The asymmetric contribution of consonants and vowels to phonological similarity

Evidence from lexical priming

Rory Turnbull[i, ii] and Sharon Peperkamp[ii]
[i]Department of Linguistics, University of Hawai‘i at Mānoa /
[ii]Laboratoire de Sciences Cognitives et Psycholinguistique, Département d’Etudes Cognitives, ENS, EHESS, CNRS, PSL University

Lexical priming is known to arise from phonological similarity between prime and target, and this phenomenon is an important component of our understanding of the processes of lexical access and competition. However, the precise nature of the role of phonological similarity in lexical priming is understudied. In the present study, two experiments were conducted in which participants performed auditory lexical decision on CVC targets which were preceded by primes that either matched the target in all phonemes (CVC condition), in the first two phonemes (CV_ condition), the last two phonemes (_VC condition), the initial and last phonemes (C_C condition) or no phonemes (unrelated condition). Relative to the unrelated condition, all conditions except CV_ led to facilitation of response time to target words. The _VC and C_C conditions led to equivalent facilitation magnitude, while the CV_ condition showed neither facilitation nor inhibition. Accounting for these results requires appeal to processes of lexical competition and also to the notion that phonemes do not lend equivalent phonological similarity; that is, vowels and consonants are processed differently.

Keywords: auditory priming, French, phonological priming, phonological similarity

Phonological priming has long been used to study the mechanisms by which the acoustic signal is associated with the phonological representations of words in the mental lexicon. In this paradigm, a prime word is presented immediately prior to a target word, and some task – such as lexical decision or word shadowing – is performed on the target word. The type and extent of phonological similarity between the prime and target has been found to affect response latency for a wide variety of

The Mental Lexicon 12:3 (2017), **404–430**. DOI 10.1075/ml.17010.tur
ISSN 1871-1340 / E-ISSN 1871-1375

tasks. This paper presents the results of two auditory lexical decision experiments which investigate the nature of phonological similarity.

There is evidence from a diversity of auditory tasks that overlap in the syllable rime between prime and target (e.g. *hat* priming *cat*) leads to facilitation, that is, faster or more accurate responses to the target (Dufour & Peereman, 2009; Dumay et al., 2001; Gray, Reiser, & Brinkley, 2012; McQueen & Sereno, 2005; Norris, McQueen, & Cutler, 2002; Radeau, Besson, Fonteneau, & Castro, 1998; Radeau, Morais, & Segui, 1995; Slowiaczek, McQueen, Soltano, & Lynch, 2000; Slowiaczek, Nusbaum, & Pisoni, 1987). This facilitatory effect is well-studied and it has been argued to be due to overall prelexical excitation caused by the phonological similarity between the prime and target (Slowiaczek & Hamburger, 1992). However, a good deal of the effects uncovered by early investigations have subsequently been demonstrated to be due, in part, to participant response bias (Dufour, 2008; Goldinger, 1998; Hamburger & Slowiaczek, 1996; McQueen & Sereno, 2005; Norris et al., 2002; Slowiaczek & Hamburger, 1992). This bias arises due to systemic patterns which may be present in the stimulus lists. For example, in a lexical decision task, if all nonword trials involve stimuli with no phonological overlap, then the presence of phonological overlap in some of the word trials suffices to cue the listener that the target is a word. The listener can then respond quickly, without actually accessing the target stimulus. This speedy strategy leads to an apparent facilitation for trials with phonological overlap, but is due entirely to strategic effects. For this reason, phonological priming experiments must be designed with carefully balanced sets of stimuli, with equal care taken over the non-target trials as over the target trials (Dufour, 2008).

Overlap located at the beginning of the words (e.g. *cab* priming *cat*), often termed "onset overlap", has been reported to lead to inhibition, that is, slower or less accurate responses to the target (Desroches, Newman, & Joanisse, 2008; Dufour & Peereman, 2009; Gaskell & Dumay, 2003; Goldinger, Luce, Pisoni, & Marcario, 1992; Hamburger & Slowiaczek, 1996). However, some studies failed to find such an effect (Gray et al., 2012; McQueen & Sereno, 2005; Radeau et al., 1995; Slowiaczek & Pisoni, 1986), and indeed, early experimental forays into this phenomenon reported *facilitation* (Slowiaczek & Hamburger, 1992; Slowiaczek et al., 1987). After subsequent investigation, a general consensus has been reached that any facilitation observed can be attributed to expectancy-based strategies arising due to bias in the stimuli set; absent this bias and with a short ISI between prime and target, onset overlap leads to inhibition from cohort competition. That is, the presentation of *cab* causes lateral inhibition of cohort competitors, such as *cat, can, candle*, and so on. This competition is short-lived, though, such that for designs with a longer ISI (e.g. 500 ms), neither inhibition nor facilitation is observed (Dufour, 2008; McQueen & Sereno, 2005).

Several studies have compared the effects of the *size* of the phonological overlap – for example, Slowiaczek and Hamburger (1992) compared the effect on the target *still* by the primes *still* (identity), *stiff* (three-phoneme overlap), *steep* (two-phoneme overlap), *smoke* (one-phoneme overlap), and *dream* (unrelated). This kind of classification overlooks the kinds of phonemes which overlap: just by counting the number of overlapping phonemes, it is not clear whether the overlapping phonemes are vowels or consonants. Consideration of phoneme type is important because consonants and vowels are processed differently (Cutler, Sebastián-Gallés, Soler-Vilageliu, & van Ooijen, 2000; Wiener & Turnbull, 2016), and there is some evidence that consonants contribute more to lexical access than vowels (Delle Luche et al., 2014; Nespor, Peña, & Mehler, 2003). It is not unreasonable to expect that calculating phonological similarity is more complex than simply counting the number of overlapping phonemes.

Consideration of the nature of the overlap between prime and target reveals another unexplored direction. While the onset overlap condition examines what happens when there is phonological mismatch at the end of the word, and the rime overlap condition examines what happens when there is phonological mismatch at the beginning of the word, there are precious few studies which have examined what happens when there is phonological mismatch in the *middle* of the word. An example of such a prime-target pair with non-contiguous overlap is *cot* and *cat*, which differ only in the vowel. Whether non-contiguous overlap leads to the same magnitude of priming effects as contiguous overlap is currently unknown. Indeed, the only study we are aware of which has investigated prime-target pairs with non-contiguous overlap found that an auditory prime *pen* facilitates access to a visual target *pan* (Clopper & Walker, 2017). However, this study was not focused on the overall effects of phonological similarity on priming and therefore did not compare non-contiguous to contiguous overlap.

An additional question is whether the observed priming truly involves a phonological level of representation, or whether it is phonetic (Dufour & Frauenfelder, 2016). While effects due to lexical competition necessarily involve a phonological representation, the facilitation effects of rime overlap have been proposed to be prelexical, and therefore may or may not involve a phonological level of representation. A straightforward approach to shed light onto this issue is to use different talkers for the prime and the target word presentation. Ideally, the talkers are relatively acoustically distinct, for example a male and a female. This approach was used by Dufour, Dumon, and Nguyen (2015) and Dufour and Nguyen (2017), who demonstrated inhibitory effects of onset overlap even when the talkers differ, and Clopper and Walker (2017), discussed above. However, none of these studies investigated the rime overlap condition.

This paper presents the results of two experiments on the effects of phonological similarity on lexical priming. All target words were of the shape CVC, ensuring a one-to-one correspondence between overlap type and syllable structure. Our results show that non-contiguous overlap, such as the prime-target pair *cot-cat*, leads to facilitation of equivalent magnitude to contiguous overlap in the rime, such as the prime-target pair *hat-cat*. We interpret these results in terms of our understanding of the role of phoneme type in determining phonological similarity.

