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Episodic accessibility and morphological processing: Evidence from long-term auditory priming

Sid Kouider *, Emmanuel Dupoux

Laboratoire de Sciences Cognitives et Psycholinguistique, CNRS/EHESS/DEC-ENS, Ecole Normale Supérieure, 29 rue d'Ulm, 75005 Paris, France

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ABSTRACT

Long-term priming studies of lexical processing have yielded conflicting claims as to whether abstract versus episodic representations are involved during word recognition. A critical piece of evidence that could separate the two accounts rests on the existence of full morphological priming, where morphologically related words yield the same amount of priming as repeated words. In this study, participants performed speeded lexical decision on lists of auditory words and non-words, which contained repeated, morphologically related, semantically related and phonologically related pairs of items. In order to minimize the involvement of episodic factors, we increased the prime–target interval and decreased their physical similarity by introducing a change in speaker's voice. We show that under conditions that minimize access to episodic features, the magnitude of repetition priming decreased to attain that of morphological priming. Importantly, morphological and repetition priming for words were always observed in the absence of any semantic and phonological priming, suggesting that they cannot be reduced to formal or meaning overlap. Our results support the view that long-term priming taps both abstract lexical codes with a morphological format and episodic memory components. Further, they show that episodic influences on priming can be modulated by prime–target interval and physical similarity.

1. Introduction

What are the representations underlying word recognition? Psycholinguistic models that address this issue can be classified into two broad classes: abstractionist models posit that word identification involves a series of processes aimed at eliminating irrelevant variation in word forms (script, speaker identity, affect and phonological processes) in order to map these inputs onto an abstract invariant lexical or morphological representation (Bowers, 2000; Morton, 1969). Episodic models propose that surface variations in word form are not discarded, but are kept into a rich instance-specific representation. Each encounter with a word form is, therefore, stored as a distinct episode (Goldinger, 1998; Luce & Pisoni, 1998). Episodic models, by opposition to abstractionist models, deny the existence of an abstract lexicon and propose that lexical and non-lexical traces are conjointly stored in a single episodic memory system. Between these two extreme positions, there exists a rich continuum of hybrid models which recognize two components, an abstract lexical component and an episodic component (e.g., Goldinger, 2007; Pisoni & Levi, 2007). What is lacking within such hybrid accounts, however, is a characterization of the respective influence of these two components during word recognition.

Many studies have relied on the priming phenomenon as a method to investigate word processing (e.g., Bowers, 2000; Tenpenny, 1995). Priming refers to the facilitation in the identification of an item (the *target* word) due to the prior encounter with a related item (the *prime* word). By manipulating the prime–target relationship (physical identity, abstract identity, etc.), one can study the format of lexical representations. In *long-term priming*, prime and target are separated by minutes, hours, or even days. Because of this delay, participants are usually not aware of the prime–target relation. Long-term priming is thus considered to measure non-conscious, non-declarative, or implicit memory (e.g., Bowers, 2000).

Long-term priming has been one of the first tools for studying word recognition (Morton, 1969), but has been subsequently criticized for being too much influenced by episodic memory compared to masked priming (Forster & Davis, 1984). Yet, many of the long-term priming studies, that have shown instance-specific effects (e.g., voice effects on repetitions), have used unspeeded tasks where participants have to guess the identity of the target, such as in stem completion, or perceptual identification with degraded stimuli (Church & Schacter, 1994). These effects are due to episodic memory components, because the same tasks performed in amnesic patients, who have no episodic recall of recent

E-mail address: sid.kouider@ens.fr (S. Kouider).
URL: http://www.lscp.net/persons/sidk (S. Kouider).

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events, show long-term repetition priming in the absence of voice effects (Schacter, Church, & Bolton, 1995). However, when long-term priming is used in conjunction with a speeded task, such as lexical decision, the influence of instance-specific features is largely diminished. Indeed, with lexical decision, long-term repetition priming does not depend on low level visual similarity between prime and target (e.g., kiss-KISS versus read-READ) (Bowers, 1996, see also Bowers and Michita (1998) with priming between Hiragana and Kanji Japanese scripts).[1] Similarly, Luce and Lyons (1998) found that long-term repetition priming is unaffected by a change in voice (e.g., from female to male), when using auditory lexical decision. These results suggest that long-term priming is mediated, as least in part, by abstract lexical representations.

Another critical piece of evidence relies on the characteristics of long-term morphological priming (Tenpenny, 1995). Indeed, in models of the lexicon that comprise abstract morphological entries, the morphological variants (e.g., car-cars) share the same lexical representation (Caramazza, Laudanna, & Romani, 1988; Murrell & Morton, 1974; Taft & Forster, 1975). These models predict that, in the absence of episodic contributions, there should be *full morphological priming*, that is a situation in which the amount of morphological priming (cars-car) equals the amount of repetition priming (car–car). Importantly, these abstractionist models claim that morphological priming cannot be reduced to phonological (card-car) or semantic overlap (automobile-car). In contrast, a system based on episodic memory does not have lexical entries. All word forms variants are listed as episodes, and produce priming according to their similarity with the priming event. Responses driven by episodic memory should have a gradient signature, with repetition condition producing the largest effect, and morphological, phonological and semantic conditions producing an effect reduced in size according to the prime–target similarity. The possibility of full morphological priming is hence crucial to measure the relative contribution of these two kinds of systems (Bowers, 2000; Tenpenny, 1995).

