cutler and Norris, 1979; Dell and Newman, 1980; Mehler, 1981; Cutler, Mehler, Norris, and Segui, 1987). In other more interactive models, lexical and prelexical information interact during speech processing. But even in these models there is, functionally, a race between stimulus-driven bottom-up activation and lexical top-down feedback (McClelland and Elman, 1986). In all these models, which we will refer to as *time-course models*, the prediction is the same: Only the relative time-course of prelexical and lexical information determines the phoneme monitoring latencies.

The second view holds, on the contrary, that phoneme monitoring is quite opaque to the time-course of processing, and that subjects are relatively free to choose whatever information type they want. According to Cutler, Mehler, Norris and Segui (1987):

> Phoneme monitoring experiments require subjects to perform two tasks - listening to speech and detecting a target. [..] If the stimuli are highly monotonous, it is boring to listen to them as speech. [..] Instead, attention will be focused on the target detection process, increasing the likelihood that detection responses will be based purely on prelexical representations. Conversely, if the stimuli are interesting, attention is likely to be shifted to the comprehension task, and hence away from the target detection task: Under these conditions the likelihood of lexically sensitive responses rises.

We could propose a radical formulation of this position, whereby subjects can control where to focus their attention and consequently whether to use either lexical or prelexical information at will (see also Eimas *et al.*, 1990). In other words, according to this attentional focus hypothesis, certain information types relevant to phoneme monitoring could be *ignored* by subjects even though they are available by the time subjects make a response. We will refer to such models as *attentional models* of phoneme detection.

The question that arises, then, is: are phoneme monitoring reaction times determined solely by the time-course of processing or are they governed by strategic parameters? If the first hypothesis is correct, then we have gained a powerful experimental tool to investigate the potential interaction between lexical and prelexical information. If the second holds, then the tool becomes more complicated, and many interpretations and/or models of speech processing that were derived from phoneme monitoring or classification data will have to be reconsidered. In the next section we evaluate these two options in the light of existing data.

Time-course versus free choice

The exact conditions under which lexical effects influence word-initial phoneme monitoring latencies has been the focus of considerable debate. However, there is one variable that seems to have a consistent effect throughout the literature: Word length. For monosyllabic items, many intances of lexical effects have been reported: Lexical status effects (Rubin, Turvey and Van Gelder, 1976; Cutler *et al.*1987; Eimas *et al.*, 1990; Dupoux, 1989) and word frequency effects (Dupoux and Mehler, 1990; Eimas *et al.*, 1990). Such effects have not so far been reported for longer, polysyllabic items (Foss and Blank, 1980; Segui, Frauenfelder and Mehler, 1981; Dupoux, 1989; Dupoux and Mehler, 1990).

Such a pattern can be readily accounted for in terms of a race between prelexical and lexical information. Indeed, since we are dealing with phonemes that always occur at stimulus onset, the prelexical information needed to perform the task is always a fixed initial portion of the stimulus item. As a result, the time needed by the prelexical route is relatively independent of syllabic length. In contrast, the lexical route is, on most accounts, dependent on word length. Short, monosyllabic words are more likely to have their identification point earlier than longer words. As a consequence, lexical information is more likely to have an influence on detection latencies for short words than for longer ones.[1]

So far, time-course models seem to be well supported, but there are a number of empirical observations that do not fit into this picture very comfortably. To start with, failures to find lexical effects with monosyllabic words have been reported (Foss and Gernsbacher, 1983; Cutler *et al.*, 1987; Eimas *et al.*, 1990). Cutler *et al.*(1987) claim that these failures are no accident, but are due to the properties of the distractors included in the experimental list. When the list

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[1] This has to be qualified, since certain disyllabic items could in principle have their identification point earlier than certain monosyllabic items. Also, disyllabic items are not twice as long as monosyllabic items.

is monotonous, that is, only composed of CVC items, lexical effects tend to disappear. In contrast, when the distractors include a variety of structures (monosyllabic and disyllabic items), a lexical superiority effect re-emerges. Similarly, Eimas *et al.*(1990) reported neither a lexical superiority effect nor a frequency effect for monosyllabic CVCs.[2] However, when a secondary task was added, the lexical effects re-emerged. Nothing in the formulation of time-course models allows for such effects of list monotony or secondary tasks.

Even more damaging are instances where a lexical effect has been reported in polysyllabic words. For instance, in the context where the target phoneme can appear in any position within the word, both a lexical superiority effect and a frequency effect can be observed in disyllabic words, even though the phoneme in the test items only appeared in initial position (Frauenfelder and Segui, 1989; Frauenfelder, Segui and Dijkstra, 1990; Segui and Frauenfelder, 1986). Similarly, lexical effects have been found in disyllabic items when they appear in contexts with high sentential predictability (Segui, 1984).

Are attentional models correct in claiming that the attentional requirements of a task, or even worse, the subject's own choices, govern the use of one type of information rather than another? The case is not as clear as it might seem. If what subjects do is to focus their attention consistently at one of two levels, completely shutting off the other, there should be no interaction between lexical effects and length when items of different lengths are tested in the same experiment. However, Dupoux and Mehler, (1990) and Dupoux (1989) have reported such an interaction. If they are right, then a race component still needs to be postulated independently of attentional effects.

