FACILITATION AND INHIBITION
USING A SEGMENTAL PHONETIC PRIMING PARADIGM

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ABSTRACT
This research explores the representation and access of lexical form during spoken word recognition. Two experiments were conducted examining segmental priming effects. In the first set of experiments, a single fricative segment functioned as a prime to targets with either a matching or mismatching fricative in initial (Experiment 1a) or final (Experiment 1b) position. In the second set of experiments, a CV or VC combination functioned as a prime to targets either matching or mismatching this consonant vowel combination in onset (Experiment 2a) or offset (Experiment 2b) position. Results show a significant matching (match versus mismatch) by position (onset versus offset) interaction. For fricative primes, facilitatory priming is evident in onset position and inhibition in offset position. For consonant-vowel primes, an opposite pattern is evident with inhibitory priming in onset position and facilitation in offset position. The results will be discussed in terms of recent models of auditory word recognition.

1. INTRODUCTION
This research examines access processes during spoken language comprehension. In particular, we are interested in the effects of precursors (primes) on the recognition of a following target word. Many researchers have investigated the effects of semantically related, or even lexically identical prime words. In the present research, however, we investigate priming effects in the case where prime and target are related not lexically or semantically, but only phonologically — the prime is a speech fragment that is phonologically related to, or partly overlaps, the target word. The most extensively studied topic in this domain is rhyme priming (e.g., Meyer, Schvaneveldt, & Ruddy [1]). In both visual and auditory modalities (e.g., Burton, Jongman, & Sereno [2]), reaction time to a target item is faster when preceded by a phonologically related prime in comparison to a preceding control prime. Rhyming can be defined in terms of a preponderant overlap of phonological information between prime and target, involving coincidence at the end of words.

In a series of experiments, Slowiaczek, Nusbaum and Pisoni ([3]) began investigating priming effects in which overlap in phonological information occurred starting from word onset. Although their original facilitatory effects have been difficult to replicate, most subsequent studies have shown that when prime and target share initial phonological information, inhibitory effects are observed (Radeau, Morais, & Dewier [4]). These inhibitory effects are more variable than the rhyme priming data in that they are often mediated by relatedness proportion, ISI, and task demands and there is some evidence for persistent bias effects (Goldingar [5], but see Hamburger & Slowiaczek [6]).

Nevertheless, experiments examining overlap between target words and preceding primes do show a somewhat regular pattern of facilitation and inhibition (Slowiaczek, McQueen, Soltano, & Lynch [7]). In general, the results show contrasting effects depending on whether overlap is initial or final. When overlap occurs in onset position, inhibitory effects are typically found. Explanations for such effects point to the involvement of lexical competition. With final overlap, results are often facilitatory in nature although this facilitation seems to require rime overlap. These results have been attributed to the operation of automatic perceptual processes.

A series of segmental phonetic priming experiments were conducted in Dutch to address the automatic and perceptual nature of the processes involved. In the quest for pure priming, a single phonetic segment (rather than a word or nonword) was used to prime a target containing that segment (Sereno & Jongman [8]). The phonetic priming paradigm offers several advantages. As with previous methodologies, it allows variation in overlap (e.g., initial or final) between prime and target. Importantly, however, using a single phonetic segment strips the prime of lexical status. Onset and offset priming can be directly compared. Presentation of a single phonetic segment also allows for a reduction of the temporal interval between prime and target, enhancing sensitivity to early processes in auditory word recognition.

The present paper presents data from two experiments: a fricative priming experiment and a consonant-vowel priming experiment. For the fricative experiment, an isolated fricative segment served as a prime for target words. Overlap between prime and target was either in initial position (Onset Fricative Priming – Experiment 1a) or in final position (Offset Fricative Priming – Experiment 1b).