Experiment 1

Methods

Materials

From the Lexique lexical database of French (New, Pallier, Ferrand, & Matos, 2001), 84 monosyllabic CVC words, including nouns, adjectives and verbs, were selected as critical target words. Each target word had five primes, not necessarily of the same syntactic class, associated with it, one for each of the five priming conditions. The five conditions are summarized in Table 1, and are described in terms of the extent and type of phonological overlap between the prime and target. In the CVC condition, the prime word and the target word are identical; in the _VC condition, the VC overlaps and the first consonant differs; in the C_C condition, the consonants overlap and the vowel differs; in the CV_ condition, the CV overlaps and the last consonant differs; and in the unrelated condition, all of CVC differ. While every effort was made to select critical target words with all five possible prime types, the presence of accidental gaps in the lexicon meant that 23 potential prime-target pairs could not be constructed. In total, 397 words (84 targets × 5 prime types − 23 impossible combinations) were chosen as primes. Of these primes, 21 differed from their targets in subsyllabic structure: for example, *style* /stil/ was used as the onset competitor for *ville* /vil/, due to the paucity of possible onset competitors of shape CVC.[1]

1. All of the possible CVC competitors listed in Lexique were rejected either because they were used as primes or targets elsewhere in the experiment or because their frequency of occurrence is too low.

Table 1. Overview of the five priming conditions for example target word *bac* /bak/ 'tray'. Note that not all stimuli were nouns; a full stimulus list is provided in the appendix

Prime type	Example	Phonology	Gloss
CVC	*bac*	/bak/	"tray"
_VC	*sac*	/sak/	"bag"
C_C	*banque*	/bãk/	"bank"
CV_	*baffe*	/baf/	"slap"
Unrelated	*mangue*	/mãg/	"mango"

To act as fillers, 46 additional target words with unrelated primes were selected. In addition, 126 target nonwords were generated with the pseudoword generator Wuggy (Keuleers & Brysbaert, 2010). Each nonword had an edit distance of 1 from a real French word and had similar phonotactic probabilities to real French words. Half of the nonwords had unrelated French primes, a sixth had _VC primes, a sixth had C_C primes, and a sixth had CV_ primes. Overall, exactly half of the nonwords and half of the words thus had primes with some degree of phonological overlap.

In total, there were 130 word targets, 126 nonword targets, and 569 primes. All targets appeared in a group of prime-target pairs (such as the *bac* group exemplified above); in 252 (58%) of these pairs, prime and target were of the same syntactic class (e.g. both were nouns), while in 185 (42%) they were in different classes (e.g. a noun prime and an adjective target). Using pairs of different syntactic classes allowed us to maximize the possible number of stimuli. There were 256 total groups of prime-target pairs. They were organized into five counterbalanced lists, each one consisting of the following:

– 63 word trials with a related prime: trials where the target item was a lexical word, and the prime was identical or overlapping (15–17 trials of each subtype).
– 63 word trials with an unrelated prime: trials where the target item was a lexical word, and the prime was phonologically unrelated.
– 63 nonword trials with a related prime: trials where the target item was not a lexical word, and the prime was phonologically overlapping.
– 63 nonword trials with an unrelated prime: trials where the target item was not a lexical word, and the prime was phonologically unrelated.

The lists were constructed in Latin square fashion such that each participant was only presented with each target word in one of the five priming conditions; the critical comparisons of this design are therefore between participants. Table 2 provides the complete breakdown of number of trials per condition for each of the five lists.

Table 2. Number of trials in each cell of the experimental design for each stimulus list. Note that the 'CVC overlap nonword' condition is impossible, as all primes are lexical words

List 1	Related				Unrelated	Total
Nonword	63				61	124
Word	63				61	124
	CVC	_VC	C_C	CV_		
Nonword	—	20	21	22		
Word	16	16	15	16		
List 2	**Related**				**Unrelated**	**Total**
Nonword	63				61	124
Word	63				61	124
	CVC	_VC	C_C	CV_		
Nonword	—	20	21	22		
Word	17	16	15	15		
List 3	**Related**				**Unrelated**	**Total**
Nonword	63				61	124
Word	63				61	124
	CVC	_VC	C_C	CV_		
Nonword	—	20	21	22		
Word	17	15	16	15		
List 4	**Related**				**Unrelated**	**Total**
Nonword	63				61	124
Word	62				61	123
	CVC	_VC	C_C	CV_		
Nonword	—	20	21	22		
Word	17	15	15	15		
List 5	**Related**				**Unrelated**	**Total**
Nonword	63				61	124
Word	62				60	122
	CVC	_VC	C_C	CV_		
Nonword	—	20	21	22		
Word	17	14	16	15		

All items (targets and primes) were presented with a preceding particle, such as *le* "the" or *il* "he, it". The kind of particle used was constrained by the syntactic class of the item itself – either noun, adjective, or verb. These particles were included because in French, particles are grammatically obligatory for common nouns and inflected verbs. Including particles for the adjectives therefore allowed maximal similarity among stimuli. While previous studies (e.g., Radeau et al., 1995) have used French bare nouns, these studies only used words from a singly syntactic class. Our piloting suggested that lexical decision on isolated monosyllables from various syntactic classes is difficult for French listeners.

Table 3 lists each of the particles used for each syntactic class. Care was taken to ensure that the distribution of particles before nonwords (which can take any particle) was the same as the distribution before words, thus avoiding the potential development of task-specific strategies. For prime-target pairs, different particles were used between the prime and the target (e.g. *plus belle, très belle)* so as to avoid artificially enhancing the degree of phonological identity in this condition.

Table 3. List of particles used for each of the three word classes used as primes and targets

Before nouns			**Before adjectives**			**Before verbs**		
de	/dœ/	"of, from"	*moins*	/mwɛ̃/	"less"	*elle*	/ɛ/	"she, it"
des	/de/	"of.PL, some"	*pas*	/pa/	"not"	*elles*	/ɛ/	"they.FEM"
la	/la/	"the.FEM"	*plus*	/ply/	"more"	*il*	/i/	"he, it"
le	/lœ/	"the.MASC"	*très*	/tʁɛ/	"very"	*ils*	/i/	"they.MASC"
les	/le/	"the.PL"				*je me*	/ʒœm/	"I.REFL"
un	/ɛ̃/	"a.MASC"				*pas*	/pa/	"not"
une	/yn/	"a.FEM"				*qu'elle*	/kɛ/	"that she"
						qu'il	/ki/	"that he"
						tu	/ty/	"you"

Abbreviations

FEM *feminine*
MASC *masculine*
PL *plural*
REFL *reflexive.*

Prime phrases were recorded by a male fluent French speaker, while target phrases were recorded by a female fluent French speaker. The use of the acoustically dissimilar male and female voice helps us in disentangling phonetics from phonology in identifying the locus of priming effects. A full list of all stimuli is provided in the appendix.

Procedure

In each trial, the prime phrase was presented both orthographically on a computer screen, and, following a 500 ms delay, auditorily over headphones at a comfortable volume. At the offset of the audio, the visual display was replaced by a fixation cross. After another 500 ms delay, the target was presented over headphones. Thus, the presentation of the prime was both auditory and visual, while the target presentation was auditory only. Participants responded "word" or "nonword" to the last word of the target phrase. The next trial began 750 ms after a response was registered. If no response was registered within 3000 ms of target onset, the experiment proceeded to the next trial. The PsychoPy package (Peirce, 2009) was used to manage stimulus presentation and to log response times and accuracy. Reaction time was measured from word offset.

To encourage the participants to attend to the prime phrase as well as to the target phrase, every eighth trial was a memory task: a word was presented visually and participants were asked if they had heard the word before during the course of the experiment. Participants were made aware of this additional task at the beginning of the experiment, and they received feedback on their accuracy on this task.

Participants

Thirty-eight French native speakers participated in the experiment (23 females, 14 males, and 1 participant who did not volunteer gender identity). Ages ranged from 18 to 32, with a median of 23.

