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## Relative frequency effects in the light of a morphological priming study

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### Abstract

The present study investigates the effect of relative surface frequency (SF) of suffixed derived primes regarding to SF of their base targets, using French materials (e.g., *mariage-marier* 'wedding-marry'). Two morphological priming configurations were manipulated: (A) High SF primes paired with Low SF targets, i.e., using weakly decomposable primes and (B) Low SF primes paired with High SF targets, i.e., using highly decomposable primes. Priming conditions were used at three different stimulus onset asynchronies (SOAs), 42 ms, 57 ms and 250 ms. Under masked priming conditions, our data revealed that in both manipulated SOAs (42 and 57 ms), High SF primes (configuration A) were much more efficient in facilitating the recognition of their lower SF targets than the reverse configuration (configuration B). These priming effects were measured relative to both orthographic (e.g., *marine-marier* 'navy-marry') and unrelated control conditions (e.g., *courage-marier* 'courage-marry'). When primes were visible (250 ms SOA), both A and B configurations showed significant morphological priming effects compared to their control conditions. Moreover, in the three SOAs, the magnitude of facilitation for High SF primes was systematically almost twice as large as that for Low SF primes. Our findings are interpreted within a word-based framework, highlighting the importance of considering both the individual word and its paradigmatic relationships, such as family and series, in understanding morphological priming effects.

Keywords: morphological processing, visual word recognition, masked priming, frequency

### 1. Introduction

Morphology deals with the structure of words, specifically their internal structure. For example, the word *speaker* is constructed with the base *speak* and the suffix *-er* illustrating its syntagmatic dimension. Morphology also entails exploring the relationships that words establish with others that are semantically and formally connected. For instance, *speaker* can be analyzed in terms of its relationships with *speak*, *speaking*, *speakable*, as well as with words like *hunter*, *seller*, *worker*, etc., highlighting its paradigmatic dimension. Therefore, any understanding of how morphological information is encoded within the mental lexicon should account for both these dimensions.

Drawing from the connectionist theory of visual word recognition (Seidenberg, 1987), which suggests that the mental lexicon is organized hierarchically, featuring different levels of representation that capture various linguistic characteristics of words (ranging from form to

semantics), the main issue in morphology revolves around its representation (structure/relationships or both) and the cognitive processes engaged in word recognition and access (morphological or holistic).

Psycholinguists have extensively delved into morphological complexity to emphasize the role of morphology in lexical structuring. The connectionist theory of visual word recognition (Seidenberg & McClelland, 1989) proposes that the lexicon comprises interconnected representations at different levels, reflecting the linguistic characteristics of words and the cognitive processes involved in recognizing complex words. The specific role of lexical morphology in relation to formal and semantic representations is a central concern. On one hand, morphology may play a peripheral role in accessing the mental lexicon, influencing the development of orthographic representations and reflecting word syntax, as suggested by the morpheme-based approach (Taft, 1994; Longtin, Segui, & Halle, 2003; Rastle, Davis, & New, 2004; Marantz, 2013). On the other hand, morphology may have a central role in the structuring of the mental lexicon, with morphological relationships expressed through form-meaning mappings between related words and abstract schemas, as proposed by lexeme/word and construction-based approaches (Giraudo & Grainger, 2000, 2001; Booij, 2010, 2018). Within this approach, morphological schemas serve two functions: expressing the predictive properties of complex words and enabling the creation of new words (Jackendoff, 1975).

In terms of cognitive processes, the morpheme perspective suggests that words are systematically parsed into stem + affix and accessed through the activation of their stem. In contrast, the lexeme approach posits that word representations are accessed through the activation of their entire form and the simultaneous activation of the whole network of morphologically connected words. In other words, morphology can serve as either an access key for opening the mental lexicon or an organizational key within it.

Models such as interactive activation (McClelland & Rumelhart, 1981) and serial models (Forster, Davis, Schoknecht, & Carter, 1987) consider word/surface frequency as a crucial factor in lexical access. Word/surface frequency determines the 'resting level' or residual activation of a lexical unit, influencing the amount of activation needed to reach its identification threshold. Higher frequency words have lower activation thresholds and are therefore easier to activate (Voga & Giraudo, 2017). Masked priming protocols, with short stimulus onset asynchronies (SOAs) ranging from 42 to 57 milliseconds, are particularly sensitive to these mechanisms. Behavioral data obtained through masked priming experiments using a lexical decision task have revealed clear and contrastive morphological priming effects in different languages, including English, French, Spanish, German, Greek, Basque, and Hebrew (Rastle, Davis, Marslen-Wilson, & Tyler, 2000; Giraudo & Grainger, 2000; Dominguez, Cuetos, & Segui, 2000; Drews & Zwitserlood, 1995; Voga & Grainger, 2004; Duñabeitia, Laka, Perea, & Carreiras, 2009; Frost, Deutsch, Gilboa, Tannenbaum, & Marslen-Wilson, 2000).