Long-term morphological priming has been observed in the absence of form-priming (e.g., car-card; Murrell & Morton, 1974) in both auditory and written modalities, and long-term semantic priming is typically not observed at all (e.g., car-truck; Bentin & Feldman, 1990). Feldman and Moskovljevic (1987) studied long-term morphological priming in Serbo-Croatian, a language in which words can be transcribed in either Roman or Cyrillic alphabets, and manipulated whether the prime and target were in the same or different alphabets. They found that alphabet change has no effect on the magnitude of morphological priming, suggesting that it involves an abstract morpholexical level with no episodic contribution. In a more recent study using written words, Feldman (2000) compared all these forms of priming within the same experiment. She found that while orthographic, semantic and morphological priming are all reliable in immediate priming, only morphological priming is significant in long-term priming. Such data are compatible with the view that long-term priming is sensitive to an abstract lexical system. Yet, full morphological priming has not always been reported. When averaged across studies, morphological priming is actually weaker than repetition priming, suggesting a role for episode-specific features (Tenpenny, 1995).

To account for this discrepancy, we propose that exact repetitions are affected by both episodic and abstract components. Episodic traces intervene only when the episodes are easily accessible (i.e., when the prime–target interval is short or when the prime–target similarity is high, see Bowers, 2000). In contrast, morphological priming is affected primarily by abstract components, since it implies a change in word form and hence typically does not trigger the retrieval of a memory episode. It then follows that any difference between repetition and morphological priming should be eliminated as soon as episodic contaminations are discarded, by increasing the prime–target delay and by decreasing the prime–target similarity (e.g., repetitions in same versus different voices). Consistent with this idea, Fowler, Napps, and Feldman (1985) found a partial morphological priming effect with a short-lag of 6–12 intervening items, but a full morphological priming effect when the mean lag was increased to 48 intervening items.[2] Bentin and Feldman (1990) found that contrary to repetition priming, morphological priming is unaffected by an increase of lag from 0 to 15 items. With the same lag increase, semantic priming totally vanishes. Although these results are scattered across different studies which did not control for all of these parameters simultaneously, the results are consistent with the idea that differences between repetition and morphological priming are especially true at short lags (because episodic factors are effective), but that such differences will reduced at longer lags and/or by decreasing the prime–target similarity (because influences are no longer operative). The current work was aimed at testing this hypothesis.

The present study aims at clarifying situations under which episodic and abstractionist long-term priming effects are found during spoken word recognition. First, we studied the effect of episodic accessibility on the emergence of full morphological priming. We measured repetition priming and morphological priming using gender inflected pairs in French (e.g., "grand"-"grande": big_{masc}-big_{fem}) across three experimental situations as follows: in Experiment 1, we used a relatively short lag where prime and target, presented in the same voice, are separated by an average of 18 items. Under these conditions, we expected episodic accessibility to be relatively high. In Experiment 2, we used the same stimuli as in the first experiment, but the lag was increased fourfold (72 items) in order to decrease episodic accessibility. Finally, in Experiment 3, we further doubled the lag (144 items) and introduced a change in talker between the prime and the target to further decrease the possibility of episodic accessibility. Here, we expected that episodic influences should be so minimal that it would lead to full morphological priming, i.e., a morphological priming effect of the same magnitude as repetition priming.

2. Methods

2.1. Participants

The participants were 24, 24 and 26 right-handed university students in Experiments 1, 2 and 3, respectively. All were native French speakers and they reported no hearing impairment.

2.2. Stimuli

Ninety-six prime–target pairs of noun or adjective words and 96 pairs of non-words were selected. Word pairs were divided into 24 pairs in the repetition condition, 24 pairs in the morphological condition, 24 pairs in the phonological (and pseudo-morphological) condition, and 24 pairs in the semantic condition (see Table 1 and Appendix). In the repetition condition, the prime and target were identical. In the morphological condition, the prime was feminine ("cousine"), whereas the target was masculine ("cousin"). For half the pairs, the prime had an additional consonant in the final

[1] Note that in both studies (Bowers, 1996; Bowers & Michita, 1998), cross-modal repetition priming (from spoken to written word) was also measured and was weak or absent, ruling out interpretations in terms of phonological or semantic prime–target overlap.

[2] Note that full and partial morphological priming is defined in relation to repetition priming. Accordingly, the two degrees of morphological priming not only can have the same magnitude but also can be defined as partial or full depending on whether repetition priming is larger.

Table 1
Example of prime and target, frequency (Freq, mean logarithmic frequency, based on the Brulex database and normalized to one word per million) and length (Nsyl, total number of syllables) for each conditions