Predictions

As summarized in the introduction, there is ample evidence that _VC primes lead to faster responses than CV_ primes. This finding has been explained in terms of an inhibitory effect of initial overlap, and a facilitatory effect of final overlap. The central question for this study, then, is where the C_C primes fall in relation to these well-established endpoints. Under an account where initial and final overlap effects are the only relevant factors, the hierarchy depicted in (1) is expected:

(1) *_VC < C_C < CV_*

That is, the C_C condition experiences both the initial inhibitory effects and the final facilitatory effects, ending up in the middle of the reaction time continuum. This hierarchy relies on the assumption that all phonemes are equal, and that phonological similarity can be reduced to the absolute number of shared phonemes, regardless of their identity. It will serve as a baseline upon which we can consider effects of other potential factors.

One such factor is sensitive to phoneme type, in particular vowels versus consonants. Note that the C_C condition involves overlap of two consonants, whereas the other conditions involve an overlap of one consonant and one vowel. This consonant-heavy condition could lead to greater phonological similarity: in addition to cross-linguistic evidence that vowels and consonants are processed differently (Cutler et al., 2000; Wiener & Turnbull, 2016),[2] there is evidence that in French, consonants are easier to process and contribute more to speech comprehension than vowels (Havy & Nazzi, 2009; Nazzi, Floccia, Moquet, & Butler, 2009; New, Araújo, & Nazzi, 2008). Perhaps, then, the overlapping vowel of the _VC and CV_ conditions contributes less to phonological similarity than do the overlapping consonants. Under this view, the C_C primes should cause stronger facilitation than otherwise expected, meaning that the facilitatory effect of C_C primes is equal to or exceeds that of the _VC primes, as depicted in (2).

(2) $$\left\{\begin{matrix} \_VC \\ \\ C\_C \end{matrix}\right\} < CV\_$$

Another possible factor is overlap of phonological constituents, which predicts the hierarchy in (3). Here, the _VC condition, which has an overlapping phonological constituent (the rime), is facilitated, while the C_C and CV_ conditions are slower due to their lack of a coherent constituent.

(3) $$\_VC < \left\{\begin{matrix} C\_C \\ \\ CV\_ \end{matrix}\right\}$$

Two other logically possible hierarchies remain. In (4), the C_C condition leads to the greatest degree of facilitation. This hierarchy is predicted under an account where consonant overlap is of supreme importance to priming, to a greater degree than the initial or final overlap effects. This reasoning runs contrary to our present understanding of cohort effects and we therefore regard this outcome as unlikely.[3]

(4) $C\_C < \_VC < CV\_$

In (5), the C_C condition is the slowest of all. This hierarchy is not predicted by any combination of the current factors under consideration, but we mention it here for the sake of completeness. Observation of this hierarchy would in fact suggest that there is a benefit to vowel overlap over consonant overlap, an unexpected outcome.

2. Note that the exact nature of this difference appears to be language-specific; Wiener and Turnbull (2016) presented evidence that Mandarin behaves differently from European languages in this respect.

3. It should be noted that this hierarchy is possible as an extreme version of (2) where the magnitude of the consonant overlap facilitation exceeds that of the final overlap facilitation.

(5) *_VC < CV_ < C_C*

In sum, then, the behavior of the C_C primes relative to the _VC and CV_ primes is determined by whether or not consonants cause greater facilitation than vowels, and by whether or not phonological constituents are relevant for priming.

Analysis

All analyses reported here used linear mixed effects regression modelling to model log reaction time. Each model was constructed using the stepdown algorithm described by Turnbull (2017), which begins with a maximally specified model and removes fixed effects and interactions which do not significantly contribute to data likelihood. This method of model comparison is regarded as more conservative than some other methods of significance evaluation current in mixed effects modelling (Barr, Levy, Scheepers, & Tily, 2013). All continuous variables were centered around the mean before being entered into the model. Prior to analysis, all log reaction times beyond three standard deviations of each participant's mean were excluded.

An important set of covariates included in the model was that of frequency. Independently of the nature of the prime, we anticipated frequency effects, both of the target word and of the prime relative to the target word (Radeau et al., 1995). That is, we expected faster responses to higher-frequency targets than to lower-frequency targets, and slower responses to targets with relatively frequent primes than to targets with relatively infrequent primes. We operationalized target frequency as the absolute frequency of the target word, and relative prime frequency as the log ratio of the absolute prime frequency over the absolute target frequency. This relative prime frequency value can be interpreted as the "weight" of the prime – if positive, the prime is more frequent than the target; if negative, the target is more frequent than the prime; and if zero, the prime and target are equally frequent.

A model was constructed to predict log response time to correctly-answered target words. Fixed effects were prime type, target frequency, relative prime frequency, target neighborhood density, relative prime neighborhood density, and all possible 2-way interactions between them. The prime type variable was coded with Helmert contrasts to reflect the predicted hierarchy of results as outlined in (1). That is, the first level of coding compared the CV_ condition with the unrelated condition; the second level compared the mean of CV_ and unrelated with the C_C condition; and the third level compared the mean of unrelated, CV_, and C_C with _VC.[4] Random intercepts of participant, target, and prime were included.

4. Note that since all primes were lexical words, responding correctly to a CVC prime simply required phonological matching of the prime and target, rather than true lexical access. For this reason, responses to CVC primes were excluded prior to analysis.

Results

One participant's accuracy in the lexical decision task was 11%, significantly different from chance but in the wrong direction, suggesting that the participant had confused the response keys. This participant's responses were inverted and their data were included in the analysis. Thirteen target items (10 words and 3 nonwords) were removed due to at-chance accuracy.[5] This filtering resulted in data from 2,091 target word trials being available for analysis, 1,995 of which were correct responses. Mean response times for each prime type are shown in Table 4.

Table 4. Mean response times (ms) to correctly answered target words for each prime type in Experiment 1

Prime type	**_VC**	**C_C**	**CV_**	**Unrelated**
Mean RT (ms)	659	681	690	707

The model revealed significant effects of prime type ($\chi^2(3) = 11.164$, $p = .011$): _VC primes led to significantly faster responses than the mean of C_C, CV_, and unrelated primes. A summary of the model output is provided in Table 5, and the effects are graphed in Figure 1. Additionally, a significant effect of target word frequency was observed ($\chi^2(1) = 12.149$, $p < .001$). Response times were faster for trials with high frequency words than for trials with low frequency words, as depicted in Figure 2. This result is consistent with our understanding of the role of frequency in lexical access (Marslen-Wilson, 1990).

Table 5. Model output for optimal model predicting response times to target words in Experiment 1, with Helmert coding. Significant p-values are highlighted in boldface

Effect	***β***	***SE***	***t***	***p***
Intercept	−0.011	0.031	−0.346	.731
CV_ vs. Unrelated	0.005	0.011	0.468	.641
(CV_ & Unrelated) vs. C_C	−0.011	0.007	−1.652	.100
(CV_ & Unrelated & C_C) vs. _VC	−0.014	0.005	−2.839	**.005**
Target word frequency	−0.025	0.007	−3.588	**<.001**

5. The word items were, in reverse order of accuracy, *elles paissent, ils vêtent, la conque, la manne, la Pâque, les guimpes, pas laide, pas ouïr, une vouge, un pope,* and the nonword items were *pas dôsse, une gippe, une nêlle.*