Despite the fact that the relative frequencies of morphologically related prime-target pairs may influence target recognition latencies, so far only two masked priming studies have directly tested the interaction between morphology and frequency.

## **2. Frequency effects in masked morphological priming**

Giraudo and Grainger (2000) conducted experiments using French materials and showed that larger priming effects were obtained with high-frequency derived primes compared to low-frequency ones. These findings suggest that the frequency of the embedded base does not significantly affect the early stages of complex word recognition. However, McCormick, Brysbaert and Rastle (2009) did not observe an interaction between prime frequency and morphological facilitation in English.

These contrasting outcomes may be due to methodological variations among experiments and the use of different SOAs. Giraudo and Grainger manipulated the frequency of the primes

including both derived primes with a high frequency as whole words (i.e. Surface Frequency SF hereafter) and derived primes composed with a high frequency base (i.e. Base Frequency, BF hereafter, which considered the cumulative SF of all derived words constructed with the same base). In the four masked priming experiments base words were used as targets. They compared morphological priming effects induced by suffixed primes with high SF (e.g., *amitié-ami* meaning ‘friendship-friend’ relative to those with low SF (e.g., *amicable-ami* meaning ‘amicable-ami’). Interestingly, they also examined suffixed primes composed with high frequency base BF (e.g., "*menteur-mentir*" meaning ‘liar-lie’) compared to matched suffixed words with low BF (e.g., "*ourson-ours*" meaning ‘bear cub-bear’). The results consistently showed an interaction effect of surface frequency and masked morphological priming: Only morphologically related primes with high SF (e.g., "*amitié*") significantly facilitated their target recognition (e.g., "*ami*") relative to both orthographic (i.e., *amiral-ami* ‘admiral-frind’) and unrelated controls (i.e., *juillet-ami* ‘July-friend’). However, when manipulating the BF of the primes, no such an interaction emerged. Crucially, by using orthographic primes (e.g., *menton-mentir* ‘chin-lie’, *ourlet-ours* ‘hem-bear’) that were strictly matched in frequency and number of letters with the morphological primes, the authors were able to separate the role of formal overlapping effects between related prime-target pairs: orthographic primes did not produce any significant priming effects. This pattern of results highlighting the unique impact of the the surface frequency of the primes seems to indicate that the activation stems from the prime word as whole, rather than from the base embedded in the prime, since the manipulation of base frequency of the primes didn’t influence morphological priming effects. Therefore, such findings suggest that morphological priming effects do not directly result from a mechanism decomposition during the early stages of lexical access.

McCormick, Brysbaert, and Rastle (2009) revisited frequency effects but focused only on the surface frequency of the primes. In an experiment using English materials, they compared the masked effects of different types of primes on base word recognition: suffix word primes with high SF (e.g., *national - nation*), suffixed word primes with low SF (e.g., *notional - notion*), and morphologically structured non-word primes, which were assumed to have no surface frequency (e.g., *alarmal - alarm*). All three priming conditions produced significant facilitation effects of similar magnitudes (+24ms, +27ms, +21ms, respectively) relative to their respective unrelated conditions (i.e., *physical-nation*, *farcical-notion*, *feveral-alarm*). The authors concluded that decomposition was a routine process applied to any morphologically structured primes, whether words or non-words. However, it is worth noting that, contrary to Grainger and Grainger (2000), these authors did not use any orthographic controls to ensure that the observed effects were genuine morphological effects, free from the influence of formal overlap in prime-target pairs. The absence of such a crucial control in examining morphological effects could explain these two opposite patterns of results.

In summary, the contrasting findings regarding frequency effects in morphological priming can be interpreted within the framework of different resting levels of activation, leading to different predictions based on the lexeme and morpheme approaches to morphological processing. The morpheme approach suggests no effect of surface frequency but a strong effect of base frequency, while the lexeme approach predicts the opposite. The issue of frequency effects in morphological priming remains a point of contention between these two approaches.

### **3. Our morphological masked priming study**

To better understand how frequency impacts priming effects, in the present study we will implement the notion of ‘relative frequency’ introduced by Hay (2001). According to the author, "[t]he frequency of the base form is involved in facilitating decomposability. When the base is more frequent than the whole (i.e., the surface frequency of the base is higher than the surface frequency of its derivation, as in configuration B below), the word is easily and readily decomposable. However, when the derived form is more frequent than the base it contains"

(i.e., the surface frequency of the base is lower than the surface frequency of its derivation, as in configuration A below), "it is more difficult to decompose and appears to be less complex" (Hay, 2001, pp. 1049-1050 cited by McCormick et al., 2009). To date, the notion of relative frequency has not been implemented into experimental designs which leverage the masked-priming paradigm. Neither Giraudo and Grainger (2001) nor McCormick et al. (2009) tested this hypothesis; in their respective studies, the frequency of the targets was kept constant.