Relation	Target			Prime		
	Example	Freq	Nsyl	Example	Freq	Nsyl
	Words					
Morphological	Gamin	0.8	39	Gamine	1.3	39
Phonological	Mandarin	0.9	38	Mandarine	1.2	38
Semantic	Garçon	0.9	39	Fille	1.3	39
Repetition	Justice	1.3	39	Justice	1.3	39
	Non-words					
Pseudo-morphological	Janois		39	Janoise		39
Phonological	Fourmand		39	Chourmand		39
Repetition	Tavorce		39	Tavorce		39

position (e.g., “marquise” → “marquis”: /markiz/ → /marki/); for the remaining half, the stem’s final vowel and final consonant differed (“cousine” → “cousin”: /kuzin/ → /kuzɛ̃/. Pairs in the Phonological condition displayed the same phonological alternations as in the morphological condition, but did not share any morphological or semantic relation: as above, half the pairs differed by an additional final consonant on the prime (e.g., “devise” → “devis”: /dəviz/ → /dəvi/), whereas the other half differed in the final vowel and consonant “mandarine” → “mandarin”: /mɑ̃ndarin/ → /mɑ̃ndarɛ̃/). The semantic condition comprised 12 pairs of semantic associates (mean prime–target associative rate: 30.9% forward and 30.9% backward) and 12 conceptually related pairs sharing many conceptual features but differing in gender/sex (such as “fille” → “garçon”). As one can see in Fig. 1, the four conditions were matched in frequency (using the Brulex database) and in length (number of syllables).

Non-words were divided into 32 pairs in the non-word repetition condition, 32 pairs in the non-word pseudo-morphological condition and 32 pairs in the non-word phonological condition. In the non-word repetition condition, primes and targets were identical. The non-word pseudo-morphological condition was analogous to the phonological condition for words and used the same specific prime–target formal variations as in the morphological condition (e.g., a non-word pair like “tarquise” → “tarquis” was constructed from the morphological pair “marquise” → “marquis”). In the non-word phonological condition, primes and targets were also formally similar, but they were not flexional variations: only the first phoneme (the onset) differed (as in “zarotte” → “farotte”). Primes and targets were the same token (female voice), except in Experiment 3 (male voice for primes, feminine voice for targets). Thirty additional items were selected for training purpose.

2.3. Procedure

Participants made speeded lexical decisions (right hand for words versus left hand for non-words) on auditory prime and target stimuli presented through headphones. The response deadline was 3 s, and the inter-trial interval was 1 s. Auditory stimuli were recorded by a female and a male native French speakers, and were digitized on a PC compatible computer using an OROS-AU22-A/D board. The experiments were programmed and ran using the EXPE script language. In Experiment 1 (short-lag), there were eight blocks each consisting of 24 targets preceded by 12 primes. Half the targets were related to one of the preceding primes and half were not (control condition). The number of intervening items varied randomly with a range of 12–24 items and a mean of 18 items. Experiment 2 (medium-lag) comprised 2 blocks with 48 primes followed by 96 targets (range = 48–96; mean = 72). In Experiment 3 (long-lag + voice-change), participants received a first block consisting of 96 primes followed by a block of 192 targets (range = 96–192; mean = 144). Thus, the list length was identical for the three experiments. The participant had no way to distinguish “primes” from “targets”, and had to perform lexical decision on all items. Furthermore, there was no delimitation between the different blocks such that the whole protocol appeared to the participants as a continuous list of words and non-words only interrupted by a pause halfway. The notion of “block” was only known to the experimenter, and was used to precisely control for the distance between primes and targets, while having a different pseudorandom order for each participant. Participants were randomly divided into two groups (G1 and G2) and primes were divided into two sets (sets 1 and 2). Both groups received all the targets. However, participants in G1 received the primes from set 1, whereas participants in G2 received the primes from set 2.

3. Results

Two ANOVAs on mean correct response times (RTs) to target stimuli were performed, one with participants as random variable, the other with items as random variable. We declared priming

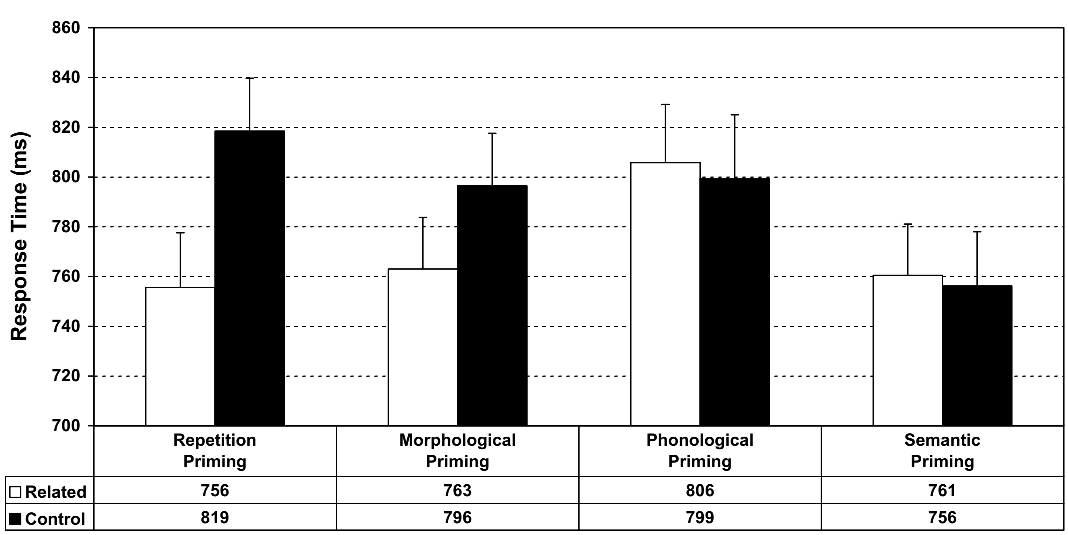


Fig. 1. Priming effects for words as a function of the prime–target relation. Error bars correspond to 2 standard-errors.

