Inhibitory priming effect in auditory word recognition: The role of the phonological mismatch length between primes and targets.

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Abstract

Three experiments examined lexical competition effects using the phonological priming paradigm in a shadowing task. Experiment 1 replicated Hamburger and Slowiaczek' s [1] finding of an initial overlap inhibition when primes and targets share three phonemes (/bʀiz/-/bʀik/) but not when they share two phonemes (/bʀɛz/-/bʀik/). This observation suggests that lexical competition depends on the number of shared phonemes between primes and targets. However, Experiment 2 showed that an overlap of two phonemes was sufficient to cause inhibition when the primes mismatched the targets only on the last phoneme (/bol/-/bot/). Conversely, using a three phonemes overlap, no inhibition was observed in Experiment 3 when the primes mismatched the targets on the last two-phonemes (/bagɛt/-/bagaj/). The data indicate that what essentially determines prime-target competition effects in word-form priming is the number of mismatching phonemes.

1. Introduction

There are now ample evidences from various experimental paradigms that multiple lexical candidates are activated and compete with one other during target word processing. However, the precise mechanism by which competition among lexical candidates is supposed to arise still remains controversial. In some models such as TRACE [2] and Shortlist [3], lexical competition is due to intra-level inhibition that operated between activated lexical entries. Conversely, in the Cohort [4] or the NAM model [5], lexical competitors have no direct influence on the activation level of target word, but competition effects are mediated at a decision stage, where the presence of close competitor slow down the process of discrimination among lexical candidates.

A way to study competition processes consists in measuring target performance after the presentation of one of its lexical competitor. All current models predict that priming a target word by one of its competitors should slow down its recognition. Indeed pre-activation of the competitor should increase its inhibitory influence during target processing in models such as TRACE or Shortlist. Also the activation level of the target word should take longer to exceed that of its competitors in the Cohort model. Surprisingly however, the literature on phonological priming reports very few inhibitory effects. The aim of the present study was to assess the best conditions under which the expected competition effect can be consistently demonstrated.

Hamburger and Slowiaczek [1] asked participants to perform a shadowing task on monosyllabic targets preceded by primes sharing zero (e.g. scream-dread), one (dove-dread), two (drill-dread) or three (dress-dread) phonemes with the target words. It was found that responses were faster when primes and targets shared one or two phonemes than when there was no phonemic overlap between them. Moreover, in comparison with zero phoneme overlap, an inhibition effect was observed when primes and targets shared three phonemes. The results suggest that the likelihood that an inhibitory priming effect emerges is dependent of the number of shared initial phonemes. Inhibitory effects are more likely to occur with an overlap of three phonemes than with an overlap of two phonemes between the primes and the targets. Nevertheless, such a finding is incompatible with the data obtained by Radeau, Morais and Segui [6] using monosyllabic words. With a 20 ms inter-stimuli interval (ISI) and primes less frequent than the targets, Radeau et al. reported an inhibitory effect in a shadowing task, despite the fact that the primes and the targets shared only the first two phonemes (e.g. Bouche /buʃ/- Boule /bul/).

Why did Radeau et al. observed an inhibitory effect with an overlap of two phonemes while Hamburger and Slowiaczek did not? Examination of Hamburger and Slowiaczek 's materials reveals that the phonological mismatch length between primes and targets covaried with the size of the phonological match. In their study, the authors used four or five-phoneme monosyllabic words. This implies that in the case of an overlap of two phonemes, the primes mismatched the targets at least on the last two phonemes (drill-dread). In contrast, in Radeau et al.'s study, three-phoneme monosyllabic words were used, meaning that with the same overlap, the primes mismatched the targets only on the last phoneme (e.g. bouche /buʃ/- boule /bul/). It is thus likely that the amount of inhibition exerted by a competitor on target word recognition is a function of the size of the phonological mismatch. The present study was undertaken to provide an empirical examination of this hypothesis.