The present masked priming study specifically focuses on the predictions made by Hay (2001). Specifically, we compared two morphological priming configurations:

- a) High Surface Frequency (HighSF) suffixed prime - Low Surface Frequency (LowSF) simple target, i.e., using weakly decomposable primes
- b) Low Surface Frequency (LowSF) suffixed prime - High Surface Frequency (HighSF) simple target, i.e., using highly decomposable primes

According to the decompositional approach, the 'extractability' of the base is the most determinant factor for lexical access during the early stages of word recognition. Following Hay, when the word prime is easily and readily decomposable, i.e., LowSF complex primes whose constituent base is much more frequent than its suffixed derivation, morphological priming should be greater than when using derived primes that appear to be less complex, i.e., HighSF complex primes whose constituent base has a relatively lower surface frequency its derived form.

On the contrary, adopting an holistic approach of lexical access according to which only the surface frequency of the complete form determines the speed of lexical access, the reverse pattern of results is expected: HighSF complex primes should be more efficient than LowSF complex primes for target recognition, precisely because during the early stages of lexical access, complex word recognition is not based on their morphological decomposability.

To disentangle the morphological effects from the formal overlap between prime and target pairs, we opted to incorporate an orthographic control condition alongside an unrelated baseline condition, in accordance with the recommendations of Grainger, Colé, and Segui (1991) and Giraudo & Grainger (2000).

Finally, to compare our results with those found by Giraudo & Grainger (2000) and McCormick et al. (2004), we manipulated two different stimulus onset asynchronies (SOAs) in our masked priming experiment: 42 ms and 57 ms. Additionally, we introduced a third prime duration of 250 ms to investigate the later stages of lexical access (unmasked priming). Prime frequencies are expected to have a less decisive impact on priming effects in overt priming, as the time window allocated to prime processing is generally sufficient to access the mental lexicon regardless of the prime words' resting activation level. This comparison between masked and unmasked priming effects aims to elucidate which prime properties contributed to any variations in priming effects.

## *2.1 Method*

### *2.1.1 Participants*

Seventy-six psychology students from the University of Toulouse Jean Jaurès (France) participated in the experiment. All participants were native speakers of French and reported having normal or corrected-to-normal vision. The average age was 27 years (range: 19-45; SD: 7.89).

As compensation for their time, which lasted approximately 30 minutes, the students received school credit. Additionally, all participants provided written informed consent to participate.

### *2.1.2 Stimuli*

Sixty pairs of words composed with a suffixed word as prime and its base word as target, were selected in French. 30 pairs in which the suffixed words had a systematically higher surface frequency than their base (Configuration A: HighSF prime - LowSF target, i.e., using weakly



decomposable primes) and 30 pairs in which the suffixed words had a lower surface frequency than their base (Configuration B: LowSF prime - HighSF target, i.e., using highly decomposable primes).

In both A and B configurations, each base word target was primed by (1) a morphologically related word (e.g., *mariage-marier* 'wedding - marry'), (2) an orthographically related word (e.g., *marine-marier* 'navy - marry'), and (3) an unrelated word (e.g., *courage-marier* 'courage - marry'). The 180 derived words were equally divided into the three prime conditions (stimulus characteristics are reported in Table 1).

In both configurations, the primes were matched in terms of the number of letters (averaging 6.4 and 7 letters, respectively) and surface frequency (averaging 6.48 and 40.64 occurrences per million, respectively).

The pairings of primes and targets were counterbalanced across three experimental lists, each associated with an independent group of participants. This ensured that each participant was tested in all three priming conditions but only saw a given target word once.

Additionally, thirty pseudoword targets that resembled the base words (e.g., *bate*) were included for the lexical decision task. Each pseudoword target was primed by either a related derived pseudoword sharing the same pseudo-stem (e.g., *batise-bate*) or an unrelated pseudoword (e.g., *montal-bate*). Both related and unrelated pseudoword primes were matched in terms of the number of letters. In total, 240 words (60 bases and 180 derived words) and 240 pseudowords were used.

Complete list of words used as stimuli included in Annexe 1.

Table 1. Stimuli controlled for frequency and length in configurations A and B. Frequency was calculated in occurrences per million using the Lexique corpus database (New, Pallier, Ferrand & Matos, 2001), and length corresponds to the average number of letters. The difference between the high and low frequency items was statistically tested and found to be significant in all conditions.