Table 2
Mean reaction times (in ms) for control and related targets as a function of priming condition and lag (standard-errors are given in parentheses)

	Words				Non-words		
	Repetition priming	Morphological priming	Phonological priming	Semantic priming	Repetition priming	Pseudo-morphological priming	Phonological priming
Short-lag							
Related	753 *(20)*	766 *(17)*	831 *(17)*	776 *(16)*	877 *(20)*	886 *(18)*	879 *(24)*
Control	834 *(16)*	797 *(16)*	809 *(22)*	783 *(17)*	888 *(18)*	875 *(24)*	890 *(23)*
Medium-lag							
Related	806 *(15)*	816 *(16)*	860 *(16)*	819 *(13)*	923 *(14)*	908 *(18)*	910 *(15)*
Control	868 *(16)*	846 *(15)*	869 *(16)*	812 *(13)*	921 *(14)*	907 *(15)*	919 *(18)*
Long-lag + voice-change							
Related	712 *(17)*	711 *(15)*	732 *(18)*	692 *(15)*	829 *(19)*	813 *(21)*	778 *(15)*
Control	759 *(16)*	749 *(19)*	726 *(19)*	679 *(15)*	795 *(17)*	803 *(19)*	792 *(19)*

(control versus primed target), condition (repetition, morphological, phonological, semantic, non-word repetition, non-word pseudo-morphological and non-word phonological condition) and experiment (Experiments 1, 2 or 3) as main factors. In addition, the participants analysis included a counterbalancing factor of participant group (two levels), and the items analysis included a counterbalancing factor of item group (two levels). Responses on targets leading to an incorrect response or for which the prime gave rise to an incorrect response were discarded (5.7%). The mean correct response time was estimated in a robust way, with RTs more than two standard-deviations above or below the mean for each condition and participant (or condition and item in the items analysis) were trimmed to the appropriate threshold (4.1% of RTs were discarded). We found significant effects of priming [11 ms; $F1(1,68) = 25.30$, $p < 0.0001$; $F2(1,178) = 22.12$, $p < 0.0001$], condition [$F1(6,408) = 150.08$, $p < 0.0001$; $F2(6,178) = 10.64$, $p < 0.0001$] and experiment [$F1(2,68) = 15.73$, $p < 0.0001$; $F2(2,356) = 301.31$, $p < 0.0001$]. Priming interacted with the condition factor [$F1(6,408) = 21.10$, $p < 0.0001$; $F2(6,178) = 13.06$, $p < 0.0001$]. A first planned comparison between words and non-words revealed a lexicality effect [$F1(1,68) = 318.45$, $p < 0.0001$; $F2(1,178) = 54.70$, $p < 0.0001$] with a 83 ms advantage for words. The detailed results for control and related targets as a function of priming condition and lag are displayed in Table 2.

For words, priming was restricted to the repetition [63 ms; $F1(1,68) = 116.25$, $p < 0.0001$; $F2(1,22) = 67.48$, $p < 0.0001$] and morphological conditions [33 ms; $F1(1,68) = 33.16$, $p < 0.0001$; $F2(1,22) = 13.31$, $p < 0.002$].[3] Regarding phonological and semantic priming, small inhibitory trends were observed (−6 ms and −4 ms, respectively), but they were not significant (all $Fs < 1$).[4] For non-words, a significant priming effect was observed only in the non-word phonological condition [12 ms; $F1(1,68) = 4.35$, $p < 0.05$; $F2(1,30) = 5.98$, $p < 0.05$]. An inhibitory trend (−9 ms) was found in the repetition condition which was marginally significant in the participants analysis ($0.10 > p > 0.05$) and did not approach significance by items ($F2 < 1$). Another inhibitory trend (−8 ms) appeared in the non-word pseudo-morphological condition, and did not approach significance in any of the analyses (both $F < 2$). The absence of non-word repetition priming in this study is consistent with past long-term priming studies using lexical decision (e.g., Scarborough, Cortese, & Scarborough, 1977).

We compared the four types of priming for words (collapsed across experiments) to determine whether morphological priming was different from the others. Morphological priming was significantly larger than phonological priming [$F1(1,68) = 13.09$, $p < 0.001$; $F2(1,44) = 10.72$, $p < 0.005$] and semantic priming [$F1(1,68) = 25.36$, $p < 0.0001$; $F2(1,44) = 9.01$, $p < 0.005$], but significantly weaker than repetition priming [$F1(1,68) = 15.97$, $p < 0.0001$; $F2(1,44) = = 9.87$, $p < 0.005$]. In other words, we obtained overall partial morphological priming.

In order to determine whether partial morphological priming depended on episodic accessibility, we analysed the difference between morphological and repetition priming as a function of experiment (see Fig. 2). The interaction between priming, the morphological and repetition conditions and the two extreme episodic accessibility conditions (Experiment 1 versus Experiment 3) was significant by participants and marginal by items [$F1(1,46) = 6.01$, $p < 0.02$; $F2(1,44) = 2.94$, $p < 0.10$]. This triple interaction was due to the fact that priming and experiments interacted with each other, significantly by items and marginally by participants for the repetition condition [$F1(2,68) = 3.01$, $p < 0.06$; $F2(2,44) = 4.10$, $p < 0.05$], whereas this interaction did not approach significance for the morphological condition (both Fs < 1).

