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► **To cite this version:**

Manuel Carreiras, Ludovic Ferrand, Jonathan Grainger, Manuel Perea. Sequential Effects of Phonological Priming in Visual Word Recognition. *Psychological Science*, 2005, 16 (8), pp.585-589. 10.1111/j.1467-9280.2005.01579.x . hal-03879167

HAL Id: hal-03879167

<https://hal.science/hal-03879167>

Submitted on 29 Mar 2024

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Sequential effects of phonological priming in visual word recognition

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Word count:2493

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ABSTRACT

Two masked priming experiments were conducted to examine phonological priming of bisyllabic words in French, and whether it operates sequentially or in parallel. Bisyllabic words were primed by pseudowords that shared either the first or the second phonological syllable of target words. The results show that only the first syllable overlap –and not the second– produced facilitation in both the lexical decision and naming tasks. These findings suggest that, for polysyllabic words, phonological codes are computed sequentially during silent reading and reading aloud.

A large body of research in cognitive psychology has been devoted to the study of the role played by phonological information in silent reading. Many of these studies have used monosyllabic pseudohomophones as primes, thus maximising phonological overlap between primes and targets in the related condition (e.g., Drieghe & Brysbaert, 2002; Ferrand & Grainger, 1992, 1993, 1994; Frost, Ahissar, Gottesman, & Tayeb, 2003; Lukatela & Turvey, 1990; Ziegler, Ferrand, Jacobs, Rey, & Grainger, 2000). More recently, there is evidence that shows phonological priming effects with only partial phonological overlap in polysyllabic words (*conal-CANAL* faster than *cinal-CANAL*, Pollatsek, Perea, & Carreiras, in press).

The study of phonological effects when there is only partial phonological overlap across primes and targets raises a number of issues, one of them being whether phonological codes are computed sequentially from beginning-to-end, or rather in parallel. Although most of the literature on masked phonological priming has assumed that phonological coding occurs in parallel for all letters of the input, some theories (e.g., the Dual Route Cascaded [DRC] model, see Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) predict that position of overlap may have an influence on phonological priming. In the DRC model, nonlexical letter-to-sound conversion procedures operate serially across the input string. Accordingly, phonological priming effects should be most evident when prime stimuli share phonology with the beginning compared to the end of target words. Although this appears to a likely solution for reading aloud (since articulatory output necessarily requires serial order), the key question is whether or not the same sequential computation applies to the situation where no articulatory output is required (i.e., silent reading, lexical decision).

Furthermore, one important prediction from strong phonological accounts of visual word recognition (see Frost, 1998) is that phonological priming should be observed in the absence of little graphemic overlap (see Rastle & Brysbaert, 2004). If the mandatory phonological codes are computed early in the process of visual word recognition (Frost et al., 2003), these effects could be greater when the phonological prime and their controls are graphemically very different from the target word (e.g., *yoice-USE* vs. *douke-USE*). In the present study, prime stimuli shared only a single letter with target stimuli in the related conditions.

Thus, the present experiments address two key issues regarding the role of phonology in reading polysyllabic words: a) whether it is possible to obtain phonological priming in a lexical decision task when the overlap between primes and targets is partial (one out of two phonological syllables) and when orthographic overlap is minimal (e.g., *fo.mie-FAU.CON*), and b) whether phonological codes are computed sequentially or in parallel (i.e., whether the two syllables of bisyllabic words carry equal weight or not). To examine these questions, we

used bisyllabic target words in French (e.g., *FAU.CON*) that were preceded by: i) a briefly presented nonword prime that shared the first phonological syllable (*fo.mie*), ii) a briefly presented orthographic control that shared only the first phoneme/grapheme of the first syllable (*fé.mie*), or iii) a briefly presented unrelated control (*pé.mie*). We also used bisyllabic target words (e.g., *GA.TEAU*) that were preceded by i) a nonword prime that shared the second phonological syllable (*re.tôt*), ii) an orthographic control that shared only the first phoneme/grapheme of the second syllable (*re.tin*), or iii) an unrelated control (*re.din*).

EXPERIMENT 1: LEXICAL DECISION

METHOD

Participants. Thirty psychology students at René Descartes University took part in the experiment for course credit. They were tested individually in a quiet room. All participants reported being native French speakers, with normal or corrected-to-normal vision.