Condition	Example	Fx	Length	Example	Fx	Length	Prime-Target frequency significance
<i>Configuration A: High Surface Frequency primes – Low Surface Frequency targets</i>							
	<i>Primes</i>			<i>Target</i>			
Morphological	mariage 'wedding'	53	8				F(1,29)=29.39, p<.001
Orthographic	marine 'marines'	28	7	marier 'marry'	10	6	F(1,29)=8.43, p<.007
Unrelated	courage 'courage'	53	8				F(1,29)=41.05, p<.001
<i>Configuration B: Low Surface Frequency primes – High Surface Frequency targets</i>							
	<i>Primes</i>			<i>Target</i>			
Morphological	amical 'friendly'	7	8				F(1,29)=71.71, p<.001
Orthographic	amiral 'admiral'	6	7	ami 'friend'	56	5	F(1,29)=88.09, p<.001
Unrelated	mérite (merit)	7	8				F(1,29)=71.53, p<.001

### 2.1.3 Apparatus and procedure

A priming procedure was conducted using the DMDX software (Forster & Forster, 2003). Each trial consisted of a sequence of three stimuli: first, a forward pattern mask composed of 13 hash marks (#) presented for 500 ms, followed by the prime stimulus presented for either 42 ms, 57

ms, or 250 ms, immediately replaced by the target string (word or nonword), which remained on the screen until participants responded. Primes and targets were presented in lowercase, including the necessary accents in French. Participants were seated 50 cm away from the computer screen and were instructed to respond as quickly and accurately as possible, indicating whether the lowercase letter string was a French word or not. They were instructed to press one of two response buttons with their right-hand forefinger for "yes" and an other button with their left-hand forefinger for "no". The three different stimulus onset asynchronies (SOAs) were assigned to three separate groups of participants (42 ms: 26 participants, 57 ms: 26 participants, and 250 ms: 24 participants) to avoid any potential target repetition effects.

For the 42 ms and 57 ms SOAs, participants were not informed about the presence of prime words. After 20 practice trials, with the opportunity for participants to ask questions if needed, the 120 experimental trials were presented consecutively in a single block.

## Results

An analysis of variance (ANOVA) was conducted on the data, with participants treated as random variables. Error responses and reaction times exceeding 1500 ms or below 300 ms were excluded from the analysis, as well as time points outside of 2.5 standard deviations (SD) (accounting for 7.72% of the total data).

Table 2 presents the reaction times (in milliseconds) and standard deviations (SD) for lexical decisions on word targets in each frequency configuration and priming condition. Table 3 provides the net priming effects relative to the orthographic and unrelated prime conditions.

SOA	<i>Configuration A: High SF primes - weakly decomposable primes</i>			<i>Configuration B: Low SF primes - highly decomposable primes</i>		
	Morphological	Orthographic	Unrelated	Morphological	Orthographic	Unrelated
42	614 (97)	654 (96)	655 (88)	571 (82)	587 (81)	591 (66)
57	618 (84)	660 (118)	674 (110)	583 (87)	597 (92)	597 (73)
250	682 (106)	739 (135)	732 (127)	634 (106)	676 (104)	658 (97)

Table 2. Reaction Time reported in ms (and SD)

SOA	<i>Configuration A</i>			<i>Configuration B</i>		
	U-M	O-M	U-O	U-M	O-M	U-O
42	41*	40*	1	20*	16+	4
57	56*	42*	14	14	13	0
250	51*	57*	-6	23*	42*	-18

Table 3. Numerical difference between conditions in in milliseconds (ms) for the RT (marked with an \* if significant, + if marginal).

For the three different SOAs, the ANOVA results indicated significant main effects for frequency ( $F(1,73) = 119.55, p < .0001$ ), prime type ( $F(2,146) = 35.37, p < .0001$ ), and duration ( $F(2,73) = 4.99, p < .001$ ). The global interaction between frequency and prime type was also significant ( $F(2,146) = 7.71, p < .001$ ). Consequently, separate analyses were conducted for each SOA.

For SOA 42ms: There was a significant main effect of frequency ( $F(1,25) = 74.85, p < .001$ ), a significant main effect of prime type ( $F(2,50) = 10.84, p < .001$ ), and a marginally significant interaction of frequency and prime type ( $F(2,50) = 3.07, p = .05$ ). Planned comparisons showed that High SF morphological primes differed significantly from both the orthographic (+40 ms,  $F(1,25) = 22.12, p < .0001$ ) and unrelated conditions (+41 ms,  $F(1,25) = 18.49, p < .0002$ ). High SF orthographic primes did not differ significantly from the unrelated condition ( $F < 1$ ). In the reverse configuration (Low SF primes), morphological priming showed a significant effect relative to the unrelated condition (+20 ms,  $F(1,25) = 5.56, p < .026$ ), but it did not reach

significance compared to the orthographic conditions (+16 ms,  $F(1,25) = 3.42$ ,  $p = .076$ ), which, in turn, did not differ from the unrelated condition (+3 ms,  $F < 1$ ). These findings suggest an advantage for High SF primes in morphological priming effects, which moreover exhibited a priming effect twice as large as Low SF morphological primes (+41 ms vs. +20 ms). More important, only High SF morphological primes significantly differed from the orthographic control condition.