More importantly, in most of the earlier studies, attentional effects were confounded with a rather important factor: *Speed of response*. For instance, in Eimas *et al.*(1990), lexical effects are observed for comparatively long latencies (i.e. around 700 ms) but not for comparatively short ones (i.e. around 400ms). Similarly, the *generalized phoneme monitoring* task used by Segui and Frauenfelder (1986), where the target can occur anywhere in the word, yielded a substantial increase in response times to initial targets. As Dupoux (1993) argues, differences in speed of response can yield quite different results, since the amount of information that subjects have access to when they make a response varies with whether they respond early or late. Note that most models of speech processing would actually *predict* this: The slower the response time, the more likely it is that lexical access will have been completed, and hence the more likely that lexical effects will be observed. Clearly, in order to understand the role of attention in phoneme monitoring, one has to disentangle changes in attention from speed of response per se. The only case, to our knowledge, where the emergence of lexical effects was not correlated with speed of response occurred in Cutler *et al.*(1987)'s experiments 1 and 7.[3] In Experiment 1, in which French stimuli were presented with a mixture of distractors, lexical effects were observed at a mean latency of 462 ms. In contrast, in Experiment 7, a list of French CVC stimuli was used with monosyllabic distractors. This time, at the similar mean latency of 497 ms, no lexical effect emerged. Unfortunately, the materials in these two experiments were different; that is, the phoneme targets, syllabic structures, vowels, and perhaps stimulus lengths were not the same in Experiment 1 and 7, so any comparison must remain speculative.

In brief, even though the major assumptions of time-course models have been challenged, the empirical basis for such a challenge is not all that strong. Our aim in this paper is to present further data that assess the extent to which attentional effects can have an impact on phoneme monitoring and can override the effect of word length. If the disappearance of lexical effects for short monosyllabic items in monotonous lists is a recurring (although not well understood) finding, their emergence in disyllabic words when the context is predictable is less well documented. Importantly, the contribution of this paper is to determine whether such waxing and waning of lexical effects could be solely due to reaction time differences, or to genuine attentional factors. To assess the influence of lexical information in phoneme monitoring responses, we manipulated contextual predictability (Experiment 1), frequency (Experiment 2) and lexical status (Experiment 3).

Experiment 1

Time-course models state that the presence or absence of lexical effects in word-initial phoneme monitoring can be accounted for solely in terms of a) the intrinsic properties of the stimulus (i.e., identification point or overall duration), b) the mean response latency of the subject relative to the completion time of the lexical and prelexical processes. In other words, with a similar mean latency and mean stimulus duration across experiments, one should observe a similar presence (or absence) of lexical effects. As we discussed earlier, it has been reported that lexical effects emerge in monosyllabic but not in bisyllabic items. This has been interpreted as supporting a time-course model, because the relative speed of completion of lexical and prelexical information is likely to depend on stimulus length. On this account, the lexical route wins the race in short words, whereas the prelexical route does so in longer words. In contrast, models that put a heavy emphasis on attentional variables would predict that one can bias subjects to respond either exclusively on the basis of the lexical route or on the basis of the prelexical route, irrespective of word length.

We evaluate these contrasting predictions in an experiment in which only real words are presented, and stimulus length and attentional focus are independently controlled. The interest of using real words is that most of the experiments on

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[2] All the items in the experiment were monosyllabic and they were always preceded by the same, presumably, "monotonous" sentence fragment: "The next word is".

[3] Eimas *et al.*(1990) in their Experiment 9 and 10 report very long reaction times coupled with an absence of lexical effects when subjects are given a *non-semantic* secondary task. Note, however, that in these experiments, there was a marginally significant trend in the right direction (19-25 ms).

lexical effects in phoneme monitoring have used mixed lists of words and non-words, which may cause subjects to ignore lexical information altogether (since the lexicon is of no use in half of the trials). Therefore, using real lexical items arguably maximizes the number of response strategies potentially available to subjects: They could perform the task using any strategy ranging from a pure prelexical to a pure lexical one.

In order to assess whether the lexical route or the prelexical route has been used, one needs to compare the reaction time of two matched items, which receive identical prelexical treatment but differ in their lexical characteristics. In previous experiments, lexical status or word frequency have been manipulated in stimulus pairs that were matched as closely as possible in terms of prelexical variables (initial phoneme, vowel quality, syllable complexity, etc). However, it is never completely possible to factor out possible acoustic/phonetic effects when the stimuli are physically different. In this experiment, words are presented in uninterrupted lists and we manipulated the associative strength of the word preceding the target. Using associative priming as an indication of lexical influence is interesting since we can make sure that the target bearing stimuli are physically identical in the related and unrelated condition, and that any difference in reaction time can therefore only be attributed to the influence of the preceding lexical context. The reasoning is then that a response purely based on prelexical information should be insensitive to the associative strength of the context. In contrast, a response based on lexical information is likely to be sensitive to the presence of a related context, as numerous experiments demonstrating lexical priming effects have shown. So, with some precautions in mind, it is possible to use the amount of lexical priming as an indication of whether prelexical or lexical information has been predominantly used in performing the task.

In this experiment, half of the stimuli were monosyllabic and half were bisyllabic. A time-course model should predict that in monosyllabic words, the lexical route will win the race, and hence a lexical priming effect will be observed. In contrast, in disyllabic items, the prelexical route will more often win the race and hence any effect of priming should be smaller. In contrast, a radical attentional account expects that priming should show up or not, as the case may be, irrespective of word length. To get a better handle on attentional variables, we tested two groups of subjects. Both groups received exactly the same stimuli, but different instructions. The first group was asked to perform a standard phoneme detection task. The other group was instructed, in addition, to pay attention to and memorize the semantic associations present in the experimental list. This requirement was assumed to direct subject's attention to the lexical route. An attentional account would expect that instructions rather than word length should influence any potential priming effect.