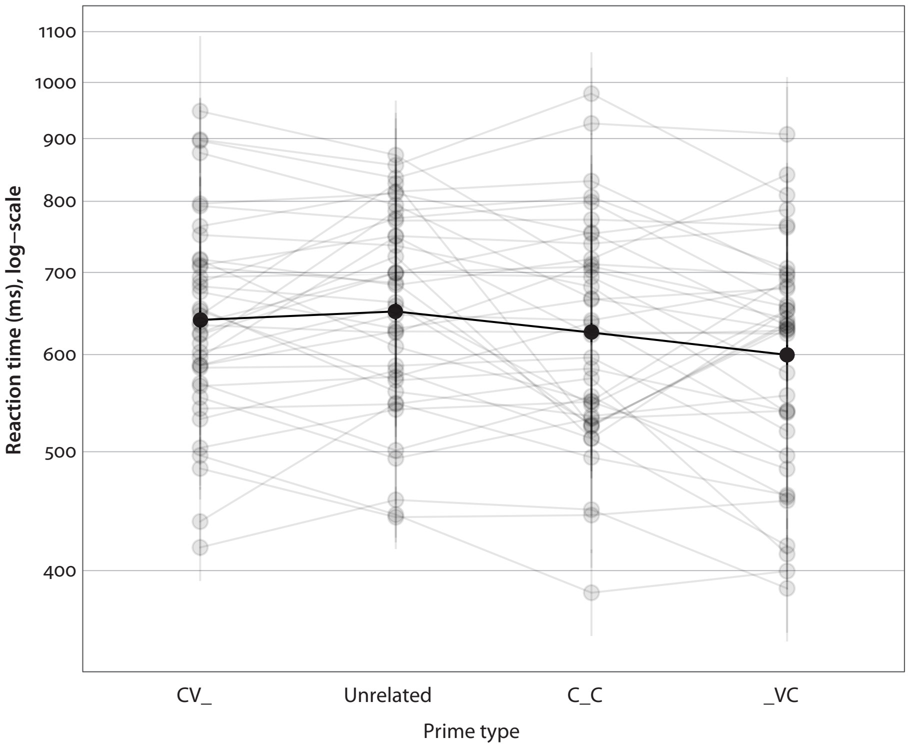

Figure 1. Grand mean response times with standard errors for target words for different prime types in Experiment 1. Lighter points and bars show individual participant means and standard errors.

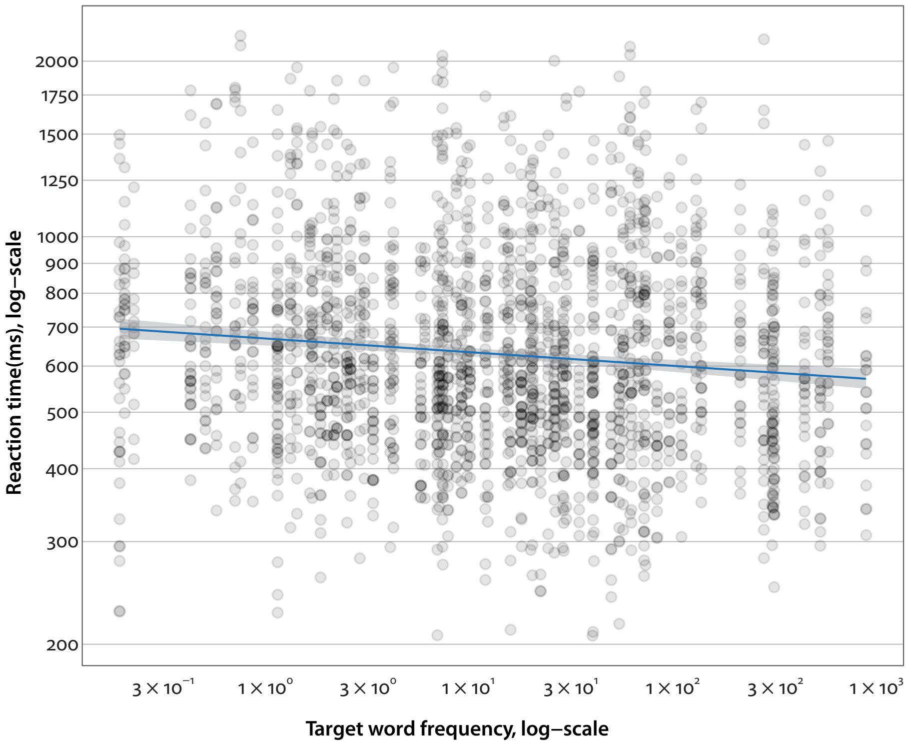

Figure 2. Response times as a function of target word frequency in Experiment 1. Linear trend overlaid.

In order to directly test other aspects of the predicted hierarchy of relative response times for each prime type, the model was refit with the prime type variable recoded with treatment contrasts, with the _VC condition as baseline. The results of this model are reported in Table 6. Here, it can be seen that the _VC condition was significantly faster that the unrelated and CV_ conditions, and neither faster nor slower than the C_C condition.

Table 6. Model output for optimal model predicting response times to target words in Experiment 1, with treatment coding where _VC condition is the baseline. Significant p-values are highlighted in boldface

Effect	*β*	*SE*	*t*	*p*
Intercept	−0.025	0.034	−1.515	.134
Unrelated	0.072	0.023	3.101	**.001**
CV_	0.061	0.024	2.549	**.012**
C_C	0.033	0.024	1.387	.167
Target word frequency	−0.025	0.007	−3.588	**<.001**

Discussion

As predicted, both analyses provided evidence that _VC primes (e.g. *sac* priming *bac)* led to faster responses than unrelated (e.g. *mangue* priming *bac*) or CV_ primes (e.g. *baffe* priming *bac*). Crucially, C_C primes (e.g. *banque* priming *bac*) did not differ from _VC primes in terms of response time, suggesting that in addition to a faciliatory effect of final overlap there is a facilatatory effect of consonant (as opposed to vowel) overlap.

This interpretation, however, is complicated by the fact that some trials had a noun priming a verb, others had a verb priming an adjective, and so on. While this design feature maximized the number of usable stimuli, it introduced a confound of syntactic class. It is plausible that this match or mismatch in syntactic class affected response times.

To assess this possibility, a post hoc analysis was carried out. The same linear mixed effects regression model from the results section was modified to include the additional fixed effect of presence of syntactic class overlap as a binary factor. The model output is summarized in Table 7. As can be seen, the overall patterns of significance are the same as in Table 6. The fixed effect of syntactic class was significant: when syntactic class matched between prime and target, response times were faster. The results of this reanalysis demonstrate that when this trend is controlled for, _VC and C_C primes still led to faster responses than CV_ and unrelated primes. Table 8 shows the mean reaction times for all trials where the syntactic class of the target and prime matched.

Table 7. Model output for optimal model predicting response times to target words in Experiment 1, with treatment coding where _VC condition is the baseline, and with additional fixed effect of syntactic class match or mismatch between target and prime. Significant p-values highlighted in boldface

Effect	β	*SE*	*t*	*p*
Intercept	−0.033	0.036	−0.936	.352
Unrelated	0.076	0.023	3.293	**.001**
CV_	0.064	0.024	2.704	**.007**
C_C	0.035	0.024	1.471	.142
Syntactic class match	−0.039	0.019	−2.005	**.046**
Target word frequency	−0.025	0.007	−3.645	**<.001**

Table 8. Mean response times (ms) to correctly answered target words for each prime type in Experiment 1, only considering trials where the prime and target matched in syntactic class

Prime type	**_VC**	**C_C**	**CV_**	**Unrelated**
Mean RT (ms)	637	658	674	708

Taken together with the two analyses presented in the results section, these results replicate previously-established findings: the _VC primes led to facilitation relative to the CV_ primes. Additionally, the results of the reanalyses confirm that the _VC and C_C conditions were not significantly different from each other in terms of facilitation, and hence provide support for the consonant facilitation hypothesis. Nevertheless, due to the uncontrolled nature of the syntactic class mismatch across trials, additional data is required to provide iron-clad evidence for this pattern of results.

Experiment 2

The second experiment sought to establish differences between prime types in the absence of any possible effects of syntactic class (mis)match. All stimuli – primes and targets – were nouns.