For SOA 57ms: There was a significant main effect of frequency ( $F(1,25) = 45.44$ ,  $p < .001$ ), a significant main effect of prime type ( $F(2,50) = 14.99$ ,  $p < .001$ ), and a significant interaction of frequency and prime type ( $F(2,50) = 5.25$ ,  $p < .011$ ). In Configuration A (High SF primes), planned comparisons yielded similar results as observed with an SOA of 42ms. Morphological priming effects significantly facilitated recognition compared to both the orthographic (+42 ms,  $F(1,25) = 18.03$ ,  $p < .0003$ ) and unrelated conditions (+56 ms,  $F(1,25) = 32.51$ ,  $p < .0001$ ), while these two priming conditions did not differ significantly (+14 ms,  $F(1,25) = 2.86$ ,  $p = .10$ ). However, in Configuration B (Low SF primes), neither comparison reached statistical significance (+14 ms,  $F(1,25) = 1.86$ ,  $p = .18$ ; +13 ms,  $F(1,25) = 2.59$ ,  $p = .12$ ; 0 ms,  $F < 1$ , respectively). When increasing the prime exposure, the surface frequencies of morphological primes played a significant role in determining morphological priming effects, with High SF suffixed primes leading to a substantial reduction in recognition latencies for their Low SF base targets, while Low SF suffixed primes did not produce significant effects.

For SOA 250ms: There was a significant main effect of frequency ( $F(1,23) = 24.57$ ,  $p < .001$ ), a significant main effect of prime type ( $F(2,46) = 12.21$ ,  $p < .001$ ), but no significant interaction of frequency and prime type ( $F(2,46) = 1.21$ ,  $p = .307$ ). When primes are visible, the surface frequency of the prime do not have a significant impact on morphological priming effects. In both configurations, morphological primes significantly facilitated target recognition relative to their respective orthographic control conditions (+57 ms for Configuration A,  $F(1,23) = 18.01$ ,  $p < .0003$ , and +42 ms for Configuration B,  $F(1,23) = 9.71$ ,  $p < .005$ ) and unrelated control conditions (+51 ms for Configuration A,  $F(1,23) = 12.38$ ,  $p < .002$ , and +23 ms for Configuration B,  $F(1,23) = 3.65$ ,  $p = .069$ ). However, as observed using very short SOAs, orthographic primes did not induce significant priming (+6 ms for Configuration A,  $F < 1$ , and -18 ms for Configuration B,  $F(1,23) = 1.53$ ,  $p = .23$ ). Consequently, a non-significant inhibition effect was observed for the orthographic condition in both configurations. This might be attributed to the conscious processing of primes in these conditions, where the activation of orthographic neighbors may have interfered with the recognition of the target word at a semantic level.

## General Discussion

The aim of the present experiment was to investigate the impact of the relative surface frequency (SF) of morphologically related prime-target pairs on priming effects. Specifically, two configurations were examined: a) the effect of high SF primes on lower SF targets and b) the effect of low SF primes on higher SF targets. We manipulated the most common morphological word pairing, suffixed prime - base target, which has been consistently associated with strong morphological priming effects in previous literature (Grainger, Colé, & Segui 1991; Drews & Zwitserlood, 1995; Giraudo & Grainger, 2000; Rastle, Davis, Marslen-Wilson & Tyler, 2000; Rastle, Davis & New, 2004; Diependaele, Sandra & Grainger, 2005; McCormick, Rastle & Davis, 2008; Kazanina, 2011; Orfanidou, Davis & Marslen-Wilson, 2011).

Based on the predictions derived from two opposing approaches to morphological processing, namely the morpheme-based/decomposition view and the word-based view, we aimed at testing two specific hypotheses. According to the morpheme-based approach, we expected to observe stronger morphological priming effects in the low SF prime - high base frequency (BF) target configuration (A) – i.e., using highly decomposable primes – compared to the high SF prime –



low BF target configuration (B) – i.e., using weakly decomposable primes. Accordingly, the morpheme-based approach posits that the base extracted from the suffixed prime leads to lexical access. Therefore, the high frequency of the base is crucial in configuration A, resulting in supposedly stronger priming effects. In contrast, the word-based view suggests that lexical access is mediated by the activation of the entire word form. Consequently, in masked priming, primes with higher surface frequency whose resting level of activation is low, should have quicker lexical access. Thus, suffixed word primes with high surface frequency are expected to be more efficient than those with low surface frequency, regardless of the frequency of their base and the decomposability of the complex prime. Within this perspective, we anticipated a reverse pattern of results: configuration B should induce greater priming effects than configuration A.