Three experiments were carried out in order to examine whether variations in the number of mismatching phonemes cause variations in the competition effect between prime and target words. In each experiment, the primes and targets were presented auditorily and the subjects performed a shadowing task. The stimulus lists included a weak proportion of related pairs (25%) to minimize the influence of strategic factors that could counteract the expected inhibitory effects. A short ISI (50 ms) was also used to avoid activation produced by the primes dissipating before target presentation.

2. Experiment 1

Experiment 1 consisted in a partial replication of the Hamburger and Slowiaczek's experiment to assess the generality of their effect with French materials. Primes and targets shared zero (/mwan/-/bʀik/), two (/bʀɛz/-/bʀik/) or three (/bʀiz/-/bʀik/) phonemes.

2.1. Method

2.1.1. Participants

Fifty-four students at the University of Bourgogne participated in the experiment for course credits. All were native speakers of French and reported no hearing or speech disorders.

2.1.2. Materials

Forty-two monosyllabic target words, four phonemes in length, were selected from BRULEX [7]. Three monosyllabic prime words, four phonemes in length, were paired with each of these 42 target words. Two primes were phonologically related to the target: One shared the first two phonemes with the target and mismatched the target on the last two phonemes (e.g. BRAISE /bʀɛz/-BRIQUE /bʀik/), the other shared the first three phonemes with the target and differed from the target only on the last phoneme (e.g. BRISE /bʀiz/-BRIQUE /bʀik/). A third prime having no phoneme in common with the target was used as a control (e.g. MOINE /mwan/-BRIQUE /bʀik/). All primes were matched on word frequency.

Because each target was paired with three different primes and no subject was to be presented with the same target more than once, three experimental lists were created. The lists were counterbalanced so that each target was preceded by the three types of prime. In order to have a proportion of related prime-target pairs of 25%, 70 filler trials without any relation between the primes and the targets were added in each list.

2.1.3. Procedure

The stimuli were recorded by a female native speaker of French on a digital audio tape recorder. The items were digitized at a sampling rate of 44 kHz with 16-bit analog to digital recording. The presentation of the items was controlled by a personal computer and RTs were collected via a voice key. The primes and the targets were presented over headphones at a comfortable sound level. An interval of 50 ms (ISI) separated the offset of the prime and the onset of the target. The participants were asked to repeat the target as quickly and accurately as possible. The subject's response and the onset of the prime of the following trial were separated by 2 seconds of silence. The naming latencies were measured from the onset of the target to the subject's response. The experiment began with a block of 16 practice trials.

2.1.4. Results

Two items giving rise to an error rate of more than 20% were excluded from the analyses. For each subject, both reaction times (RTs) longer than 1200ms and those greater than 2.5 standard deviations above and below the participant's overall response time were removed from the analyses. Incorrect responses were also removed from the latency analyses. Mean RTs in each priming condition are presented in Table 1. Because few errors occurred in this experiment as well as in the following ones, analyses were performed on RTs only. Analyses of Variance (ANOVA) by participants (F1) and by items (F2) were conducted with prime type ("two-phoneme", "three-phoneme" and control) as variable. In order to reduce inter-individual variability, the variable list was also included in the analyses. Only the results concerning the interest variable "prime type" are reported below.

Table 1. Prime-target conditions used in Experiments 1 to 3, and mean reaction times as a function of the phonemic match and mismatch lengths.

Prime Types [1]	Prime-Target length[2]	Phonemic mismatch length[2]	RTs (in ms)	Priming effect (in ms)
Experiment 1				
Control	4		825	
Two-phoneme	4	2	817	+ 8
Three-phoneme	4	1	840	- 15 *
Experiment 2				
Control	3		798	
Two-Phoneme	3	1	808	- 10 *
Experiment 3				
Control	5		862	
Three-Phoneme	5	2	869	- 7
Four-Phoneme	5	1	885	- 23 *

Notes. [1] Primes are designed as a function of the number of phonemes shared with the Targets ; [2] in number of phonemes; * significant effect

The main effect of prime type was reliable (F1(2,102) = 10.21, p<.001; F2(2,74) = 8.93, p<.001). Planned comparisons show that responses were 15 ms slower when targets were preceded by the "three-phoneme" primes in comparison with the control primes. The difference was reliable (F1(1,51) = 7.42, p<.01) ; (F2(1,37) = 5.47, p<.05). No significant difference was observed between the "two-phoneme" primes and the control primes (F1(1,51) = 2.78, p = .10); (F2(1,37) = 1.99, p=.17).