Method

Materials. Forty triplets of French words of the form [*related prime, unrelated prime, target*] were chosen. The related primes were strong associates of the targets.[4] The *unrelated primes* were not associates of the targets, but were formally similar to the related primes in number of syllables, initial phoneme, and word frequency (e.g.: [*bateau (boat), bureau (desk), voile (sail)*]). Of the 40 *targets*, 20 were monosyllabic and 20 disyllabic. The forty triplets were used to form two counterbalanced versions of the experimental material in the following way: Targets that started with the same phoneme were put together, resulting in eight different blocks (/b/, /t/, /k/, /p/, /d/, /v/, /m/ and /n/). In each of these eight blocks, a target item was immediately preceded by a prime (either its related item or the matched unrelated control), which in turn was preceded by 1 to 7 filler words that did not start with the target phoneme. Moreover, a training session containing an average of 4 target words preceded each block. There was an average of 1 target item every 5 words. A matched version of the same eight blocks was constructed by substituting the related prime with the unrelated prime or vice-versa. Thus a given target (*voile*) would occur preceded by a related prime in one version and by an unrelated prime in the other.

A master list was recorded by a female native speaker of French at a regular rate of one word every two seconds. Stimuli were digitized (16 kHz) and edited on a PDP 11-73. Each target was immediately preceded by the two possible primes (related or unrelated). From this master list, we obtained the two experimental versions, list A and list B, by digitally deleting one of the two primes. The two matched lists contained thus physically identical target items. Two tapes (A and B) were prepared, one for each version.

Procedure.

All eight blocks were presented to each subject. Before each of the eight blocks the target phoneme was specified auditorily with 3 examples: "P as in Paris, Pau, Poitier".

Subjects. Forty native speakers of French participated as volunteers in the experiment. A group of twenty students tested at the École S^{te} Geneviève, Versailles, were asked to detect word-initial phonemes as fast and accurately as possible. (This is the *Detection group*.) Another group of twenty students (same age range, 18–20) tested at the Faculté de psychologie, Paris V, was given the same instructions with the addition of a secondary task. (This is the *Comprehension group*.) Subjects in this group were warned that there were many associated words; they were encouraged to pay attention to these and to try and remember the most obvious ones in view of a recall and recognition test that would be presented at the end of the experiment. In each of these groups, half of the subjects were assigned to version A and the other half to version B. The experiment lasted 15 minutes.

Results

The results of the two groups were analyzed separately. The data are summarized in Table 1.

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[4] As assessed from the association norms of Lieury, Iff and Duris (1976).

In the Detection group, reaction times above 1000 ms and under 100 ms were rejected (1.2% of the responses). The mean reaction time was 470 ms and the error rate (including the rejected responses) was 4.3%. Two analyses of variance were run, one with *subjects*, the other with *items* as random factors. The subjects analysis involved the between-subjects *Version* factor (a given subject heard each experimental item only once, either preceded by its associate or by the corresponding control item), and the two within-subjects *Relatedness* and *Length* factors. The items analysis involved the within-items *Relatedness* and between-items *Length* factors. The difference between the related and unrelated conditions was very small and did not reach significance ($monosyllabic\ items : 12\ ms, F1 < 1, F2 < 1; disyllabic\ items : 0\ ms$). No other factor nor any interaction between factors was significant.

The Comprehension group had an average reaction time of around 600 ms. A cut-off of 1000 ms for this group would have rejected too many responses. We therefore decided to keep responses within the 100–1500 ms range (this resulted in less than 1% of the responses being rejected). The error rate for this group was 4.0%. For this group, the interaction between the fctors Relatedness and Length was marginally significant in the subjects analysis ($F1(1,18) = 3.86, .05 < p < .1; F2(1,36) = 2.67, p > .1$). This trend was due to the fact that monosyllabic items produced a strong Relatedness effect ($44\ ms, F1(1,18) = 7.45, p < .02; F2(1,18) = 9.45, p < .01; minF\ (1,36) = 4.17, p < .05$), whereas no trace of such an effect was found for the disyllabic items ($-3\ ms$).

A global analysis of variance was run by collapsing the two groups and including a new between-subjects Task factor. The Task factor produced a highly significant effect ($130\ ms, F1(1,36) = 16.84, p < .001, F2(1,36) = 249.5, p < .001; minF\ (1,41) = 15.78, p < .001$). The Relatedness effect was significant only by subjects($F1(1,36) = 4.27, p < .01; F2(1,36) = 2.49, p > .1$); so was the Length effect ($F1(1,36) = 6.54, p < .02; F2(1,36) = 1.15, p > .1$). The interaction between Length and Relatedness reached significance in the subjects analysis only ($F1(1,36) = 4.10, p = .05; F2(1,36) = 2.33, p > .1$). For the monosyllabic items, a robust priming effect was found ($28\ ms, F1(1,36) = 7.13, p < .02; F2(1,36) = 6.66, p < .02; minF\ (1,72) = 3.44, .05 < p < .1$). For the disyllabic items, there was no trace of a priming effect ($-2\ ms, allFs < 1$). These effects did not show a significant interaction with the Task factor.

Discussion

The results of this experiment are somewhat intermediate between those predicted by attentional models and those predicted by time-course models.