Methods

Materials
The materials were a subset of those used in Experiment 1. Of the words, only items that were nouns were included; of the nonwords, only items with noun particles were included. The 5 prime types (CVC, _VC, C_C, CV_, unrelated) were retained. Counterbalancing was as in Experiment 1. The stimuli were organized into 5 lists of 92 prime-target pairs each consisting of the following:

- 21 word trials with a related prime (4–6 trials of each subtype).
- 23 word trials with an unrelated prime.
- 24 nonword trials with a related prime.
- 23 nonword trials with an unrelated prime.

Procedure
The procedure was identical to that of Experiment 1.

Participants
Thirty-one French native speakers participated in the experiment.

Analysis
Response times were analyzed via linear mixed effect regression modelling, as in Experiment 1. The same model structure and stepwise procedure were used to evaluate model fit. The baseline for the prime type variable was the unrelated condition.

Results

One participant's accuracy in the lexical decision task was 10%, significantly different from chance but in the wrong direction, suggesting that the participant had confused the response keys. This participant's responses were inverted and their data were included in the analysis. Three target items (two words and one nonword) were removed for accuracy at chance.[6] This filtering resulted in data from 1,075 target word trials being available for analysis, 1,010 of which were correct responses. Figure 3 visualizes the patterns of results, and mean response times for each prime type are shown in Table 9. As summarized in Table 10, the model revealed a significant effect of target word frequency ($\chi^2(1) = 4.922$, $p = .027$) such that more frequent targets had faster response times than less frequent targets. However, prime type was not returned from the model selection procedure ($\chi^2(3) = 6.434$, $p = .092$).

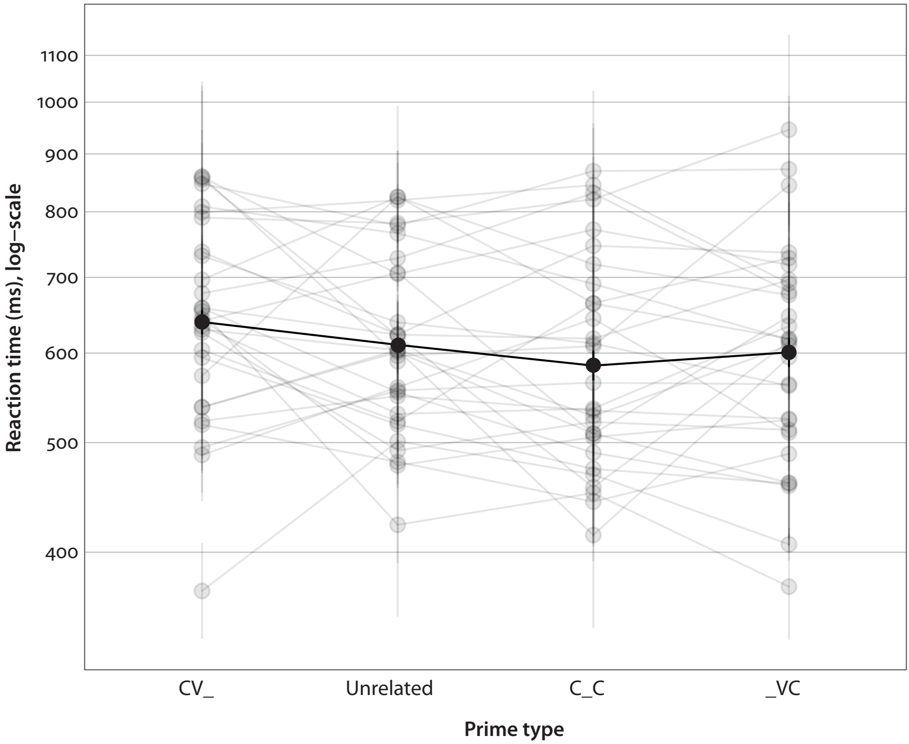

Figure 3. Grand mean response times with standard errors for target words for different prime types in Experiment 2. Lighter points and bars show individual participant means and standard errors.

6. The word items were *la lice* and *la manne;* the nonword item was *une nêlle.*

Table 9. Mean response times to correctly answered target words for each prime type in Experiment 2

Condition	_VC	C_C	CV_	Unrelated
Mean RT (ms)	647	624	679	655

Table 10. Model output for optimal model predicting response times to target words in Experiment 2. Significant p-values highlighted in boldface

Effect	β	*SE*	*t*	*p*
Intercept	−0.023	0.036	−0.630	.532
Target word frequency	−0.026	0.011	−2.280	**.028**

In light of the patterns evident in Figure 3, and indeed the result of Experiment 1, this lack of a significant effect of prime type is troubling. However, given the reduced number of stimuli in this experiment, it is possible that an effect is present but there is not enough power to observe it. We therefore sought to specifically test the consonant facilitation hypothesis in a post hoc analysis. This hypothesis predicts that _VC and C_C primes should pattern together, separate from the CV_ and Unrelated primes. A new model was constructed with the prime type variable changed into a binary variable, with the baseline level the CV_ and Unrelated primes, and the treatment level the _VC and C_C primes. Table 11 summarizes the results – here we see that the _VC and C_C primes are indeed faster than the CV_ and Unrelated primes.

Table 11. Model output for optimal model predicting response times to target words in Experiment 2 with prime type coded as a binary factor. Significant p-values highlighted in boldface

Effect	β	*SE*	*t*	*p*
Intercept	−0.005	0.036	−0.136	.893
_VC, C_C	−0.057	0.023	−2.448	**.017**
Target word frequency	−0.025	0.011	−2.237	**.031**

Discussion

The results of this experiment provide additional evidence of facilitation in the C_C condition relative to the CV_ and unrelated conditions. Crucially, there was no potential confound of syntactic class, as all items – primes and targets – were nouns. As such, these effects cannot be attributed to syntactic class and must instead be due to phonological overlap between the prime and target.

With these additional data in hand, it was possible to examine the precise hierarchy of priming effects observed in the present study. In order to do this, we conducted a grand analysis by pooling together the data from Experiment 2 and a subset of the data from Experiment 1, namely trials where both the prime and the target were of the same syntactic class. This provision ensures that syntactic class is not a confound in this analysis. Such pooling yielded a dataset of 1,657 analyzable trials. The patterns of response times are displayed in Figure 4.

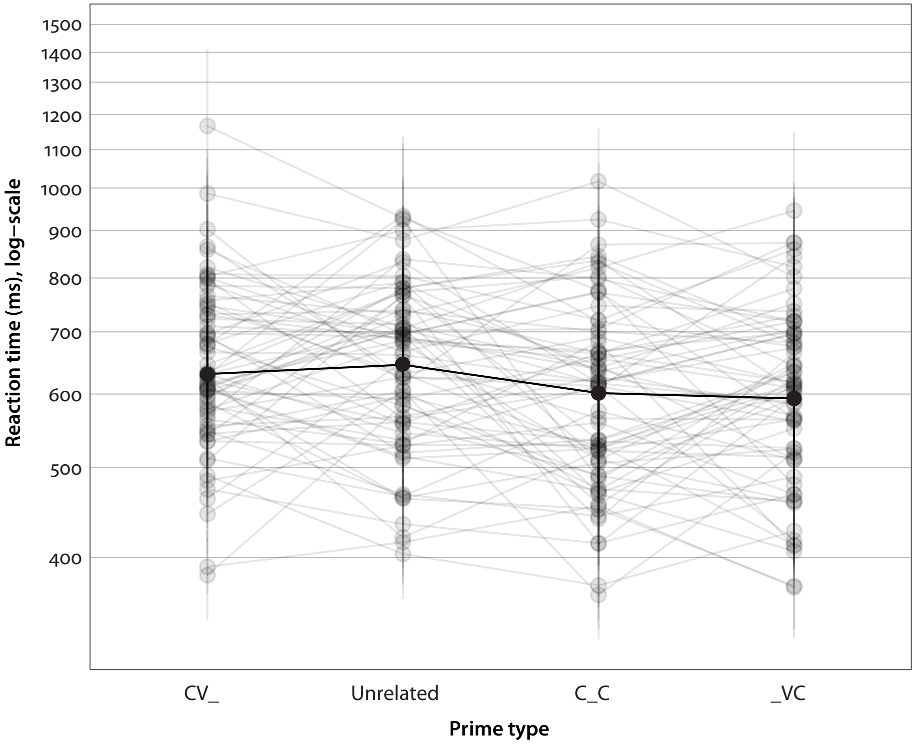

Figure 4. Grand mean response times with standard errors for target words for different prime types, aggregated data from Experiments 1 and 2 where syntactic class of prime and target match. Lighter points and bars show individual participant means and standard errors.