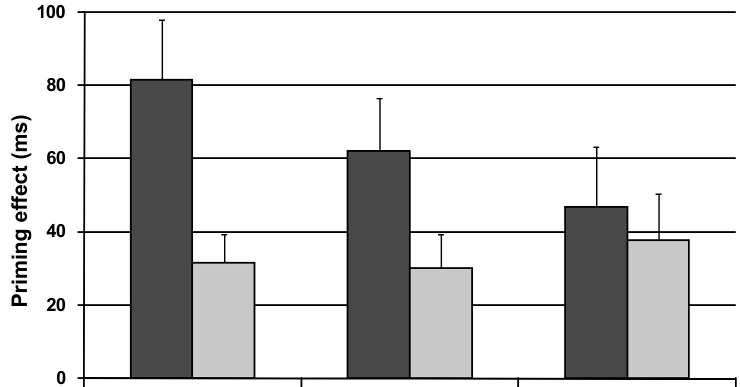
Finally, comparisons between morphological priming and repetition priming across the different experiments revealed that repetition priming was significantly greater than morphological priming in Experiment 1 [$F1(1,22) = 19.68$, $p < 0.0005$; $F2(1,44) = 8.10$, $p < 0.01$] and Experiment 2 [$F1(1,22) = 4.65$, $p < 0.05$; $F2(1,44) = 7.89$, $p < 0.01$], but crucially not in Experiment 3 (both $Fs < 1$). These results reflect the fact that morphological priming was always significant but remained almost constant across the three experiments [32 ms for Experiment 1: $F1(1,22) = 16.36$ $p < 0.0005$; $F2(1,22) = 4.93$ $p < 0.05$; 30 ms for Experiment 2: $F1(1,22) = 8.58$ $p < 0.005$; $F2(1,22) = 5.15$ $p < 0.05$; and 38 ms for Experiment 3: $F1(1,24) = 11.11$ $p < 0.005$; $F2(1,22) = 10.02$ $p < 0.005$], whereas repetition priming was also always significant but its size decreased drastically from Experiments 1 to 2, and even more drastically in Experiment 3 [82 ms for Experiment 1: $F1(1,22) = 55.60$, $p < 0.0001$; $F2(1,22) = 51.63$, $p < 0.0001$; 62 ms for Experiment 2: $F1(1,22) = 29.86$, $p < 0.0001$; $F2(1,22) = 51.00$, $p < 0.0001$; and 47 ms for Experiment 3: $F1(1,24) = 33.62$, $p < 0.0001$; $F2(1,22) = 10.84$, $p < 0.005$].

4. Discussion

In this study, participants performed speeded lexical decision on lists of words and non-words, which contained matched repeated, morphologically related, semantically related or phono-

[3] A post-hoc analysis was conducted separately for the morphological pairs with simple concatenative suffixes and pairs where there was an additional change in the stem vowel. Concatenative pairs gave rise to a significant 46 ms morphological priming effect ($p < 0.001$ by participant, $p < 0.01$ by item), and pairs with vowel change gave rise to 23 ms priming ($p < 0.003$ by participant, $p < 0.01$ by item). Priming did not differ between the two types of pairs (both $ps > .05$) and did not interact with lag (both $ps > .1$).

[4] Post-hoc analyses of the semantic condition revealed no significant priming for either the semantically associated or the conceptually related pairs, nor any interaction between priming and these two sub-conditions (all $Fs < 1$).



	Short-lag	Medium-lag	Longlag + voice-change
■ Repetition	82	62	47
□ Morphological	32	30	38

Fig. 2. Long-term morphological and repetition priming as a function of the prime–target delay (short-lag = 18 intervening items; medium-lag = 72 intervening items; long-lag = 144 intervening items). Error bars correspond to 2 standard-errors, 1 above and 1 below the mean.

logically related prime–target pairs. Primes and targets were tested in three episodic accessibility situations: short-lag, medium-lag and long-lag + voice-change. Across the three situations, we obtained morphological long-term priming and repetition priming in the absence of semantic priming and phonological priming. This is congruent with previous studies in the visual modality showing long-term morphological priming in the absence of orthographic priming and semantic priming (e.g., Feldman, 2000). In addition, we observed that contrary to morphological priming, repetition priming decreases with episodic accessibility. At the shortest lag, identity priming was significantly greater than morphological priming. In contrast, at the longest lag with a change in talker, repetition priming was reduced to the size of morphological priming. In other words, in the situation with the lowest episodic accessibility, we observed full morphological priming in the absence of either semantic priming or phonological priming.

These results have implications regarding theories of long-term priming. We have confirmed in the auditory modality that morphological relationships can induce long-term effects and that these effects are not reducible to semantic or phonological similarity. This is consistent with the notion that long-term priming corresponds, at least in part, to permanent changes in abstract lexical entries during the presentation of a stimulus (e.g., Murrell & Morton, 1974). However, our results also suggest that depending on the experimental conditions, both abstract lexical and episodic effects can be observed. In the general case, it shows that repetition priming reflects the additive contributions of both episodic and morphological priming. More precisely, the balance between the two types of effects depends on accessibility of the prime, which is modulated by the physical distance and overlap between prime and target. When the distance is short and prime and target share the talker characteristics, episodic influences are still active, as shown by a greater repetition priming effect compared to morphological priming. When the interval is long and in addition there is a change in talker voice, episodic influences become very small, as shown by full morphological priming. Of course, we have chosen only two factors (lag increase and voice-change), and we have not studied each of them separately. Thus, which of them is having the strongest influence on episodic accessibility, and whether other factors could also matter (e.g., context, stimulus degradation, task, etc.) remains to be established. In any case, what we show here is that the combination of these two factors is sufficient to eliminate episodic contamination during long-term priming.