On the one hand, the overall result of this experiment is that the phoneme monitoring responses were open to priming effects when the target phoneme occurred in a monosyllabic word but not in a disyllabic word. In particular, the absence of a lexical effect in disyllabic items held even for the group that was focusing on the semantic properties of the materials. This aspect of the data is consistent with a pure time-course interpretation: Since disyllabic words are comparatively long, lexical access is delayed and the prelexical route wins, whether the subject is paying attention to semantic or to acoustic properties of the speech signal. In contrast, for monosyllabic words lexical access is faster and so this route wins out. Hence, the interaction between priming and word length (only significant in the subjects analysis) can be readily accommodated within a time-course model.

Table 1

Mean reaction times and error rate for monosyllabic and disyllabic words as a function of associative relatedness with the prime word in the two groups of subjects (Experiment 1).

Number of Syllables	Prime Word: Unrelated	Prime Word: Related	Priming Effect (ms)
	Detection Group		
Monosyllabic	466 (4.5%)	454 (3.0%)	12
Disyllabic	479 (5.0%)	480 (3.0%)	-1
	Comprehension Group		
Monosyllabic	612 (5.5%)	568 (5.5%)	44
Disyllabic	608 (3.5%)	611 (3.5%)	-3

Note. Error rates are in parentheses.
* p<.05 by MinF'

On the other hand, there are aspects of the data that do not fit so well within such a framework. Attentional variables seem to play a role in the present experiment. The two groups with different tasks showed a difference in the amount of priming: The Comprehension group showed a significant overall priming effect (20 ms), whereas the Detection Group did not (6 ms, not significant). It is not possible, however, to conclude firmly that the two groups used different processing strategies, since the interaction between group and amount of priming did not reach significance. But the fact that no significant priming effect was observed in the Detection group, even on monosyllabic items, is problematic for a strict time-course model.

Still, there is one major objection that could be raised in defense of a time-course model. The two groups greatly differ in reaction time. Subjects who attended to the meaning of the words (*Comprehension* group) had much slower reaction times than subjects in the Detection group (a 130 ms difference). This difference alone might account for the result, given that the response in the detection group might have arisen before lexical access was completed. Conversely, subjects in the Comprehension task might have been distracted by the secondary task, and by the time they got around to making their response, lexical information had arrived.

To find out whether the obtained results are really due to shifts in attention or to absolute speed of response, we conducted the following post-hoc analysis. A sub-group of 26 subjects was taken from the total population. Thirteen of them were the fastest subjects in the Comprehension group (mean RT 527 ms) and the other thirteen were the slowest of the Detection group (mean RT 538 ms), see Figure 1. A new analysis of variance was performed on this restricted population. In this analysis, the only significant factor was word length ($F(1,24) = 5.04, p < .05$). The priming factor was not significant ($F(1,24) = 2.50$), nor was the Task factor ($F < 1$), however, these two factors interacted significantly ($F(1,24) = 6.49, p < .02$) because subjects taken from the Comprehension group showed a significant priming effect for the monosyllabic items (43 $ms, F(1,12) = 7.20, p < .02$) but not for the disyllabic items (18 $ms, F(1,12) = 2.44, p > .1$). In contrast, no priming effect was found for the subjects taken from the detection group, neither on the monosyllabic items (-6 $ms, F < 1$), nor on the disyllabic ones (-8 $ms, F < 1$). The Task factor showed a significant interaction with the priming effect on the monosyllabic items ($F(1,24) = 6.09, p < .03$).

In brief, when mean reaction times were matched, a significant interaction between group and priming effect was uncovered. Thus, this analysis allows us to discard differences in speed as an explanation for the difference between groups. The most straightforward conclusion is that the instructions given to subjects did influence their processing strategies, although an alternative hypothesis may account for this result, as we will see in Exp. 3.

Note that we are in a mixed situation. It is not the case that a single factor (attentional or time-course) can account for the entire pattern of data. As attentional models would expect, the two groups of subjects differed in their amount of priming, even when speed and input factors were equated. However, as time-course models would expect, the amount of priming was also influenced by word length.

Before turning to the next experiment, we want to address a possible criticism that proponents of time-course models might raise. So far, we have used the amount of priming as an indication of the use of lexical information. Indeed, the standard account of priming places its locus at the lexical activation stage; the word prime *preactivates* related words in such a way that the target word needs only minimal sensory evidence in order to trigger a response. This is not the only view, however, and it remains possible that priming could be due in part to sources outside the recognition lexicon (for instance in the semantic memory, or at post access stages, e.g. Norris, 1986). If this interpretation is correct, presence or absence of priming would not necessarily indicate whether the lexical route has been used. More precisely, it could be that in the normal course of events the lexical route would be used in the absence of priming effects. It is only in the case of explicit instructions that subjects would engage their post-access mechanisms and hence demonstrate priming (for instance by trying to guess what the next word in the list might be). This would be a rather extreme view and it is not obvious that such a story could be made to account for the detailed pattern of data (e.g. the absence of priming effect in disyllabic items.) Nevertheless, we wanted to address this concern by examining the relative role of time-course and attention using variables that are less controversially linked to lexical information, e.g. word frequency.

Experiment 2

Frequency effects are pervasive in lexical processing, and some models claim that these effects have an earlier locus than semantic priming effects (Forster, 1976; 1979; 1981). Frequency effects have been uncovered for short monosyllabic words using the phoneme monitoring task (Dupoux and Mehler, 1990; Eimas *et al.*, 1990). Is it possible that minimal attentional manipulations like those in Experiment 1 would modulate the magnitude of frequency effects?