The results of the present study were straightforward. In masked priming conditions, with both stimulus onset asynchronies (SOAs) of 42ms and 57ms, in configuration (a), i.e. high surface frequency primes produced significant morphological priming effects that differed from both the orthographic and unrelated control conditions. Moreover, such effects were stronger than those observed in the prime-target configuration (b).

Specifically, at the 42ms SOA, low SF morphological primes yielded a small facilitation effect compared to unrelated (+24ms) and orthographic primes (+14ms), but these effects were not statistically significant, and their magnitude was only half of those induced by high surface frequency primes, respectively (+41ms and +40ms). At the 57ms SOA, the morphological condition with low SF primes did not significantly differ from either the unrelated (+12ms) or orthographic condition (+12ms).

For the unmasked prime presentation (250ms), significant facilitation effects were observed for both configurations. The surface frequency type factor did not interact with priming, indicating that morphological priming effects emerged independently from the surface frequency of the morphological primes with this SOA.

To sum up, the results of the present study provide evidence that high surface frequency primes induce stronger morphological priming effects compared to low surface frequency primes, regardless their morphological decomposability. These findings align with the predictions of the word-based view and emphasize the importance of considering both formal and morphological factors in understanding word processing.

### **Surface frequency effects in morphological priming**

The results obtained in the present study basically align with those of Giraudo and Grainger (2000), experiment 3. Specifically, using a SOA of 57ms, only high-frequency morphological primes facilitate the recognition of their base targets (configuration A), while low-frequency morphological primes (configuration B) did not significantly induce priming, i.e., morphological condition did not differ from orthographic and unrelated ones.

At the 42ms SOA, the morphological priming induces a significant effect even in the configuration B, however the amplitude of such an effect is half of the effect observed in the configuration A. More importantly, the morphological effect in configuration B is not significantly different from the one obtained in the orthographic condition. The inclusion of an orthographic condition in our experimental design is crucial as it allows us to distinguish formal effects from genuinely morphological ones. In combination, our results do not replicate the findings of McCormick et al. (2009), who observed equivalent priming effects for both high-frequency suffix word primes (e.g., *national* on *nation*), and low-frequency suffixed word primes (e.g., *notional* on *notion*) that they only compared to the unrelated condition. Additionally, a priming effect was observed with morphologically structured non-word primes (e.g., *alarmer* on *alarm*), which were considered orthographic controls due to their assumed lack of surface frequency.

The recommendation to include an orthographic prime - in addition to a morphological one - had already been suggested by Grainger, Colé, and Segui (1991), who emphasized the importance of disentangling effects resulting from purely formal overlap from morphological effects, where the similarity between prime and target words extends to semantics. Once again, our study highlights this necessity by suggesting that the contradictory results found by Giraudo & Grainger (2001) and McCormick et al. (2009) could be attributed to the absence of orthographic controls in the latter study.

Furthermore, our data indicate that the duration of prime exposure also plays an important role. With a shorter SOA (42ms), the observed morphological priming effects may reflect a combination of formal and morphological facilitation, particularly for low surface frequency morphological primes: their effects differ from unrelated controls but not from orthographic controls. In contrast, with a longer SOA (57ms), the crucial interaction between frequency and morphological priming effects appear to emerge from a higher level of processing, which clearly differentiates them from formal processing.

Our data also indicate that the duration of prime exposure also plays a role in the emergence of morphological effects. This is particularly evident in configuration B, where low-frequency primes are involved. A genuinely morphological effect is observed only with the longest SOA (250ms), when the prime is visible to the participants. On the other hand, at the shortest SOAs (42ms), the effects observed in the morphological condition, while significantly different from those obtained with unrelated controls, are not significantly different from those yielded by orthographic controls. Therefore, what we observe in the morphological condition may, in fact, reflect a combination of formal and morphological facilitation. This seems to be confirmed by the fact that even, at an SOA of 57ms, no facilitation is observed in the morphological condition, neither with unrelated controls nor with orthographic ones.