These results also have implications for models of lexical representations. They are consistent with studies proposing an independent abstract morphological level, while, by contrast, they are difficult to reconcile with models that posit that words are coded as a distributed set of phonological, orthographic and semantic representations (Gonnerman, Seidenberg, & Andersen, 2007). In such models, lexical or morphological identity results from the similarity among the episodes. They predict that independent of lag, priming should be a gradual function of similarity, with repetition priming always giving rise to bigger effects than either form-based or semantic-based priming. Of course, it could be argued that we did not test a condition in which words were related at both the semantic and formal levels without being morphologically related (e.g., screech–scream). Thus, we cannot totally refute the possibility of a gradient effect of semantic and formal overlap, as postulated by proponents of a distributed lexicon-free (PDP) architecture (e.g., Gonnerman et al., 2007). Nevertheless, the fact that we obtained null priming effects for the formal and the semantic relations tested separately makes it difficult to argue that these relationships were at the origin of our long-term morphological effects. Let us note in addition that even if priming turned out to reflect the joint overlap of semantic and formal similarity, it would remain to explain why morphological priming equals repetition priming at the longest intervals. Indeed, according to this perspective, morphological priming should always remain smaller than repetition priming, formal and semantic overlap being smaller for morphologically related words than for repetitions.

Of course, there are several remaining theoretical possibilities that we cannot discard in the present study. In particular, it could be that our results are due to a larger semantic overlap in the morphological pairs compared to that in the semantic pairs. While the important variation within the morphological pairs and within the semantic pairs made it such that some pairs are probably as semantically related to each other across the two conditions (for instance cousin-cousine and oncle-tante), other pairs such as grand-grande are full synonyms differing only in whether the noun they modify is syntactically masculine or feminine. As we could not rely on semantic association norms for morphologically related pairs, because participants probed with a word (for instance "grand") might consider morphological-related words ("grande") as the same word or an illegal association, we cannot fully exclude a semantic explanation of the morphological priming effect, despite the absence of a semantic priming effect.

It is of note that in light of our findings, the terminology "full morphological priming", which is usually employed in the priming literature to define situations of equal magnitude for repetition and morphological priming, may not be the most appropriate one to use. Indeed, it presupposes that morphological priming varies in comparison to repetition priming. Our study suggests that exactly the reverse is happening; while, the magnitude of morphological priming remained remarkably constant across lags, the magnitude of repetition priming, by contrast, was affected by our manipulations of lag and talker voice. Thus, apparent cases of full morphological priming are not reflecting an increase in the amount of morphological priming up to the level of repetition, but a situation where the amount of repetition priming is in fact decreasing down to the level of morphological priming. Future studies should replace this descriptively inadequate terminology with the more theoretically motivated one of "episodic" versus "abstract" priming. To do so, we need of course to develop additional measures to diagnose, for a particular experimental condition, the respective contribution of episodic and abstract components on priming.

In sum, our results are compatible with hybrid models of lexical representations that include abstract entries or features (Bowers, 2000) and episodic components (Goldinger, 2007; Pisoni & Levi, 2007). In such a view, lexical symbols are encoded under an abstract and morphological format: formal variations-based upon the same root morpheme (e.g., ≪grand≫, ≪grande≫ or ≪grandes≫) are not represented as separated entries; rather they are encoded as a single morpholexical entry. In addition, lexical items also appear in an episodic component, which stores detailed information regarding the context and specifics of the word that was presented on a particular episode. Long-term priming is especially well suited to study these hybrid accounts, but further studies remain to be done in order to have a better understanding of how these two kinds of information interact during word recognition. First, it would be important to study in more detail the effect of type of morphological relation. The case of the French gender is somewhat particular, since it is less phonologically transparent and less productive than the cases of regular inflexional morphology that has been studied in English. It remains unclear whether the effect of lag would be similar in cases that are either more transparent or less transparent.

Similarly, although the exact format of morphological representations was not the central theoretical issue here, it remains to establish whether our results can be extended to other types of morpholexical representations. Indeed, here we only studied inflectional morphology, whereby the suffixation process does not create a new stem. In derivational morphology, in contrast, new stems can be created by affixation, like in the pair "view" and "viewer", or "view" and "preview". It remains possible that the lexical organization principles differ between inflectional and derivational morphology. In addition, as reported by Feldman and Fowler (1987), one can find differences even within inflexional morphology, when dissociating stem-preserving and stem-alternating rules. As a consequence, it would be interesting to investigate whether our full morphological priming results found with a long-lag and voice-change can be generalized to other cases of morphological relationships.

Furthermore, our results may be specific to the auditory modality, and the precise balance of episodic and lexical influences may be different in the written modality. For instance, Fowler et al. (1985) compared presentation in the auditory and visual modalities and found that, at least under some conditions, a difference between morphological and repetition priming was observed for the visual modality, but not for the auditory modality. It remains to be established whether it is the morpholexical features or the episodic components that differ across modalities.