Stimuli and Design. A set of 120 French words and 120 nonwords served as target items in Experiment 1. All stimuli were bisyllabic and were 5 to 8 letters long. Half of the target words were primed on the first syllable ("first-syllable targets"), the other half being primed on the second syllable ("second-syllable targets"). "First-syllable targets" and "second-syllable targets" were matched in length in letters (5.86 and 5.85, respectively) and frequency (35 and 31 occurrences per million, respectively, New, Pallier, Brysbaert, & Ferrand, in press). Each type of target (first-syllable vs. second-syllable targets) was preceded by three types of nonword prime. First-syllable targets (such as *FAUCON* [*hawk*]) were preceded by: (1) nonword primes sharing the first phonological syllable (but not the orthographic syllable) with the target (e.g., *fomie-FAUCON*); (2) nonword primes sharing the first phoneme only with the target (e.g., *fémie-FAUCON*); and (3) nonword primes that were unrelated (both orthographically and phonologically) to the target (e.g., *pémie-FAUCON*). Second-syllable targets (such as *GATEAU* [*cake*]) were preceded by: (1) nonword primes sharing the second phonological syllable (e.g., *retôt-GATEAU*); (2) nonword primes sharing the first phoneme only of the second syllable (e.g., *retin-GATEAU*); and (3) nonword primes that were unrelated (both orthographically and phonologically) to the target (e.g., *redin-GATEAU*). It should be noted that the single phoneme prime condition also served as an orthographic control for the syllable prime condition, since they had the same level of orthographic overlap. Priming condition was crossed with target type. Prime-target pairs were rotated across the priming conditions across three groups of participants such that no participants saw any single prime or target more than once, but each participant received all three priming conditions. Every

participant saw 120 nonword prime/word target pairs, 20 in each condition, and 120 nonword prime/nonword target pairs. The participants were presented with 20 practice trials before the experiment proper.

Procedure. The experiment was run using DMDX (Forster & Forster, 2003). First, a forward mask consisting of a row of 11 hash marks (#####) together with two vertical lines (i.e., one above and one beneath the center of the forward mask) was presented for 500 msec. This was followed immediately by the presentation of the prime stimulus. The prime was presented in lowercase in 12-pt. Courier New Font, and stayed on the screen for 59 msec. The prime was followed immediately by the presentation of the target stimulus in uppercase. Both prime and target were presented in the same screen location as the forward mask on the center of the screen. The target remained on the screen until the participants responded. The participants were instructed to answer as rapidly and as accurately as possible whether or not the letter string in uppercase that remained on the screen was a French word or not. The existence of a prime stimulus was not mentioned. The participants responded "yes" by pressing one of the two response buttons with the forefinger of the preferred hand and "no" by pressing the other response button with the forefinger of the nonpreferred hand on a Logitech Wingman Gamepad. The inter-trial interval was 1 sec. Stimulus presentation was randomized, with a different order for each participant.

RESULTS

Mean lexical decision latencies and percentage of errors in the word targets are given in Table 1. Planned comparisons were conducted on the reaction times and error rates to assess syllable priming (phonological-syllable prime vs. unrelated prime and phonological-syllable prime vs. shared-onset prime) and phoneme priming (shared-onset prime vs. unrelated prime) for both first-syllable targets and second-syllable targets. F values are reported by subjects (F_1) and items (F_2). Prior to the response time analyses, response times higher than 1500 msec were removed (less than 2% of the data rejected).

<Insert Table 1 about here>

First-syllable targets. Planned comparisons showed that word targets preceded by a "phonological syllable" prime were responded to 15 ms faster than the word targets preceded by an unrelated prime (i.e., effect of syllabic priming; see Table 1) [$F_1(1,27)=8.52$, $p<.01$, $\eta^2=.24$ and $F_2(1,57)=15.24$, $p<.001$, $\eta^2=.21$]. In addition, word targets preceded by a "phonological syllable" prime were responded to 14 ms faster than the word targets preceded

by an "initial phoneme" prime [$F(1,27)=4.52$, $p<.05$, $\eta^2=.14$ and $F(1,57)=16.56$, $p<.001$, $\eta^2=.23$]. Finally, the 1 msec difference between word targets preceded by an "initial phoneme" prime and word targets preceded by an unrelated prime (i.e., phoneme priming) was not significant [$F(1,27)<1$ and $F(1,57)<1$]. Planned comparisons on the error rates showed no significant effects (all $F_s<1$).