The predicted baseline hierarchy and the phoneme type sensitivity hierarchy, taken together with the pattern of results observed in the graphs, motivates a number of comparisons: the CVC condition relative to the _VC condition, the _VC condition relative to the C_C condition, the C_C condition relative to the unrelated condition, and the unrelated condition relative to the CV_ condition. These four comparisons are not possible to implement as a unified contrast structure in a single linear model, but it is possible to construct four separate models to test each one of them, and only examine the relevant coefficients. Four linear mixed effects regression models were thus constructed, each with a different contrast coding for the prime type variable, and the prime/target frequency ratio as an additional fixed effect. Random effect structure was the same as in all previous models, that is, there were random intercepts of participant, prime, and target, and a random slope of prime type for participant. Due to the structure of these models, the fixed effect of prime/target frequency ratio is guaranteed to be the same across all four models.

Table 12 summarizes the relevant coefficients from these models, motivating the following hierarchy of priming effects:

(6) $\left\{\begin{matrix} \_VC \\ C\_C \end{matrix}\right\} < CV\_$

Table 12. Model output for model predicting response times to target words in grand model of aggregate data from Experiments 1 and 2. Significant p-values are highlighted in boldface

Effect	β	*SE*	*t*	*p*
_VC vs. C_C	−0.013	0.028	−0.467	.641
C_C vs. Unrelated	0.089	0.026	3.413	**<.001**
Unrelated vs. CV_	−0.015	0.025	−0.604	.547
Target word frequency	−0.030	0.007	−4.384	**<.001**

This hierarchy conforms to the prediction of the consonant facilitation hypothesis in (2). As expected, _VC primes facilitate lexical access to a greater degree than do CV_ primes. Crucially, the C_C primes facilitated lexical access to the same degree as the _VC primes. This pattern of results is not predicted under an account where phonological priming is solely due to onset overlap inhibition and final overlap facilitation. Rather, a mechanism whereby consonants provide more facilitatory influence than vowels is needed to account for these results.

General discussion

Summary of experiments

Two experiments were conducted to investigate the role of overlap in phonological priming. The first experiment established that _VC primes (*sac* priming *bac*) and C_C primes (*banque* priming *bac*) led to significantly faster response times than unrelated primes (*mangue* priming *bac*). However, this experiment was confounded by the variable of syntactic class mismatch, which was not controlled across priming conditions. Experiment 2 therefore sought to replicate Experiment 1 while holding syntactic class constant across stimuli. The results were not as clear as Experiment 1, but _VC and C_C primes nevertheless led to faster responses than unrelated primes. Finally, analysis of the pooled results of Experiments 1 and 2 (excluding trials with syntactic class mismatch) revealed that the C_C condition did not differ from the _VC condition. That is, the C_C and _VC primes led to facilitation of equal magnitude.

While the CVC primes were not formally analyzed, in both experiments they led to faster response times than any other condition. The results of the present study therefore replicate well-known effects documented in the phonological priming literature: primes with complete phonological overlap (the CVC condition) and overlap of the syllable rime (the _VC condition) facilitate lexical access relative to unrelated primes (Dufour & Peereman, 2009; Dumay et al., 2001; Gray et al., 2012; McQueen & Sereno, 2005; Norris et al., 2002; Radeau et al., 1998, 1995; Slowiaczek et al., 2000, 1987, *inter alia*).[7] We also observed that initial phonological overlap (the CV_ condition) leads to neither facilitation nor inhibition, consistent with previous studies with similar methodology (McQueen & Sereno, 2005; Radeau et al., 1995).

More importantly, the current results suggest that C_C primes (*banque* priming *bac*) lead to facilitation of magnitude equivalent to that of _VC priming (*sac* priming *bac*). This novel prime type has the potential to cause revision of our understanding of the mechanisms of phonological priming. That is, the standard explanation for _VC pair (rime overlap) facilitation relies on two mechanisms. The first is that the phonological similarity of the prime and the target leads to residual activation from the prime being applied to the target at the prelexical level. This activation is aided by the fact that the overlapping portion is the rime, a phonologically relevant constituent of the syllable. The second mechanism is that of the lack of cohort inhibition as a consequence of the initial phoneme differing between the prime and target. Because the initial phoneme of the target is not the same as the prime, the prime's cohort does not intersect with the target's cohort, and thus the activation of the prime's cohort does not adversely affect lexical access to the target. The first mechanism facilitates the target while the second mechanism fails to inhibit it, and the net result is facilitation.

C_C primes such as *banque* priming *bac* do not have a simple terminology in terms of overlap because the overlap is not a syllabic constituent. These primes

7. In addition, the results provide evidence that the magnitude of CVC priming is significantly larger than that of _VC priming (rime overlap), replicating a result of Slowiaczek and Hamburger (1992).

cannot easily be explained in terms of the two mechanisms hypothesized for _VC primes. That is, these primes *do* share their initial phoneme with the target word, which predicts an inhibitory effect of cohort competitors, as per the second mechanism. Likewise, the phonological overlap between the prime and target does not consist of a single syllabic constituent, but rather it is composed of the onset and the coda, which do not form a coherent unit under any theory of the syllable. Therefore, under the first mechanism, any facilitation arising from the similarity ought to be relatively weak.

Taken together, then, these results suggest two key facts. (1) Phonological overlap between prime and target need not consist of contiguous units, and need not necessarily correspond to theorized syllabic constituents. Auxiliary support for this conclusion is provided by the results of James and Burke (2000), who found that the word *abdicate* can be primed by a series of words including *indigent, abstract, truncate,* which include the diphone sequences /dɪ/, /æb/, and /keɪt/, all components of *abdicate.* This non-contiguous priming is reminiscent of the C_C condition of the current study. (2) Phonological priming is nevertheless sensitive to onset overlap: note that facilitation was not observed in the CV_ condition *(baffe* priming *bac*), where the overlap is in the initial position, despite the absolute size of the overlap being the same as in the _VC and C_C conditions.

Finally, these results also support the notion that vowels are to some extent less important than consonants in determining phonological similarity, as the effects in the _VC and C_C conditions are of similar magnitude. Assuming that consonants contribute more to phonological similarity than vowels do, the targets are more similar to the C_C primes than to the _VC primes. This boost in similarity for the C_C condition is then offset by the cohort competition arising from initial overlap (as observed in the CV_ condition). The net result is that these two conditions lead to facilitation effects of approximately the same magnitude. This interpretation is concordant with our understanding of processing asymmetries between vowels and consonants (Cutler et al., 2000; Wiener & Turnbull, 2016) and the literature on speech comprehension and acquisition in French (Havy & Nazzi, 2009; Nazzi et al., 2009; New et al., 2008). That is, vowels and consonants are not processed equally.

We now turn to caveats of the current study, and entertain some alternative explanations for our observed pattern of results. Some of these alternatives are more plausible than others; we contend that the most parsimonious interpretation of our results is an account where consonants have a greater facilitatory priming effect than vowels.