3. Experiment 2

Experiment 2 examined whether an overlap of two phonemes is sufficient to cause an inhibitory priming effect when primes mismatched the targets only on the last phoneme.

3.1. Method

3.1.1. Participants

Forty students from the same pool as Experiment 1 were recruited.

3.1.2. Materials & Procedure

Forty-two monosyllabic target words, three phonemes in length, were selected. Two monosyllabic prime words, three phonemes in length, were paired with each of the 42 target words. One prime shared the first two phonemes with the target and mismatched the target on the last phoneme (e.g. BOL /bol/-BOTTE /bot/). The other was used as a control and had no phoneme in common with the target (e.g. LOUCHE /luʃ/-BOTTE /bot/). All primes were matched on word frequency.

The targets being paired with two types of primes, two experimental lists were created. In order to have a proportion of related prime-target pairs of 25%, 42 filler trials without any relation between the primes and the targets were added in each list. The procedure was the same as in Experiment 1.

3.1.3. Results

Two items giving rise to an error rate of more than 20% were excluded from the analyses. The RT data were analyzed according to the same criteria as in Experiment 1. Mean RTs are presented in Table 1.

The ANOVAs revealed a main effect of prime type that was significant ($F1(1,38) = 6.74$, $p<.05$; $F2(1,38) = 5.34$, $p<.05$). Targets were responded 10 ms slower when they were preceded by the related primes in comparison with the control primes.

4. Experiment 3

Both Experiment 2 and the results described by Radeau et al. indicate that an inhibitory priming effect can be observed even in the case of a reduced initial overlap between the primes and the targets. At first sight, these findings appear to conflict with the data reported both in Experiment 1 and Hamburger and Slowiaczek's study. Indeed, in Experiment 1 an inhibitory effect was found only when the initial overlap was of three phonemes. Experiment 2 suggests therefore, that the lack of an interference effect in Experiment 1 for the two-phoneme overlap follows from a high level of mismatch between the primes and the targets. It seems that a prime sharing the first two phonemes with the target can slow down the recognition of the target word only when it mismatches the target on the last phoneme. A more thorough examination of the role of the number of mismatching phonemes would consist of assessing whether an initial overlap of three phonemes is still sufficient to cause inhibition when the primes mismatch the targets on the last two phonemes. This was the purpose of Experiment 3.

4.1. Method

4.1.1. Participants

Fifty-four students from the same pool as Experiments 1 and 2 were recruited.

4.1.2. Materials & Procedure

Forty-two bisyllabic target words, five phonemes in length, were selected. Three bisyllabic prime words, five phonemes in length, were paired with each of these 42 target words. Two primes were phonologically related to the target. One shared the first three phonemes with the target and mismatched the target on the last two phonemes (e.g. BAGUETTE /bagɛt/-BAGAGE /bagaʒ/). The other shared the first four phonemes with the target (e.g. BAGARRE /bagaʀ/-BAGAGE /bagaʒ/) and differed from the target only on the last phoneme. The third prime was used as a control and had no phoneme in common with the target (e.g. FLOCON /flɔkõ/-BAGAGE /bagaʒ/). All primes were matched on word frequency.

Since the targets were paired with three different types of primes, three experimental lists were created. In order to have a proportion of related prime-target pairs of 25%, 70 filler trials without any relation between primes and targets were added in each list. The procedure was the same as in Experiments 1 and 2.

4.1.3. Results

Mean RTs in each condition are presented in Table 1. The main effect of prime type was reliable ($F1(2,102) = 11.53$, $p<.001$; $F2(2,78) = 7.59$, $p<.001$). Planned comparisons indicate that responses were 23 ms slower when targets were preceded by the "four-phoneme" primes in comparison with the control primes. The difference was reliable ($F1(1,51) = 17.36$, $p<.001$; $F2(1,39) = 10.84$, $p<.01$). No significant difference was observed between the "three-phoneme" primes and the control primes ($F1(1,51) = 2.27$, $p =.14$; $F2<1$).