Second-syllable targets. None of the planned comparisons approached significance (all $F_s<1$).

EXPERIMENT 2: NAMING

METHOD

Participants. Thirty psychology students at René Descartes University took part in the experiment for course credit. All participants reported being native French speakers, with normal or corrected-to-normal vision. None of them had participated in Experiment 1.

Stimuli and Design. The stimuli and design were the same as those used in Experiment 1, except for the task employed (naming instead of lexical decision) and that only word targets were presented.

Procedure. It was the same as in Experiment 1, except that the participants' task was to read aloud the uppercase words as fast and as accurately as possible. Naming latencies were measured and recorded by DMDX via a microphone.

RESULTS

Mean naming latencies and percentage of errors are given in Table 1. The statistical analyses were parallel to those in Experiment 1, except that only reaction times were considered given that error rates were negligible (0.3%). Response times less than 300 ms or longer than 1000 ms were excluded from the response time analyses (this includes hesitation, failure of the voice key, stuttering, etc.), leading to 1.5% of the data rejected.

First-syllable targets. Planned comparisons showed that word targets preceded by a "phonological syllable" prime were named 27 ms faster than word targets preceded by unrelated primes (syllabic priming; see Table 1) [$F(1,27)=42.85$, $p<.001$, $\eta^2=.61$ and $F(1,57)=52.79$, $p<.001$, $\eta^2=.48$]. In addition, words targets preceded by a "phonological syllable" prime were named 10 ms faster than word targets preceded by an "initial phoneme" prime [$F(1,27)=10.08$, $p<.005$, $\eta^2=.27$, and $F(1,57)=7.76$, $p<.05$, $\eta^2=.12$]. Finally, unlike Experiment 1 (lexical decision), we found a 17 ms advantage for word targets preceded by an

"initial phoneme" prime with respect to the word targets preceded by an unrelated prime (phoneme priming) [$F(1,27)=33.72$, $p<.001$, $\eta^2=.56$ and $F(1,57)=14.15$, $p<.005$, $\eta^2=.20$].

Second-syllable targets. None of the planned comparisons approached significance (all $F_s < 1$).

Combined analysis of Lexical Decision and Naming

In order to examine the influence of task on syllable and phoneme priming effects, a combined analysis of the RT data from Experiments 1 and 2 was performed with Task (lexical decision versus naming) as a between-participants factor. The Priming condition x Task x Type of target interaction was significant [$F(2,108)=3.16$, $p<.05$, $\eta^2=.06$]. Syllable priming effects occurred in the first syllable in both lexical decision and naming [$F(1,54)=10.61$, $p<.01$, $\eta^2=.16$], but not in the second syllable [$F(1,54)<1$, $\eta^2=.002$], whereas phoneme priming was only present for the first syllable in the naming task [$F(1,27)=33.72$, $p<.001$, $\eta^2=.56$].

GENERAL DISCUSSION

The main findings of the present experiments can be summarized as follows: i) phonological priming effects were obtained in lexical decision and naming with only partial phonological overlap and minimal orthographic overlap between primes and targets; ii) priming effects were obtained for the first –but not the second– syllable both in lexical decision and in naming, thus suggesting a sequential phonological processing for polysyllabic words; and iii) there was an advantage for the initial phonological syllable both against the orthographic control (initial phoneme) and the unrelated condition in the lexical decision and the naming tasks, while the onset priming effect was only present in the naming task.

The observed phonological priming effects are consistent with the proposals of an early (and possibly mandatory) activation of phonology in reading (e.g., Ferrand & Grainger, 1993; Frost, 1998; Lukatela & Turvey, 1994; Lukatela, Eaton, Lee, Carello, & Turvey, 2002; Lukatela, Frost & Turvey, 1998; Pollatsek, Lesch, Morris, & Rayner, 1992; Van Orden, 1987; Van Orden, Johnston, & Hale, 1988). It is important to stress that, unlike most previous experiments –in which the phonological overlap between primes and targets was typically 100%, the overlap between primes and targets was minimal in the present experiments, both in terms of graphemes and phonemes. This clearly suggests a key role of phonology in reading polysyllabic words.