Alternative explanations

Orthographic influence

Perhaps the results of these experiments were biased by the visual presentation of the primes prior to their auditory presentation. In particular, might the access of the participants to the orthographic form of the primes have led to some degree of orthographic similarity priming, despite the purely auditory presentation of the targets? There are two principal ways this bias could manifest itself. The first is that similarity in word length in number of letters between the prime and target could have led to greater perceived similarity: for example, for the target *bac*, 3-lettered *sac* may be a better prime than 5-lettered *baffe*. However, a post-hoc analysis of the pooled data revealed no significant effect on reaction times of the difference between the number of letters in the target and the prime, either as a raw difference score ($\beta = -0.002$, $t = -0.226$, $p = .821$) or absolute difference ($\beta = 0.004$, $t = 0.364$, $p = .716$).

The other possible orthographic influence concerns the C_C condition, where we observed facilitative priming of words that differed only in the vowel. Due to French orthography, some phonologically different vowels use the same graphemes – for example, <a> is used for /ã/ in *banque* but for /a/ in *bac*. Perhaps the facilitation attributed to the C_C primes is actually driven just by pairs with orthographic overlap? Again, a post-hoc analysis revealed this concern to be unwarranted: the 15 prime-target pairs in the C_C condition (out of 84) which had some degree of overlapping vowel graphemes (e.g., *tuile~taule, coûte~côte)* did not differ significantly in reaction times relative to the non-overlapping pairs ($\beta = 0.014$, $t = 0.279$, $p = .781$). These analyses suggest that orthography did not play a role in influencing the responses of the participants.

Task-specific strategies

Task-specific strategies are a common source of bias in phonological priming studies (Dufour, 2008). In view of this, the present experiments involved carefully balanced stimuli sets specifically designed to avoid this possibility. Indeed, even if, through some oversight, participants were able to develop response strategies that permitted faster responses to phonologically related trials than to phonologically unrelated trials, our main result here is that *banque* (C_C) and *sac* (_VC) both prime *bac* equally well; that is, our main conclusion would be unaffected by such a hypothetical response bias. In any case, the present data provide no evidence that participants developed task-specific strategies.

Phonetic priming
Phonological priming and phonetic priming are distinct phenomena (Dufour & Frauenfelder, 2016; Luce, Goldinger, Auer, & Vitevitch, 2000) which are nevertheless sometimes difficult to disentangle due to the intrinsic similarity of phonetic and phonological material. In this study, we avoided to some degree possible confounds with purely 'phonetic' or 'acoustic' levels of processing through our use of different talkers, one male and one female, for prime and target stimuli.

Reduced cohort competition between experiments 1 and 2
As noted, the results of Experiments 1 and 2 are not entirely consistent with each other. One explanation for this, suggested to us by an anonymous reviewer, is that since Experiment 2 involves only nouns, the potential cohort of competitors for each target word is smaller. This reduced competition therefore would lead to reduced inhibition for overlapping onset consonants. This could account for why, in the analysis of the pooled data, the C_C condition appears to have led to faster responses in Experiment 2 ($M = 624$ ms) than in Experiment 1 ($M = 658$ ms). However, the reduced cohort of competitors would be expected to affect the CV_ primes too, but no such difference is observed between Experiments 1 ($M = 673$ ms) and 2 ($M = 679$ ms). Cohort size therefore appears to be an unlikely source for these differences. The fact remains that, in both experiments, the C_C primes were faster than both the unrelated and the CV_ primes.

Alternatives to consonant facilitation
It is worth noting that final overlap facilitation and initial overlap inhibition are not necessarily effects of the same magnitude. Could the pattern of results for C_C primes have arisen purely through asymmetric effect sizes of these two factors? While there is reason to believe that these two effects are not of the same magnitude, this alone cannot account for the results. If we suppose that final overlap provides more facilitation than initial overlap does inhibition (Radeau et al., 1995), then we expect C_C primes to overall facilitate lexical access (as observed). However, this reasoning also predicts that the _VC primes should be *even more* facilitatory, due to the larger final overlap. This is not what is observed: the _VC primes and the C_C primes are roughly equivalent in the size of the facilitation they lead to. On the other hand, an account where consonants provide more facilitation than vowels is able to explain the results.[8]

---

8. Indeed, under an account where target reaction time is a linear function of the size of initial overlap and of the total number of overlapping phonemes, it is impossible to have C_C primes being as fast as _VC primes while still being faster than CV_ primes.

Such asymmetry between consonants and vowels is to some degree expected. An anonymous reviewer noted that the C_C primes do in fact cover a phonological constituent – that of the consonant tier in nonlinear phonology. However, the consonant tier is not a constituent of the syllable or indeed of any part of the prosodic hierarchy (Selkirk, 1986). Indeed, there is little evidence that a separate consonant tier is actually phonologically active in French (see e.g. Prunet, 1987).[9] We posit instead that the most parsimonious explanation of our results is that of consonant facilitation.

Conclusion

Two experiments examined the role of phonological similarity in lexical priming in French. The effects of five prime types on a single target were compared through the use of an auditory lexical decision task. Two prime types served as controls, establishing minima and maxima of priming due to phonological similarity: the unrelated condition *(mangue-bac),* where no phonemes overlap between the prime and target; and the CVC condition *(bac-bac),* where all phonemes overlap between the prime and target. The three other prime types each involved the overlap of two phonemes: the _VC condition *(sac-bac);* the C_C condition *(banque-bac);* and the CV_ condition *(baffe-bac).*

The results demonstrate that, relative to the unrelated condition, facilitation is observed for targets preceded by CVC primes, _VC primes, and C_C primes. CV_ primes did not lead to facilitation or inhibition. The facilitatory effects of _VC and C_C primes are not significantly different from each other. This finding suggests that the syllable rime, the overlapping portion of the _VC primes, is not necessarily afforded a special status in the processes of lexical access. Rather, the phonological similarity of non-contiguous overlapping phonemes appears to be equivalent to that of contiguous overlap. As such, these results suggest that, at least for French, consonants provide greater facilitation than do vowels. We conclude that consonants enjoy a privileged position relative to that of vowels in terms of determining phonological similarity.

9. See also Lowenstamm and Kaye (1986) for arguments for an X-skeleton rather than a CV-skeleton on the timing tier, obviating the notion of a separate 'consonant tier'.

Acknowledgements

We are grateful to Michel Dutat, Lorna Le Stanc, Alexander Martin, and Auréliane Pajani for technical assistance in setting up our experiments, and Isabelle Brunet and Gerda Melnik for assisting in the recruitment and running of participants. We gratefully acknowledge feedback on earlier stages of this project from two anonymous reviewers and audiences at the LSCP and the Max Planck Institute for Psycholinguistics. This work was supported by the Agence Nationale pour la Recherche (ANR-10-LABX-0087 IEC, ANR-10-IDEX-0001-02 PSL, ANR-13-APPR-0012).

References

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, 68, 255–278. doi:10.1016/j.jml.2012.11.001

Clopper, C. G., & Walker, A. (2017). Effects of lexical competition and dialect exposure on phonological priming. *Language and Speech*, 60(1), 85–109. doi:10.1177/0023830916643737

Cutler, A., Sebastián-Gallés, N., Soler-Vilageliu, O., & van Ooijen, B. (2000). Constraints of vowels and consonants on lexical selection: Cross-linguistic comparisons. *Memory & Cognition*, 28(5), 746–755. doi:10.3758/BF03198409

Delle Luche, C., Poltrock, S., Goslin, J., New, B., Floccia, C., & Nazzi, T. (2014). Differential processing of consonants and vowels in the auditory modality: A cross-linguistic study. *Journal of Memory and Language*, 72, 1–15. doi:10.1016/j.jml.2013.12.001

Desroches, A. S., Newman, R. L., & Joanisse, M. F. (2008). Investigating the time course of spoken word recognition: Electrophysiological evidence for the influences of phonological similarity. *Journal of Cognitive Neuroscience*, 21(10), 1893–1906. doi:10.1162/jocn.2008.21142

Dufour, S. (2008). Phonological priming in auditory word recognition: When both controlled and automatic processes are responsible for the effects. *Canadian Journal of Experimental Psychology*, 62(1), 33–41. doi:10.1037/1196-1961.62.1.33

Dufour, S., Dumon, A., & Nguyen, N. (2015). Does a change in talker identity help listeners resolve lexical competition? Evidence from phonological priming. In *Proceedings of the eighteenth international congress of the phonetic sciences*.