We already know that secondary tasks increase the likelihood of observing a frequency effect (Eimas *et al.*, 1990). However, in those studies, the manipulation of the task is so extreme that the interpretation of the results is problematic. Subjects are asked to perform a lexico-syntactic categorization task (noun or verb) just after they have made a phoneme classification response. Unfortunately, this secondary task also increases the mean reaction time by a considerable amount (about 300 ms), leaving ample time for lexical information to take over. Therefore, it is not clear whether in these experiments the appearance of lexical effects is due to attention shifts or to a mere increase in mean reaction time. More importantly, nothing prevents subjects from performing part or all of the syntactic categorization first (since it is the most difficult task), and then switching to phoneme detection. If this is the case, reaction times to phonemes would be contaminated by those of the categorization task. This is why it is more informative to study the impact of attention in phoneme monitoring with a less intrusive secondary task.

We chose to replicate one of Dupoux and Mehler's (1990) experiments that showed the clearest interaction between frequency and word length. In their Experiment 3, the authors found significant frequency effects with monosyllabic items but not with disyllabic items. Strikingly, this was the case even when the materials had been artificially compressed by a factor of 50%, so that the duration of the words was halved.[5] Thus, even when bisyllabic items were physically shorter than monosyllabic items in the previous experiments, the authors failed to observe a frequency effect on multisyllabic items. Moreover, in this experiment, subjects focus was on semantic relationships, as it had been for the comprehension group of Experiment 1. The results of Dupoux and Mehler's experiment are thus consistent with what we found in Experiment 1; that is, no lexical effect emerged on disyllabic items even when subjects were biased towards the lexical level. To further assess the influence of attentional factors on phoneme monitoring, we endeavored to investigate whether frequency effects would disappear when subjects' attention is explicitly focused on the acoustic level.

Method

Materials. The materials consisted of 24 pairs of high frequency and low frequency French word. Nine pairs con-

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[5] Speech compression is a technique that allows the artificial modification of speech segment duration without altering other acoustic parameters such as pitch, timbre, formants, etc. Even at rates of 50%, stimuli remain highly intelligible (see Dupoux and Mehler, 1990).

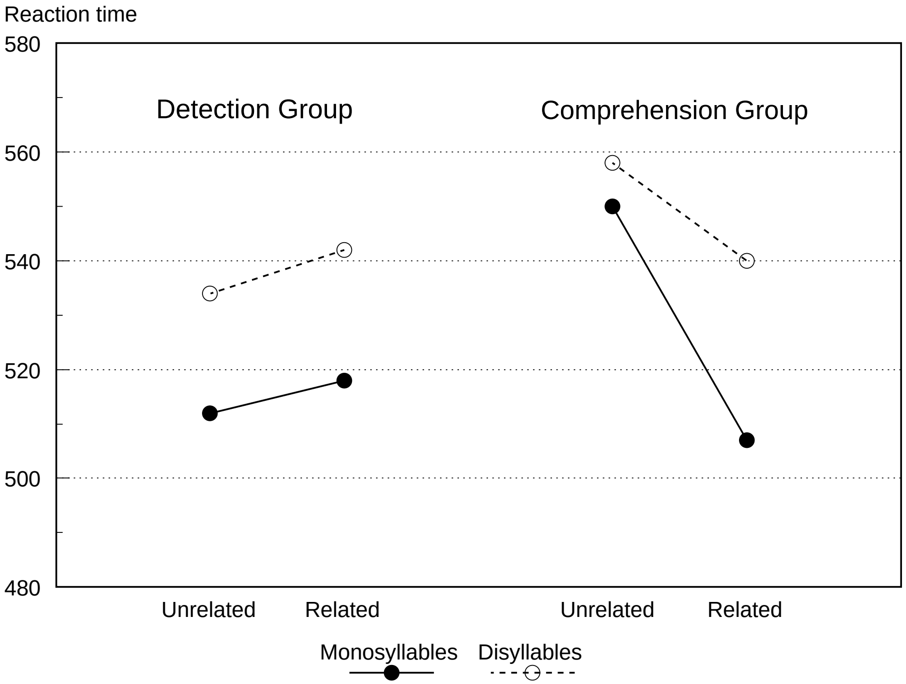

Figure 1. Phoneme monitoring latencies for monosyllabic and disyllabic words preceded by semantically related or unrelated words. The left panel shows the data for the 13 slowest subjects from the Detection Group, and the right panel shows the data for the 13 fastest subjects from the Comprehension Group (post-hoc reanalysis of Experiment 1).

sisted of monosyllabic items (average frequency: 227 per million for high frequency words and 6 per million for low frequency words) and 15 pairs were disyllabic items (average frequency: 374 and 5, respectively). These items were embedded within 5 uninterrupted lists of items, each corresponding to a particular target phoneme (/P/,/T/,/D/,/B/). Distractor words (half monosyllabic, half bisyllabic) were added in order to attain the ratio of one target to four distractors. The word preceding each experimental item was controlled in terms of length and did not start with a phonetically similar phoneme. The distractors were randomized such that there were no obvious associative relationships between successive items in the list.

The lists were read by a female native speaker of French at a regular rate of about one word every 2s. The materials were then artificially compressed so that their duration was half the duration of the natural items.[6] Intelligibility was still near perfect on these stimuli. The materials were the same as in Experiment 3 of Dupoux and Mehler (1990). The exact same tapes and test material were used.

*. Subjects and procedure

Thirty-two subjects (Ecole Polytechnique) participated in the experiment. Before each list, the target phoneme was specified auditorily with three town names as examples (“P as in Paris, Perpignan, Pau”). The task of the subjects was to press a button as soon as they heard the target phoneme at the onset of a word; they were instructed to respond as quickly as possible and to focus their attention on the acoustic information proper, without paying attention to the meaning of the words.