5. Discussion

The basic finding of the present study is that the competition effect which is predicted by competitive activation models can be consistently observed when the prime and target differ on the last phoneme, that is to say when the competitor prime word diverges later from the lexical representation of the target.

It has been recently claimed that the inhibition observed with an initial overlap reflects a surprise effect [8]. Examining the emergence of biases by comparing the magnitude of the priming effects at various points during the experimental session, Pitt & Shoaf reported an inhibitory effect only for targets occurring at the beginning of the experiment. No inhibition was observed when the targets occurred at the end of the testing session. It was therefore suggested that priming effects are contaminated by response biases developed by participants when they become aware of the presence of related pairs (see also [9]). Also, it was argued that inhibitory priming effects are due to participants' surprise that arises when they encounter the first related trial. We believe however, that the present inhibition cannot be attributed to participants' surprise. Indeed, our experimental setting also included related trials in the training session (4 related trials out of 16) so that any surprise effect should be manifested during the training session and not during the experimental session. Moreover, such an account does not explain the modulation of inhibitory priming effect as a function of lexical factors such as the lexicality [10], or the frequency of the primes [6]. Compatible with such a view, we have recently found that inhibitory priming effect also varies as a function of the neighborhood density of the target words [11].

Our results appear compatible with models such as Trace [2] and Shortlist [3] that assume lateral inhibitions between lexical candidates. In Trace, all the lexical nodes are potential candidates for recognition, continuously increasing or decreasing in activation as a function of their match with the incoming signal. In addition, the degree to which a competitor tries to inhibit the target word is a function of its activation level. The more a competitor is activated, the more inhibition the target word will receive. Because competitors are activated in proportion with their match with the incoming signal, stronger competitions should arise for large prime-target overlap. Thus, compatible with our findings, a competitor such as /bagaʀ/ should have more influence on the recognition of the target word /bagaʒ/ than a word such as /bagɛt/. Indeed, in the latter case the competitor /bagɛt/ matches the target word on the first three phonemes, and it should therefore be less reactivated during target presentation. Nonetheless, our data also indicate that the number of mismatching phonemes is a key determinant in the emergence of inhibition priming effects. So, priming occurred for a prime-target overlap of three phonemes in the case of a one-phoneme mismatch but not in the case of a two-phoneme mismatch. Similarly, a two-phoneme overlap caused inhibition only when primes and targets differed by one, not two phonemes. In the absence of simulation work, it is presently unclear how the Trace model could predict differential inhibition effects for prime-target words sharing the same number of phonemes but differing on the mismatch length.

Unlike Trace, in Shortlist competition takes place within a small list of word candidates. This model involves two distinct stages of processing. In the first stage, a short list of candidates that are roughly consistent with the incoming signal is derived. Only the candidates that match the input to some preset criterion are allowed to enter into a second stage of competition similar to that assumed by Trace. Also Shortlist predicts a stronger competition between lexical candidates that have a large phonological overlap. Thus, the competitor /bagaʀ/ should have a greater impact on target word recognition /bagaʒ/ than the word /bagɛt/ because it overlaps more with the target word.

An interesting feature of the Shortlist model is that the activation of words that mismatch the input decreases through bottom-up inhibition. Compatible with this model feature, some evidence in the literature indicates that bottom-up inhibition plays a role during word processing [12]. Hence, a possible explanation for the lack of competition when primes differed from the targets by the last two phonemes would be to assume that competitors are rapidly inhibited —through bottom up inhibition — when mismatching phonemes are detected. As a result, the earlier a mismatch phoneme between a target word and its competitor is detected, the faster the activation of the competitor turned off, thus strongly reducing its inhibitory influence during target word processing. Further studies are required to examine whether the absence of a competition effect in the case of two diverging phonemes is due to a bottom-up inhibition mechanism.

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