In the onset fricative priming experiment, fricative segments [f, s, x] were used as primes for target words (e.g., faam ‘fame’, soep ‘soup’, and gek ‘weird’). Matching pairs ([f]-faam, [s]-soep, [x]-gek) were contrasted to mismatching items ([s]-faam, [x]-soam, [f]-soep, [x]-soep, [f]-gek, [s]-gek). The offset fricative priming experiment was identical to the onset
experiment except that overlap occurred at the end of target items (e.g., [f]-dief, [s]-dief, [x]-dief ‘thief’).

The consonant-vowel experiments were run to examine the supplementary role of the vowel nucleus in mediating the initial and final overlap priming effects. For the consonant-vowel experiments, either a CV or VC cluster served as a prime for a target word. Overlap between prime and target was either in initial position (Onset CV Priming – Experiment 2a) or final position (Offset VC Priming – Experiment 2b).

In the onset consonant-vowel experiments, CV segments were used as primes for target items (e.g., [bu]-boek ‘book’; [ri]-riet ‘reed’). The offset consonant-vowel experiments were identical to the onset consonant vowel experiments except that overlap occurred at the end of the target item (e.g., [uk]-boek ‘book’; [it]-riet ‘reed’). In both onset CV and offset VC experiments, matching prime-target pairs were contrasted to mismatching pairs.

In all our experiments, both primes and targets were presented auditorily; subjects’ task was to repeat the target word (shadowing). The purpose of the present set of experiments was to determine whether a phonetic segment prime facilitates or inhibits the response to a stimulus item containing that segment, and whether this effect varies with the amount and/or location of overlap. The results should improve our insight in the mechanisms of lexical priming and competition during spoken word recognition.

2. METHODS

2.1. Experiment 1a: Onset Fricative Priming

2.1.1. Participants

Thirty-three students from the subject pool at Utrecht University were paid to participate in the experiment. All were native speakers of Dutch.

2.1.2. Material

Stimuli were recorded by a male speaker. The words were read in a list and the prime segments were produced in isolation. The stimuli were digitized and then excised using both auditory and visual criteria.

Seventy-five stimuli were used in this experiment. The 75 Dutch words were selected from the CELEX database [9]. All words were monosyllabic, with 25 words containing [f] in initial position, 25 words containing [s] in initial position, and 25 words containing [x] in initial position. All words were fricative [f, s, x] initial, with a F(C)V(C)F structure. No other fricative occurred in any other position. Duration of each of the three isolated primes was 360 ms.

In each trial, stimuli were preceded by one of the three priming fricative segments [f, s, x]. There were 45 target words and 30 fillers. For the target items, one third of the fricative-initial stimuli were preceded by matching fricative primes and two-thirds by a mismatching fricative prime. For the filler items, all items were preceded by a mismatching fricative prime. Therefore, the relatedness proportion for the experiment was 15/75 = 20%.

Three test versions were constructed so that every target was preceded by one of the three possible primes and every subject heard all target words, but no subject heard a target word more than once.

2.1.3. Design and Procedures

All subjects were tested individually in an auditory shadowing task. Subjects were told that on each trial they would hear a fricative segment followed by a target stimulus and that they were to name the target as quickly and accurately as possible. The stimuli were presented at a fixed rate with a prime followed by a target item. There was a 75 ms ISI between offset of the prime and onset of the target. Reaction times were measured from the onset of the target until a naming response was made. Following the offset of the target, there was a 3-second silent interval until the next trial started. This sequence was repeated for each stimulus item.

Following instructions, subjects were given a set of 9 practice items to introduce them to the procedure. These practice items were not used in the experiment. The experiment lasted approximately 30 minutes.

2.2. Experiment 1b: Offset Fricative Priming

2.2.1. Participants

Thirty-three students from the subject pool at Utrecht University were paid to participate in the experiment. All were native speakers of Dutch.