Furthermore, phonological priming effects occurred for the first, but not the second syllable. The presence of faster responses to *fomie-FAUCON* than to *fémie-FAUCON* (but not *retôt-GATEAU* as compared with *retin-GATEAU*) clearly suggests that the first phonological syllable plays a major role in the recognition of visually presented bisyllabic words. This is particularly clear in the lexical decision experiment where one phoneme overlap produced a 1 ms priming effect. Since syllables were composed of only two phonemes it is unlikely that the syllable priming effect is segmentally driven. These results extend some recent masked priming results in Spanish in which only the initial syllable was manipulated (e.g., Álvarez, Carreiras, & Perea, 2004; Carreiras & Perea, 2002). Two possibilities can be invoked to account for such differential role of first and second syllables. One possibility would be to assume a sequential left-to-right processing (see Coltheart et al., 2001; Taft & Forster, 1976; Taft, 1979, 1991). A second possibility would be to assign a greater weight to the initial syllable within an activation-based framework.

The present experiments also replicated the "masked onset priming effect" in the naming task (see Kinoshita, 2003). As in prior research, there was no sign of an effect of initial phoneme overlap in lexical decision (Forster & Davis, 1991; Grainger & Ferrand, 1996). As argued by Grainger and Ferrand (1996) this task difference likely reflects the articulatory output component of naming that would be overly sensitive to initial phoneme activation. On the other hand, sharing the first syllable caused an advantage both in lexical decision and in naming, and this advantage was robust relative to the onset priming condition in both tasks. Thus, the present results further demonstrate that the type of phonological code generated during visual word recognition is not identical to the one generated for articulatory output, providing evidence against the specific implementation of sublexical phonology in Coltheart et al.'s (2001) model. However, the results are consistent with a sequential computation of phonology from orthography as proposed by Coltheart and colleagues. Taken together, the present findings are consistent with proposals that assume that input phonology is an important step in visual word recognition, and that it may be organized syllabically (Ferrand, Segui & Grainger, 1996).

In sum, the present findings provide new constraints for the development of computational models of visual word recognition. These models need to account for sequential phonological priming effects that arise extremely rapidly during visual word recognition, and that are present whether or not an articulatory output is required. Given independent evidence for the role of syllables in visual word recognition, one possibility is that phonological syllables are computed serially from a printed word, and constrain the process of matching the orthographic input with a semantic interpretation. This and alternative

solutions need to be implemented in future models of single word reading that dare to go beyond the monosyllable.

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Acknowledgements

The research reported in this paper has been partially supported by grants BSO2001-3492-C04-03 and BSO2003-01135, from the Spanish MCyT, and by a “Picasso Project Acción Integrada Hispano-Francesa” (HF2001-0082). Correspondence concerning this article should be addressed to Manuel Carreiras. Departamento de Psicología Cognitiva. Campus de Guajara. Universidad de La Laguna. Tenerife-38205. Spain. (email: mcarreir@ull.es)

TABLE 1

Reaction Times (in Milliseconds) and Percent Errors on Target Words as a Function of Type of Target, Priming Condition and Task (SDs are presented between brackets)

	Task			
	Lexical Decision		Naming	
	RTs	%ER	RTs	%ER
<u>1st Syllable Targets</u>				
First Phonological Syllable (e.g., <i>fomie-FAUCON</i>)	603 (57)	5.16	529 (42)	0.0
Initial Phoneme of 1 st Syllable (e.g., <i>fémie-FAUCON</i>)	617 (60)	6.33	539 (43)	0.33
Unrelated (e.g., <i>pémie-FAUCON</i>)	618 (66)	5.66	556 (44)	0.33
Syllable priming	+15		+27	
Phoneme priming	+1		+17	
<u>2nd Syllable Targets</u>				
2 nd Phonological syllable (e.g., <i>retôt-GATEAU</i>)	620 (67)	6.83	554 (43)	0.33
Initial phoneme of 2 nd syllable (e.g., <i>retin-GATEAU</i>)	620 (63)	6.33	553 (45)	0.33
Unrelated (e.g., <i>redin-GATEAU</i>)	627 (65)	7.5	553 (41)	0.5
Syllable priming	+7		-1	
Phoneme priming	+7		0	