Results

Reaction times below 100 ms and above 1000 ms were discarded. The mean reaction time was 436 ms and the error rate was 2.2%.

An analysis of variance showed that neither Length nor Frequency showed a significant effect (all Fs less than 1). No significant interaction between Length and Frequency was found. Table 2 shows the results for the monosyllabic and the disyllabic items along with the results of the original Dupoux and Mehler’s experiment 3.

Discussion

The results of this experiment are straightforward: When subjects are instructed to pay attention only to the acoustic/phonetic aspects of the task, the previously observed frequency effect in monosyllabic items disappears. This new task did accelerate mean reaction times as compared to the Dupoux and Mehler study, but considerably less so than the attentional manipulation in Experiment 1 (the difference was only 36 ms). Thus, the absence of lexical effects can hardly be due to a change in response criterion.

Experiment 1 and 2 strongly suggest that **even when one equates for overall speed of response**, attentional factors can modify the magnitude of lexical effects found in phoneme

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[6] Compression was achieved using the Psola algorithm (see Charpentier and Stella, 1986).

Table 2
Mean reaction times and error rates for compressed monosyllabic and disyllabic items of high and low frequency, with subjects biased towards a "detection" version of the task (Experiment 2), and subjects biased towards a "comprehension" version of the task (From Dupoux and Mehler, 1990).

Number of syllables	Word frequency Low	High	Frequency Effect
Detection bias			
Monosyllabic	436 (2.1%)	436 (1.7%)	0.5
Disyllabic	434 (2.9%)	436 (2.3%)	-3
Comprehension bias			
Monosyllabic	479 (4.4%)	460 (5.0%)	19
Disyllabic	470 (2.8%)	478 (4.0%)	-8

* p<.05 by items and by subjects

monitoring. However, we consistently failed to observe any lexical effect in multisyllabic items.

It thus seems that there are **two modes** for phoneme monitoring responses. In a prelexical mode, subjects can respond in a way that completely bypasses lexical information. In the lexical mode, they use lexical information whenever it is available, and rely on prelexical information otherwise (in a pattern that conforms to a time-course model). What we have found in Experiment 1 and 2 is that the use of one mode or the other is not due to differences in mean response speed.

Given that the two ways of performing the task seem roughly equivalent in terms of performance, we should find hints of this throughout the phoneme monitoring literature. However, instructions usually bias subjects towards "detection"; that is, nothing special directs subjects' attention towards word meaning. But it is precisely this type of instruction that did *not* induce lexical effects in Experiments 1 and 2. Yet if our observation is correct, then how is it possible that anyone ever found any lexical effects at all? In a number of studies (Rubin *et al.*, 1976; Cutler *et al.*, 1987, Experiment 1; Dupoux and Mehler, 1990, Experiment 1 and 2), lexical effects in phoneme monitoring were uncovered. In these studies, the instructions to the subjects did not, in obvious ways, induce subjects to pay attention to the meaning of the words. However, in the detection group of our Experiments 1 and 2, which had quite similar conditions to those in the above mentioned studies, no lexical effect was found. What is the difference?

One difference between these studies is that they used subjects from different **populations**. As innocuous as this might seem, it could be crucial in our case. Even slight differences in the way the detection task is presented to subjects may besufficient to increase or decrease lexical effects in monosyllabic items. Other than the particular instructions used, there is nothing during the experiment itself that would force a subject to attend differentially to one level or the other, because the experimental stimuli are exactly the same. However, if different subjects interpreted the task in slightly different ways, this might account for the above-mentionned diverging set of results.

Table 3 shows a review of the studies run in French, including the present experiments. It appears that two main groups of subjects were used in all these studies. Math students are found in preparatory schools. They have been selected on the basis of school performance and are engaged in the preparation of highly competitive exams. Psychology students are found in the University of Paris V university, and represent a less selected student population. The two populations have the same age range, but there is a much higher proportion of male students in the math than in the psychology group.

One striking aspect of this table is that there seems to be a good (albeit not perfect) correlation between subject group and task on the one hand, and between subject group and the presence of lexical effects on the other. Hence, the task manipulation that we introduced in Experiments 1 and 2 is partly confounded with the group factor. Thus, in Experiment 1, the Detection group was run with maths students, whereas the Comprehension group involved psychology students. In Experiment 2, the group of subjects tested with the detection instructions were precisely the math students, i.e. the group that had previously not shown a lexical effect.

It thus appears that subject population, as unlikely a significant factor as it may seem at first, may actually be an important factor to explain the absence or presence of lexical effects. As striking as they are, coincidences may be just that: Coincidences. In most cases, the experiments run with math students as opposed to psych students were run with different materials, produced different mean reaction times, etc. If we want to attribute any influence to subject population, we have to directly compare two groups, from the two populations, in exactly the same experiment. This is what we did in Experiment 3.

Experiment 3

In this experiment, we built on a result reported in Dupoux (in preparation) who found a significant lexical effect in monosyllabic items (see table 3). The instructions to subjects were very similar to the ones used in the "detection" groups of Experiment 1 and 2. Psychology students participated in this experiment.

To directly test for an effect of population, we conducted a replication of the Dupoux experiment (in preparation), using the same materials and the same instructions, but a different group of subjects, namely those from the same population on which we had run the detection version of the task in experiments 1 and 2, i.e., non-psychologists.