On the other hand, in configuration A, with high-frequency morphological primes, the recognition of the base is facilitated by a morphological prime in all three SOA. Even at the shortest prime exposure duration (e.g., 42ms), the morphological priming effect emerged compared to both the unrelated and the orthographic condition. One may question why low-frequency morphological primes failed to produce facilitation, even relative to the unrelated condition. One possible explanation is that the frequency of these types of primes may not be high enough to reach the activation threshold. Moreover, even when this threshold is reached, the activation produced by the prime is not 'strong enough' to differentiate formal effects from morphological effects, given that morphology operates at a higher level of processing than the word form level. When comparing the results of the two orthographic conditions (High SF and Low SF) with their respective unrelated control conditions, we can observe variations in priming effects based on prime frequencies. High-frequency orthographic primes tend to slightly reduce recognition latencies (+14ms), although not significantly, compared to their unrelated controls. Conversely, low-frequency orthographic primes did not numerically differ from their unrelated controls (0 ms). These findings suggest that when the frequency of primes is high, indicating low resting levels of activation for their lexical representations, their word representations are rapidly activated, and this activation spreads to higher levels, including the morphological and semantic levels. Therefore, morphological and orthographic effects are distinct: orthographic effects produce formal facilitation, while morphological effects induce pure morphological facilitation in target recognition. On the other hand, when the surface frequency of primes is low, their word representations have high resting levels of activation, requiring more than 57ms for activation to spread to the morphological level. Within this time frame, only the word form level can be activated, while the morphological level is only partially or not activated at all. Thus, top-down facilitation effects from the morphological level cannot influence the activation of morphologically related word forms, resulting in weak morphological facilitation effects.

However, when primes are visible (as in our study with a SOA of 250ms), both frequency configurations induce morphological priming effects, with an advantage for high surface frequency morphological primes (Configuration A): their facilitation magnitude is twice as large as that of low surface frequency primes (configuration B), highlighting the significant role of surface frequency in speeding up lexical access.

### **The effect of relative frequency of prime-target in masked priming**

In the present study, we not only manipulated the surface frequency of the morphological primes but also the relative frequency in prime-target pairs. To the best of our knowledge, this is the first priming study that specifically focuses on this parameter. Previous works, such as those by Giraudo and Grainger (2001) and McCormick et al. (2009), have all used targets with systematically higher surface frequencies compared to the surface frequency of the primes. By manipulating the relative surface frequency in prime-target pairs, we were able to examine the effects of morphological relationships within a given morphological family.

In many French word families, the base word tends to have the highest frequency in the derivational paradigm, making it the most morphologically salient element. Salience, as recently explored in numerous linguistic studies (e.g., the special issue edited by Blumenthal-Dramé, Hanulíková & Kortmann, 2017), refers to the cognitive pre-activation of a stimulus (top-down salience) as observed in priming protocols, or to the inherent characteristics of the linguistic item (bottom-up salience). Giraudo and Dal Maso (2016) focused on the concept of morphological salience and suggested that it refers to the relative prominence of a morpheme (stem or affix) with respect to the complex word in which it is embedded. They argued that the salience of morphological components influences the mechanisms involved in processing, storing, and organizing complex words.

In the realm of language acquisition, Goldschneider and DeKeyser (2001) defined morphological salience as the ease of perceiving or hearing a given linguistic structure. In French, Colé, Segui, and Taft (1997) investigated the word-morpheme frequency relationships, addressing the issue of salience to some extent. Through four experiments using a lexical decision task or a naming task, they compared simple and complex words matched either in word/surface frequency (WF) or in morphemic frequency (MF) (i.e., the cumulative frequency of the word minus its surface frequency), while varying their relative word-morpheme frequency. In each matched pair of suffixed or base words, one word had a WF higher than its MF, and the other had the reverse relationship ( $WF < MF$ ). The results showed that reaction times to words with a  $WF > MF$  were only sensitive to the manipulation of their WF, whereas reaction times to words with a  $WF < MF$  were only sensitive to the manipulation of their MF. The authors interpreted these findings as evidence of competition between word representations based on their frequency status within the morphological family.

Another possible explanation is that a word with a WF higher than the MF of all the words in its morphological family, i.e., its morphemic frequency, represents the most salient element of that family. Consequently, its recognition latency would primarily depend on its own activation, i.e., its word frequency. In contrast, a word with a word frequency lower than its morphemic frequency is logically less salient within its family, and its recognition latency would depend on the overall activation of its family, i.e., its morphemic frequency. Thus, we reinterpret these data in terms of bottom-up salience: the linguistic characteristics of a word, specifically its word/surface frequency relative to the cumulative frequency of its morphological family members, make it more or less cognitively attractive. This would explain why, within a given morphological family, the most salient word ( $WF > MF$ ) is more sensitive to the manipulation of surface frequency ( $=WF$ ), while the recognition of a less salient word ( $WF < MF$ ), on the contrary, depends on its morphemic frequency (i.e., the activation of its family members).