In summary, our study shows that long-term priming is mediated by both morpholexical and episodic influences, providing support for hybrid models of spoken word recognition (e.g., Goldinger, 2007; Pisoni and Levi, 2007). We also showed that the episodic influences on priming can be manipulated and minimized to focus more specifically on lexical components. This was done here by manipulating lag and talker voice. In the future, it will be interesting to fully cross these two factors and to test the effect of additional factors such as contextual cues (e.g., testing environment). More research is needed to understand the factors that directly modulate episodic accessibility.

Appendix

Materials (see Table 1 caption for a description).

Relation	Target	Freq	Nsyll	Prime	Freq	Nsyll
Repetition	Temple	3.6	1	Temple	3.6	1
	Divorce	3.0	2	Divorce	3.0	2
	Reflet	3.7	2	Reflet	3.7	2
	Refuge	3.3	2	Refuge	3.3	2
	Caverne	3.0	2	Caverne	3.0	2
	Astre	3.4	1	Astre	3.4	1
	Filet	3.4	2	Filet	3.4	2
	Verbe	3.4	1	Verbe	3.4	1
	Talon	3.3	2	Talon	3.3	2
	Chimie	3.0	2	Chimie	3.0	2
	Four	3.0	1	Four	3.0	1
	Diva	1.2	2	Diva	1.2	2
	Nord	4.0	1	Nord	4.0	1
	Justice	4.0	2	Justice	4.0	2
	Centre	4.0	1	Centre	4.0	1
	Robe	4.0	1	Robe	4.0	1

Appendix (*continued*)

Relation	Target	Freq	Nsyll	Prime	Freq	Nsyll
	Longueur	3.3	2	Longueur	3.3	2
	Chapitre	3.9	2	Chapitre	3.9	2
	Étoile	4.0	2	Étoile	4.0	2
	Robot	1.8	2	Robot	1.8	2
	Style	3.8	1	Style	3.8	1
	Neige	3.8	1	Neige	3.8	1
	Cobra	1.5	2	Cobra	1.5	2
	Piano	3.6	2	Piano	3.6	2
Mean		3.3	1.6		3.3	1.6
Morphological	Brun	3.3	1	Brune	3.3	1
	Chien	4.1	1	Chienne	3.0	1
	Nain	2.7	1	Naine	2.7	1
	Copain	3.4	2	Copine	2.2	2
	Cousin	3.9	2	Cousine	0.9	2
	Cubain	1.4	2	Cubaine	1.4	2
	Félin	2.3	2	Féline	2.3	2
	Gamin	3.3	2	Gamine	2.7	2
	Gardien	3.4	2	Gardienne	0.6	2
	Humain	4.6	2	Humaine	4.6	2
	Radin	1.8	2	Radine	1.8	2
	Rouquin	2.4	2	Rouquine	2.4	2
	Blond	3.3	1	Blonde	3.4	1
	Froid	4.2	1	Froide	4.2	1
	Grand	5.2	1	Grande	5.2	1
	Gris	4.0	1	Grise	2.5	1
	Muet	3.7	1	Muette	3.7	1
	Sourd	3.8	1	Sourde	3.8	1
	Client	3.6	2	Cliente	3.6	2
	Danois	2.4	2	Danoise	2.4	2
	Expert	2.9	2	Experte	2.9	2
	Gagnant	2.7	2	Gagnante	2.7	2
	Gourmand	2.8	2	Gourmande	2.8	2
	Marquis	3.3	2	Marquise	3.1	2
Mean		3.3	1.6		2.8	1.6
Phonological	Banc	3.7	1	Benne	1.9	1
	Daim	2.2	1	Dune	3.0	1
	Gain	3.1	1	Gaine	2.6	1
	Main	5.0	1	Mine	3.7	1
	Pain	3.9	1	Peine	4.3	1
	Engin	2.9	2	Angine	2.2	2
	Bottin	1.5	2	Bottine	2.9	2
	Caban	1.3	2	Cabane	3.0	2
	Marin	3.5	2	Marraine	2.4	2
	Savant	3.8	2	Savane	2.2	2
	Magasin	3.5	3	Magazine	2.5	3
	Mandarin	2.2	3	Mandarine	2.1	3
	Bois	4.3	1	Boîte	2.8	1
	Cri	4.2	1	Crise	3.9	1
	Fleur	4.2	1	Flirt	2.4	1
	Flux	3.3	1	Flûte	2.1	1
	Goût	4.2	1	Goutte	3.7	1
	Gui	2.2	1	Guide	3.4	1
	Vie	5.1	1	Vide	4.2	1
	Banquet	2.9	2	Banquette	3.1	2
	Sirop	2.6	2	Cirrhose	1.5	2
	Devis	2.0	2	Devise	3.0	2
	Mairie	3.1	2	Mérite	3.6	2
	Moutard	2.1	2	Moutarde	2.4	2

(*continued on next page*)

Appendix (*continued*)