Method

Materials. The materials consisted of 25 pairs of matched words and nonwords. Five pairs had a CV (consonant-vowel) structure, 10 pairs a CVC structure and 10 pairs a CCV structure. For each of these 50 words, a short list of words and nonwords (3 to 5 items long) was constructed. Each list was associated to a target phoneme, and the exprimental word always appeared at the final position in the list. Fifty additional lists were constructed of one, two or six items in length (8 of

Table 3
Comparison of phoneme monitoring experiments run on the same materials, but varying on subjects population and/or experimental instructions.

Study	Mean RT	Task	Population	Lexical effect
Experiment 1b (reanalysis)	530	Comprehension	psych. students	Yes
Experiment 1a (reanalysis)	540	Detection	math students	No
Dupoux and Mehler (1990) Exp 2	470	Comprehension	medical students	Yes
Experiment 2	440	Detection	math students	No
Dupoux (1989)	550	Comprehension	math students	Yes
Dupoux (1989) (pilot)	400	Neutral	math students	No
Cutler *et al.*(1987) Exp 7	460	Neutral	psych students	Yes
Dupoux (in preparation) Exp 3	350	Detection	psych students	Yes

the 6 item lists were catch trials that did not contain the target phoneme at all). Globally, half of the stimuli were monosyllabic and half were disyllabic. The lists were recorded onto tape with an inaudible pulse at the onset of each target phoneme, that started a computer clock. The tapes were created by rerecording the original tapes used in Cutler *et al.*(1987)'s experiment 7.

Procedure. The materials were split into two blocks and the order in which they were run was counterbalanced across subjects. Target phonemes were specified visually before each list. The materials and procedure were the same as in the Dupoux (in preparation) Experiment 3 and in Cutler *et al.*(1987)'s Experiment 1.

Subjects. Thirty students (École Ste Geneviève, Versailles) were asked to respond, as fast and as accurately as possible, whenever they heard the target phoneme at the onset of a stimulus in a list. The experiment lasted 13 minutes.

Results

Reaction times over 1000 ms and under 100 ms were rejected (less than 1% of the data). The rate of no response plus rejected responses was 3.5%. Mean reaction times and error rates are summarized in Table 4, together with the data obtained with the same materials and instructions, but with a psychology students population from Dupoux (in preparation).

An analysis of variance with subjects as random factor revealed that only the complexity factor yielded a significant effect ($F1(2,58) = 3.39 p < .04$). The lexicality factor did not reach significance ($F1 < 1$) nor did the interaction between lexicality and complexity.

To evaluate how the present results differ from the ones reported in Dupoux (in preparation), we conducted a global analysis, on the results of both groups. The factor of subjects group did not introduce a significant main effect ($F < 1$), but it did interact with the lexical factor ($F1(1,58) = 9.92, p < .003; F2(1,22) = 6.25, p < .02; minF(1,51) = 3.83, p < .6$) reflecting the fact that only psychology students but not math students show a lexical effect. The population factor also interacted with the complexity factor, but only in the subjects analysis ($F1(2,116) = 3.55 p < .04; F2(2,22) = 1.36 ns$). No other interaction was significant.

Table 4
Mean reaction times and error rates for monosyllabic CV, CVC and CCV words and nonwords; psychology students (Dupoux, in preparation) versus math students (Experiment 3).

Syllabic structure	Lexical Status: Non-word	Lexical Status: Word	Difference
	Psychology students		
CV	370 (1%)	332 (1%)	38
CVC	341 (1%)	333 (4%)	8
CCV	387 (4%)	367 (2%)	20
	Math students		
CV	345 (5%)	347 (4%)	-3
CVC	339 (1%)	347 (4%)	-8
CCV	359 (3%)	357 (5%)	2

Discussion

The results obtained in this experiment show that the lexicality effect found by Cutler *et al.*(1987) and Dupoux (in preparation) does not generalize to a new population of subjects, even when the experimental conditions are kept identical. Experiment 3 thus shows unambiguously that there is an influence of subject population on the presence or absence of a lexical effect. Whether or not there is an effect of the instructions given to subjects remains an open question, at least as far as the present experiments are concerned. Each time an effect of instructions was observed (Experiments 1 and 2), it was confounded with an effect of population. However, Eimas et al. (1990) have shown that a secondary task may modulate lexical effects in the same population of subjects.

How could an influence of the population arise? It seems quite absurd to hypothesize that psychology students and maths students do not process speech in the same way. This would roughly amount to saying that math students have a bottom up speech processing system while psychology students have a top down one! A more reasonable hypothesis is that what counts is how subjects *interpret* the task: It seems that different subjects populations might interpret things differently.

One can speculate and argue that, when psychology students are used to perform experiments, they are probably inclined to pay attention to covert variables. Indeed, they may focus on the existence of associations between words or common semantic fields that might occur in the lists. In brief, psychology students may have a more introspective attitude than other students. Thus, they may spontaneously construe the experiment as though it were the ”comprehension” version of the task, even when not explicitly asked to do so. In contrast, students of maths and physics are not familiar with this test taking predicament. Furthermore, the math student population we tested was special in that they are trained to pass very competitive exams, and are taught to optimize their performance without asking too many questions. Such subjects may tend to perform a ”detection” version of the task even when they are also asked to pay attention to the meanings of the words. One should note, however, that these differences in strategies or biases have little impact on average speed and accuracy of performance since the two groups show very comparable reaction times and error rates (6 ms of difference).

General discussion

In this paper, we endeavored to study how the lexicon influences phoneme detection times. Our aim was to disentangle two views: One in which only the time-course of information plays a role (at which level has the stimulus been processed when the response is triggered), and the other in which attentional variables can modulate the type of information that influences phoneme-monitoring responses.