2.2.2. Materials

Seventy-five stimuli were used in this experiment. The 75 Dutch words were selected from the CELEX database [9]. All words were monosyllabic, with 25 words containing [f] in final position, 25 words containing [s] in final position, and 25 words containing [x] in final position. All words were fricative [f, s, x] final, with a C(C)V(C)F structure. No other fricative occurred in any other position.

All 75 stimuli were preceded by one of the priming fricative segments [f, s, x]. There were 45 target words and 30 fillers. For the target items, one-third of the fricative-final stimuli were preceded by matching fricative primes and two-thirds by a mismatching fricative prime. For the filler items, all items were preceded by a mismatching fricative prime. Therefore, the relatedness proportion for the experiment was 15/75 = 20%.

2.2.3. Design and Procedure

All procedures were identical to Experiment 1a.

2.3. Experiment 2a: Onset CV Priming

2.3.1. Participants

Twenty-seven students from the subject pool at Utrecht University were paid to participate in the experiment. All were native speakers of Dutch.
2.3.2. Materials
Forty-five stimuli were used in this experiment. The 45 Dutch words were selected from the CELEX database [9]. All words were monosyllabic, with 9 words each containing one of the 5 Dutch vowels (ie, oe, oo, eu, ui) in medial position. All words had a CVC structure. All stimuli were preceded by a CV prime. There were 26 different CV primes. There were 30 target words and 15 fillers. For the target items, one-third of the stimuli were preceded by matching CV primes and two-thirds by a mismatching CV prime. For the filler items, all items were preceded by a mismatching CV prime. Therefore, the relatedness proportion for the experiment was 10/45 = 22%.

Three test versions were constructed so that every target item was preceded by one of three possible primes and every subject heard all target items but no subject heard a target item more than once.

2.3.3. Design and Procedure
All procedures were identical to Experiment 1a.

2.4. Experiment 2b: Offset VC Priming

2.4.1. Participants
Twenty-seven students from the subject pool at Utrecht University were paid to participate in the experiment. All were native speakers of Dutch.

2.4.2. Materials
The 45 stimuli were the same as those used in Experiment 2a. All words had a CVC structure. All stimuli were preceded by a VC prime. There were 20 different VC primes. There were 30 target words and 15 fillers. For the targets, one-third of the stimuli were preceded by matching VC primes and two-thirds by a mismatching VC prime. For the filler items, all items were preceded by a mismatching CV prime. Therefore, the relatedness proportion for the experiment was 10/45 = 22%.

2.4.3. Design and Procedure
All procedures were identical to Experiment 1a.

3. RESULTS

3.1. Onset and Offset Fricative Priming
Tables 1 and 2 show mean naming latencies for the Onset and Offset Fricative Priming experiments, respectively. The data from the two experiments were combined and subjected to a Repeated Measures ANOVA with Matching (matching versus mismatching prime) and Position (initial versus final) as fixed factors. Of most interest is the significant Matching × Position interaction, [F(1,41) = 5.08, p=.02], [F(2,39) = 3.79, p=.05], indicating that while latencies to matching targets (590 ms) are faster relative to mismatching targets (598 ms) in onset position, the opposite is true for targets in final position, where latencies to matching targets (545 ms) are slower relative to mismatching targets (530 ms).

<table>
<thead>
<tr>
<th>Target</th>
<th>Prime</th>
</tr>
</thead>
<tbody>
<tr>
<td>[f]</td>
<td>613</td>
</tr>
<tr>
<td>[s]</td>
<td>605</td>
</tr>
<tr>
<td>[x]</td>
<td>566</td>
</tr>
</tbody>
</table>

Table 1. Mean naming latencies (in ms) to fricative-initial targets as a function of fricative prime (Experiment 1a). Cells with matching primes are printed in italics.

<table>
<thead>
<tr>
<th>Target</th>
<th>Prime</th>
</tr>
</thead>
<tbody>
<tr>
<td>[f]</td>
<td>543</td>
</tr>
<tr>
<td>[s]</td>
<td>528</td>
</tr>
<tr>
<td>[x]</td>
<td>516</td>
</tr>
</tbody>
</table>

Table 2. Mean naming latencies (in ms) to fricative-final targets as a function of fricative prime (Experiment 1b). Cells with matching primes are printed in italics.