Dufour, S., & Frauenfelder, U. H. (2016). Inhibitory phonetic priming: Where does the effect come from? *The Quarterly Journal of Experimental Psychology*, 69(1), 180–196. doi:10.1080/17470218.2015.1045911

Dufour, S., & Nguyen, N. (2017). Does talker-specific information influence lexical competition? Evidence from phonological priming. *Cognitive Science*, 41(8), 2221–2233.

Dufour, S., & Peereman, R. (2009). Competition effects in phonological priming: The role of mismatch position between primes and targets. *Journal of Psycholinguistic Research*, 38, 475–490. doi:10.1007/s10936-009-9101-y

Dumay, N., Benraïss, A., Barriol, B., Colin, C., Radeau, M., & Besson, M. (2001). Behavioral and electrophysiological study of phonological priming between bisyllabic spoken words. *Journal of Cognitive Neuroscience*, 13(1), 121–143. doi:10.1162/089892901564117

Gaskell, M. G., & Dumay, N. (2003). Lexical competition and the acquisition of novel words. *Cognition*, 89, 105–132. doi:10.1016/S0010-0277(03)00070-2

Goldinger, S. D. (1998). Signal detection comparisons of phonemic and phonetic priming: The flexible-bias problem. *Perception & Psychophysics*, 60(6), 952–965. doi:10.3758/BF03211931

Goldinger, S. D., Luce, P. A., Pisoni, D. B., & Marcario, J. K. (1992). Form-based priming in spoken word recognition: The roles of competition and bias. *Journal of Experimental Psychology: Learning, Memory, and Cognition*.

Gray, S., Reiser, M., & Brinkley, S. (2012). Effect of onset and rhyme pairs in preschoolers with typical development and specific languages impairment. *Journal of Speech, Language, and Hearing Research*, 55, 32–44. doi:10.1044/1092-4388(2011/10-0203)

Hamburger, M., & Slowiaczek, L. M. (1996). Phonological priming reflects lexical competition. *Psychonomic Bulletin & Review*, 3(4), 520–525. doi:10.3758/BF03214558

Havy, M., & Nazzi, T. (2009). Better processing of consonantal over vocalic information in word learning at 16 months of age. *Infancy*, 14(4), 439–456. doi:10.1080/15250000902996532

James, L. E., & Burke, D. M. (2000). Phonological priming effects on word retrieval and tip-of-the-tongue experiences in young and older adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 26(6), 1378–1391.

Keuleers, E., & Brysbaert, M. (2010). Wuggy: A multilingual pseudoword generator. *Behavior Research Methods*, 42(2), 627–633. doi:10.3758/BRM.42.3.627

Lowenstamm, J., & Kaye, J. (1986). Compensatory lengthening in Tiberian Hebrew. In W. L. Wetzels & E. Sezer (Eds.), *Studies in compensatory lengthening* (pp. 97–132). Dordrecht: Foris.

Luce, P. A., Goldinger, S. D., Auer, E. T., & Vitevitch, M. S. (2000). Phonetic priming, neighborhood activation, and PARSYN. *Perception & Psychophysics*, 62(3), 615–625. doi:10.3758/BF03212113

Marslen-Wilson, W. (1990). Activation, competition, and frequency in lexical access. In G. T. M. Altmann (Ed.), *Cognitive models of speech processing* (pp. 148–172). Cambridge, MA: The MIT Press.

McQueen, J. M., & Sereno, J. (2005). Cleaving automatic processes from strategic biases in phonological priming. *Memory & Cognition*, 33(7), 1185–1209. doi:10.3758/BF03193222

Nazzi, T., Floccia, C., Moquet, B., & Butler, J. (2009). Bias for consonantal information over vocalic information in 30-month-olds: Cross-linguistic evidence from French and English. *Journal of Experimental Child Psychology*, 102, 522–537. doi:10.1016/j.jecp.2008.05.003

Nespor, M., Pena, M., & Mehler, J. (2003). On the different roles of vowels and consonants in speech processing and language acquisition. *Lingue e linguaggio*, 2(2), 203–230.

New, B., Araújo, V., & Nazzi, T. (2008). Differential processing of consonants and vowels in lexical access through reading. *Psychological Science*, 19(12), 1223–1227. doi:10.1111/j.1467-9280.2008.02228.x

New, B., Pallier, C., Ferrand, L., & Matos, R. (2001). Une base de données lexical du français contemporain sur internet: LEXIQUE. *L'Année Psychologique*, 101, 447–462. doi:10.3406/psy.2001.1341

Norris, D., McQueen, J. M., & Cutler, A. (2002). Bias effects in facilitatory phonological priming. *Memory & Cognition*, 30(3), 399–411. doi:10.3758/BF03194940

Peirce, J. W. (2009). Generating stimuli for neuroscience using PsychoPy. *Frontiers in Neuroinformatics*, 2, 10.

Prunet, J. -F. (1987). Liaison and nasalization in French. In C. J. Neidle & R. Núñez Cedeño (Eds.), *Studies in Romance languages* (pp. 225–235). Dordrecht: Foris. doi:10.1515/9783110846300.225

Radeau, M., Besson, M., Fonteneau, E., & Castro, S. L. (1998). Semantic, repetition and rime priming between spoken words: behavioral and electrophysiological evidence. *Biological Psychology*, 48, 183–204. doi:10.1016/S0301-0511(98)00012-X

Radeau, M., Morais, J., & Segui, J. (1995). Phonological priming between monosyllabic spoken words. *Journal of Experimental Psychology: Human Perception and Performance*, 21(6), 1297–1311.

Selkirk, E. O. (1986). *Phonology and syntax: the relationship between sound and structure*. Cambridge, MA: MIT Press.

Slowiaczek, L. M., & Hamburger, M. (1992). Prelexical facilitation and lexical interference in auditory word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18(6), 1239–1250.

Slowiaczek, L. M., McQueen, J. M., Soltano, E. G., & Lynch, M. (2000). Phonological representations in prelexical speech processing: Evidence from form-based priming. *Journal of Memory and Language*, 43, 530–560. doi:10.1006/jmla.2000.2710

Slowiaczek, L. M., Nusbaum, H. C., & Pisoni, D. B. (1987). Phonological priming in auditory word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 13(1), 64–75.

Slowiaczek, L. M., & Pisoni, D. B. (1986). Effects of phonological similarity on priming in auditory lexical decision. *Memory & Cognition*, 14, 230–237. doi:10.3758/BF03197698

Turnbull, R. (2017). The role of predictability in intonational variation. *Language and Speech*, 60(1), 123–153. doi:10.1177/0023830916647079

Wiener, S., & Turnbull, R. (2016). Constraints of tones, vowels and consonants on lexical selection in Mandarin Chinese. *Language and Speech*, 59(1), 59–82. doi:10.1177/0023830915578000

Corresponding address

Rory Turnbull
Department of Linguistics
University of Hawaiʻi at Mānoa
1890 East West Road, Moore Hall 569
Honolulu, HI, 96822
USA

rory.turnbull@hawaii.edu