Relation	Target	Freq	Nsyll	Prime	Freq	Nsyll
Mean		3.2	1.6		2.9	1.6
Associative	Papillon	3.2	3	Chenille	2.8	2
	Ruche	2.9	1	Abeille	3.2	2
	Gant	3.4	1	Moufle	1.7	1
	Voiture	4.1	2	Pneu	2.6	1
	Aquarium	2.5	3	Poisson	3.6	2
	Lapin	3.3	2	Carotte	2.5	2
	Fourchette	2.77	2	Couteau	3.50	2
	Jupe	3.3	1	Pantalon	3.5	3
	Pelle	2.8	1	Rateau	2.4	2
	Arc	3.2	1	Flèche	3.3	1
	Biberon	2.3	2	Bébé	3.1	2
	Cheveu	4.1	2	Peigne	2.3	1
Conceptual	Grenouille	3.0	2	Crapaud	2.8	2
	Taureau	3.5	2	Vache	3.5	1
	Poule	3.3	1	Coq	3.3	1
	Cochon	3.3	2	Truie	2.3	1
	Fille	4.6	1	Garçon	4.3	2
	Singe	3.2	1	Guenon	2.1	2
	Cafard	2.6	2	Blatte	1.6	2
	Oncle	3.9	1	Tante	3.8	1
	Souris	3.0	2	Rat	3.3	1
	Frère	4.3	1	Sœur	4.2	1
	Veau	3.0	1	Génisse	2.1	2
	Bélier	2.7	2	Brebis	3.0	2
Mean		3.3	1.6		2.9	1.6
Pseudo-morphological	Pien		1	Pienne		1
	Cojain		2	Cojaine		2
	Pélin		2	Péline		2
	Roisson		2	Roissonne		2
	Kain		1	Kine		1
	Antin		2	Antine		2
	Tottin		2	Tottine		2
	Daban		2	Dabane		2
	Jarin		2	Jarraine		2
	Fravant		2	Fravane		2
	Groid		1	Groide		1
	Kli		1	Klise		1
	Vuet		1	Vuette		1
	Drient		2	Driente		2
	Janois		2	Janoise		2
	Fli		1	Flise		1
	Klû		1	Klûte		1
	Janquet		2	Janquette		2
	Pevi		2	Pevise		2
	Kairie		2	Kérite		2
	Floutard		2	Floutarde		2
	Flé		1	Fléde		1
	Guiteau		2	Guiteaude		2
	Plou		1	Ploude		1
	Gantilon		3	Gantilonde		3
	Peveu		2	Peveuse		2
	Naureau		2	Naureaute		2
	Rûie		1	Rûite		1
	Chirçon		2	Chirçonne		2
	Dafard		2	Dafarde		2
	Brénis		2	Brénisse		2
	Mélier		2	Méliere		2

Appendix (*continued*)

Relation	Target	Freq	Nsyll	Prime	Freq	Nsyll
Mean			1.7			1.7
Phonological	Vrun		1	Prun		1
	Ropin		2	Mopin		2
	Souquin		2	Vouquin		2
	Ladazin		3	Ladazine		3
	Changuarin		3	Fanguarin		3
	Flon		1	Glon		1
	Fourmand		2	Chourmand		2
	Ragnant		2	Nagnant		2
	Kleur		1	Gleur		1
	Tirop		2	Birop		2
	Puche		1	Fuche		1
	Zarotte		2	Farotte		2
	Fune		1	Mune		1
	Vamme		1	Namme		1
	Joque		1	Noque		1
	Zanche		1	Ganche		1
	Pubaine		2	Subaine		2
	Ramine		2	Bamine		2
	Huraine		2	Hupaine		2
	Beve		1	Beme		1
	Guaile		1	Guaive		1
	Nine		1	Rine		1
	Mourde		1	Nourde		1
	Glova		2	Plova		2
	Loîte		1	Roîte		1
	Pide		1	Mide		1
	Tride		1	Fride		1
	Klèche		1	Plèche		1
	Vaise		1	Raise		1
	Jouris		2	Gouris		2
	Krère		1	Grère		1
	Vounon		2	Mounon		2
Mean			1.3			1.3
Repetition	Jivemple		1	Jivemple		1
	Tavorce		2	Tavorce		2
	Dacle		2	Dacle		2
	Revérne		2	Revérne		2
	Cafuge		2	Cafuge		2
	Aflé		2	Aflé		2
	Tralet		2	Tralet		2
	Numie		2	Numie		2
	Foutice		2	Foutice		2
	Coge		1	Coge		1
	Stubot		2	Stubot		2
	Pitoile		2	Pitoile		2
	Kérbis		2	Kérbis		2
	Chagueur		2	Chagueur		2
	Nelex		2	Nelex		2
	Rano		2	Rano		2
	Fistice		2	Fistice		2
	Choubu		2	Choubu		2
	Tréstice		2	Tréstice		2
	Napir		2	Napir		2
	Berteur		2	Berteur		2
	Tensty		2	Tensty		2
	Piaclo		2	Piaclo		2
	Migueur		2	Migueur		2

(*continued on next page*)

Appendix (*continued*)

Relation	Target	Freq	Nsyll	Prime	Freq	Nsyll
	Frousin		2	Frousin		2
	Faquine		2	Faquine		2
	Barsin		2	Barsin		2
	Tarquis		2	Tarquis		2
	Noutte		1	Noutte		1
	Chaitue		2	Chaitue		2
	Pesse		1	Pesse		1
	Trande		1	Trande		1
Mean			1.8			1.8

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