3.2. Onset and Offset Consonant-Vowel Priming
Table 3 shows mean naming latencies for the Onset CV and Offset VC Priming Experiments (Experiments 2a and 2b). Like the fricative priming data, these data were subjected to a Repeated Measures ANOVA with Matching (matching versus mismatching) and Position (initial versus final) as fixed factors. A significant Matching × Position interaction was observed [F(1,52) = 4.16, p=.04; F(2,42) = 4.05, p=.04]. This interaction indicates that while naming latencies to matching targets (502 ms) are slower relative to mismatching targets (489 ms) in onset position, the opposite is true for targets in final position, where latencies to matching targets (511 ms) are faster relative to mismatching targets (517 ms).

<table>
<thead>
<tr>
<th>Position</th>
<th>Prime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onset</td>
<td>502</td>
</tr>
<tr>
<td>Offset</td>
<td>511</td>
</tr>
</tbody>
</table>

Table 3. Mean naming latencies (in ms) to targets as a function of primes that matched or mismatched in either onset or offset position.

4. DISCUSSION
The patterns of results obtained in these experiments agree with current theories of spoken word recognition. If the phonological prime overlaps with the onset of a word, then the short matching prime (single-segment prime) provides a clue to the following target word, as in [s]-soep. Note that this particular type of priming also occurs in everyday speech, when a speaker hesitates after producing the initial sound of a word or name. If the onset-overlapping prime increases in length, and most importantly includes a nuclear vowel (as in our
matching CV-primes), then it provides sufficient phonetic information to trigger a fresh recognition attempt by itself. The prime boe- activates all matching competitor words (e.g. Dutch boef, boeg, boer) which then compete with the following target word (boek). Hence, the inhibition by the matching onset-overlapping CV prime agrees with the now commonly accepted notion of lexical competition.

If the phonological prime overlaps with the offset of the target word, then the observed inhibition by single-segment offset primes may be explained as competition, albeit in a rather indirect way. We assume that listeners interpret the prime fricative as a tentative word onset. For single-segment offset primes, they will then be confused when hearing that same consonant in offset position. They may attempt to parse the offset fricative (which they have just heard as an onset, in the prime) as an onset consonant. This parsing has to be backtracked, which results in longer naming latencies, in analogy to the inhibition effects in MSS studies (e.g., Cutler & Norris [10]). This confusion or inhibition does not occur with mismatching offset primes, which therefore yield somewhat faster latencies. However, if the offset prime increases in length as a VC rhyme, listeners do not parse the vowel-initial fragment as an onset. In the stimulus sequence [uk]-boek, for example, the prime may facilitate matching competitor words (e.g. Dutch zoek, koek, doek, etc.), but these competitors are effectively suppressed by the activated target word, which has the strongest phonetic evidence in its favor by the time any phonetic evidence comes in for one of these competitors (i.e., when the vowel comes in). Thus, a facilitation of candidates by matching offset-overlapping VC primes compared to mismatching controls is observed.

Rather than hypothesizing categorically different types of mechanisms that operate in onset and offset locations, the present data suggest a uniform mechanism that engages lexical level information only when the nuclear vowel is present as part of the prime. In onset position, CV overlap produces inhibition while in offset position VC overlap produces facilitation.

5. ACKNOWLEDGEMENTS

The first author gratefully acknowledges the financial support from the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO). The authors would also like to thank Allard Jongman, Bert Schouten, Sieb Nooteboom, and Esther Janse for helpful discussions. Corresponding author: Joan Sereno, Linguistics Department, 421 Blake Hall, University of Kansas, Lawrence, Kansas, 66045, U.S.A. Email: sereno@ukans.edu.

6. REFERENCES