That the time-course of information is very important is recognized in many, if not all, models of speech processing. Everybody agrees that if phoneme monitoring responses are triggered much before the point at which a word is identified, no influence of lexical variables should be found. In contrast, if one waits long enough, lexical information will become activated and will eventually influence subsequent phonemic judgments (see e.g. Fox, 1984). In our three experiments, we found support for a time-course component in that lexical effects were more likely to occur in monosyllabic than in disyllabic items. Since the target phoneme was in initial position, time-course models predict that shorter words ought to yield greater lexical influences than longer words; and this is what we observed. The specific question we investigated was whether such time-course factors were the ONLY ones that could account for the pattern of lexical effects in phoneme monitoring, or whether some residual factors could also play a role.

In Experiment 1, we contrasted a group of subjects in a straight phoneme monitoring task with a group performing a ’semantic’ secondary task. We found evidence for lexical effects only in the group run with the secondary task. This difference was not due to an increase in mean reaction time induced by the secondary task, since a reanalysis using two sub-groups perfectly equated for mean reaction time still showed significantly different lexical effects. Experiment 2 and 3 replicated this basic observation with two new sets of materials. That is, we again uncovered differences in lexical effects in the absence of any difference in mean response time. It is thus very clear from all three experiments that the time-course of information — how much of the stimulus has been heard when the response is triggered — cannot alone account for the amount of lexical influence on reaction time. We propose that there is an additional parameter that has to be taken into account, namely, variation in subjects’ ability to ignore or attend to the lexical source of information while performing the task. We suggested in Experiment 1 and 2 that adding a ’semantic’ secondary task to phoneme monitoring might prompt subjects to pay attention to the lexical information and thus increase the chance of lexical effects. However, we demonstrated in Experiment 3 that some subjects might have a greater propensity than others to ignore or take into account lexical information. The relative weight of these two factors (task manipulation and individual variables) remains to be quantified in further studies.

From these results, we can derive both a methodological conclusion and a theoretical one. On the methodological side, it becomes apparent that studies comparing the amount of lexical effects in different conditions should always be run on the same subject and during the same experimental session. Given that the amount of lexical effects can be modulated by subjects’ biases and attentional focus during the experiment, the contrasting conditions should be run in a tight set-up that ensures that these variables stay constant. On the theoretical side, time-course models of speech processing should be supplemented to allow for modulating the amount of lexical influences in phoneme monitoring while keeping the mean performance identical. Below, we discuss implications for some current models of speech processing.

Many models posit that lexical influences on phonemic recognition occur at a very early stage, that is, at the prelexical level itself (Samuel, 1987; McClelland and Elman, 1986). As an example, in the TRACE model, phoneme units receive bottom-up information coming from the acoustic/phonetic level and top-down feedback from the lexical level. When the stimulus presented is a word, activation from non-lexical and lexical sources add up, whereas for nonwords, only prelexical sources contribute to phonemic activation. In order to account for reaction times, a decision system reads out the activation values of the phoneme units and applies a choice rule to select the appropriate response. In such a model, the only parameters that could be modified by the decision component are the response criteria or biases incorporated into the choice rule. When the stimulus is fixed, the only way to eliminate lexical effects is then to arrange to respond faster (by setting a lower threshold), so that lexical information does not have time to kick in. Similarly, to increase lexical effects, one should respond later so that more lexical activation will have accumulated. However, we argued in our three experiments that decision-related modulations of lexical effects are not necessarily correlated with response speed. Therefore, these kinds of models would need to be adjusted in order to accommodate the fact that strategic or attentional factors can modulate the amount of lexical feedback. In a model like TRACE, this would amount to positing special modulating connections that would boost or tone down lexical feedback according to higher level expectations. Of course, it is possible that adding these degrees of freedom to models will greatly diminish their predictive power.

In other models of pre-lexical processing, lexical effects in phoneme monitoring are not a direct reflection of processing, but rather a result of a late decision component. One model proposed by Newman and Dell (1980) postulates that the decision system can inspect two codes, a phonetic code which derives from the pre-lexical level, and a phonemic code which is activated by information retrieved from the lexicon (see also Cutler *et al.*, 1987). Comparisons between the target phoneme and the stimulus would be carried out in parallel between these two codes, but the decision system would be able to give differential weight to one code over another (hence enhancing or overriding the time-course advantage that one code might have over the other). At one extreme, this would lead to a pure pre-lexical mode of response, and at the other, to a purely lexical mode of response (which is actually never observed). Between the two extremes one can find a mixture of the lexical and the pre-lexical level that would depend on the relative accessibility of the two types of information.

The preceding models are in fact not the only ones that can account for the present set of data. Some other models of the phoneme monitoring task that posit a late locus of lexical effects can also be constructed. For instance, another possible model might state that the main source of evidence used throughout is the phonetic-prelexical code. Once a target phoneme has been identified at that level, the decision system has the option of checking the phonemic-lexical code to see if the phoneme is indeed present. Instead of a horse-race, we then have a serial match-then-check model. In fact, it is not even necessary that lexical-phonemic information be used at all to account for lexical effects. It could be that in the case of an unpredicted word, a very infrequent word, or a nonword, the processing system sends an alarm signal to the decision system which gets temporarily distracted from the task. This would result in an apparent advantage for, respectively, predictable words, frequent words, or actual words, without the contribution of specific lexical information. Once we enter the realm of the decision system there are many new and different theoretical alternatives to be explored. Exploring them is important because these alternatives make diverging predictions concerning the way in which the task is carried out, and how it could be used to draw inferences about the on-line architecture of speech processing.

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