### **Conclusion**

Taken together, the data presented in this study suggest that morphological priming effects primarily depend on the surface frequency of complex word primes, rather than the frequency of their embedded base or in other terms, on 'decomposability'. This finding provides evidence in support of a morphological view of word processing which posits that both the syntagmatic and paradigmatic dimensions of a word are involved in lexical access. Within the mental lexicon, word representations are connected together according to both word internal structure (simple or complex) and the formal-semantic relationships they share with other words in their morphological family and series when increasing the prime exposure.

The syntagmatic dimension is strongly influenced by the surface frequency of the word itself, while the paradigmatic dimension is influenced by the base frequency, representing the cumulative frequency of all words constructed with the same base. Additionally, relative surface frequencies also play a significant role during lexical access, particularly in the context of the masked priming paradigm. In this paradigm, the activation of the prime and its spread to other word representations depend on the time the cognitive system has to process it. Using high surface frequency primes, where the surface frequency is higher than that of the target word, is advantageous, as demonstrated by our current results.

These findings challenge approaches that assume a decomposition mechanism in which the base/stem is automatically extracted from any morphologically complex form, irrespective of its lexical status, as suggested by McCormick and colleagues (2009): "These results bolster the claims of Rastle et al. (2004) by showing unambiguously that the morpho-orthographic segmentation process is not restricted to low-frequency words or nonwords" (p. 1711). On the contrary, these data align with models that do not presuppose early mandatory decomposed 'morphological' representations but rather assign to morphology a more central role within the mental lexicon. Specifically, consistent with the *Construction Morphology* theory (Booij, 2018), morphological knowledge arises within the mental lexicon through the systematic form-semantic relationships shared among morphologically related words.

Submitted

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APPENDIX : Linguistic materials

Configuration A: High Surface Frequency (HighSF) suffixed prime – Low Surface Frequency (LowSF) simple target

<i>Suffix primes</i>	<i>Orthographic primes</i>	<i>Unrelated primes</i>	<i>Targets</i>
unité	univers	vertu	unir
nuage	nulle	paire	nuée
usage	usine	nuque	user
lueur	lundi	ferme	luire
sueur	super	fumée	suer
garage	garder	vierge	garer
rideau	ridicule	paille	rider
normal	normand	soldat	norme
nerveux	neuf	inconnu	nerf
liaison	lierre	tablier	lier
mariage	marine	courage	marier
mutation	mutuelle	suiivante	muter
vêtement	vétéran	tribunal	vêtir
mensonge	menton	jalousie	mentir
officier	offrir	comptoir	office
montagne	montre	immeuble	mont
peinture	peinard	ministre	peindre
quartier	quartz	dimanche	quart
offensive	offert	autoroute	offenser
sacrifice	sacripant	charrette	sacrifier
opération	opérette	recherche	opérer
violence	violette	intention	violer
directeur	digicode	bouteille	direct
cigarette	cigale	président	cigare
compagnie	comparer	capitaine	compagne
confiance	confiture	téléphone	confier
existence	exigence	capitaine	exister
situation	sitting	sentiment	situer
mouvement	mourir	intérieur	mouvoir
brusquement	brushing	appartement	brusquer

Configuration B: Low Surface Frequency suffixed prime – High Surface Frequency target

<i>Suffix primes</i>	<i>Orthographic primes</i>	<i>Unrelated primes</i>	<i>Targets</i>
amical	amiral	mérite	ami
calmement	calmar	autoroute	calme
chasseur	chasuble	allusion	chasser
danseur	dandiner	bascule	danser
désirable	désigner	charpente	désir
diabliesse	diabète	bourgeron	diable
faiblard	faillite	hautesse	faible
forestier	foreuse	hardiesse	forêt
froidure	froisser	boniment	froid
goûteux	gouttière	gambade	goût
grosneur	groseille	patiente	gros
hivernal	hibiscus	bassiste	hiver

hôtellerie	hotte	tambouille	hôtel
huileux	huître	finance	huile
joueur	joufflu	proche	jouer
luxueux	luxation	litanie	luxe
maigreur	mairie	disgrâce	maigre
merveilleux	mercredi	ambassadeur	merveille
ministère	minimum	proximité	ministre
muret	murène	shoot	mur
rageur	ragoût	jargon	rage
rêveur	revue	croûte	rêve
rondelle	ronfler	acrobate	rond
rosier	roseau	nomade	rose
sablier	sabots	cambuse	sable
solidité	solive	chouette	solide
sucrerie	succint	resserre	sucre
tiroir	tisane	profil	tirer
traitement	tramontane	tourbillon	traiter
verdure	vertige	édifice	vert

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Submitted