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Morphological Processing of Regular Verbs in Native French Speakers

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Over the past decades an extraordinary amount of psycholinguistic and neurolinguistic research has been carried out with the aim of understanding the nature of lexical representations and how these representations are accessed as we listen to or read words. The question that drives much of this research is whether the language processing system has access to a morpheme-based route to recognize complex words. The numerous models of lexical access that have been put forward in the literature can be categorized as taking either a *morphological* approach or a *non-morphological* approach. *Morphological* models posit that the processing system can make recourse to a morpheme level of representation. The various models within the morphological approach, however, differ in hypothesizing how often the morpheme level processing route is used or made available. Whereas some morphological models claim that all complex forms are always processed through a morpheme-based route (e.g., Stockall & Marantz, 2006; Taft, 2004), others hypothesize a dichotomous system where properties such as regularity (e.g., Allen & Badecker, 2002; Clahsen, 1999), surface-form frequency (e.g., Alegre & Gordon, 1999; Baayen et al., 1997), or semantic transparency (e.g., Marslen-Wilson et al., 1994) will influence whether the morpheme-based route is available to process a given word. In such dual-route processing accounts where the morpheme-based processing pathway is restricted at times, words with certain lexical properties (e.g., irregular form, high surface frequency) are believed to be accessed via a whole-form representation in lieu of a morphological representation. In contrast to *morphological* models, *non-morphological* models propose that the morpheme as a theoretical construct should be discarded as it is not necessary to account for the 'morphological' relationship between words (see Hay & Baayen, 2005). *Non-morphological* models, such as the Parallel Distributed Processing model (Rumelhart & McClelland, 1986) or Distributed Connectionist Approach (Gonnerman et al., 2007) instead posit that the lexicon constitutes an associative network where surface-forms are recognized through a combination of form (orthographic and phonological) and semantic information. In other words, *non-morphological* models posit that lexical access is never achieved through a morpheme-based route because it is believed that no such route or representations exist.

In recent years, priming has become a prominent methodology used in morphological processing studies involving visual word recognition. In these studies participants are visually presented with a prime word (typically an affixed word), followed by a target word. They then indicate if the target word is a real word or not as quickly as they can. In unmasked-priming studies, the participant is able to consciously perceive the presence of the prime word, whereas in masked-priming studies the prime word is presented too quickly to be consciously perceived (e.g., 50 ms). The rationale for using priming to study morphological processing is that if a pair of related words are presented sequentially, the presentation of the prime will activate the lexical representation, making target recognition faster. One can then manipulate certain features (like regularity or frequency, for example) to investigate how these lexical properties affect target recognition. An important difference between masked- and unmasked-priming is the effect of semantic information. In masked-priming tasks, the prime word is presented very quickly, and it is believed that semantic information related to the prime word is not accessed in the short period of time before the target word is presented, and consequently semantic overlap of prime and target should not facilitate target recognition. In unmasked-priming tasks, the prime is presented for a longer period of time and is consciously perceived by the participants. When there is more time between the presentation of the prime and the target, it is believed that the semantic information related to the prime word is accessible before the target is presented, and semantic overlap between prime and target may facilitate target recognition. One study that investigated the effect of prime duration and semantic information is Rastle, Davis, Marslen-Wilson, & Tyler (2000). In this study, the authors used a series of priming studies where the duration of prime exposure varied (either 42 ms, 72 ms, or 230 ms), and found that semantic information does not influence target recognition when the prime is presented for only a brief period of time (42 ms or 72 ms), whereas it does show effects at longer durations.

Support for a morphological model: single mechanism approach

Stockall & Marantz (2006) recorded magnetoencephalographic (MEG) data during an unmasked visual priming study with lexical decision to investigate if regular and irregular English past tense words primed their stems in a similar way. The MEG component of interest in the study was the M350, whose peak-latency is believed to index the early stages of lexical root access (e.g., Embick et al., 2001) when words are presented in isolation, such as in priming studies. The behavioral results of the study show that irregular forms with high orthographic overlap between the inflected form and the stem form (e.g., *gave-give*) show equal facilitation as identical prime-target pairs (e.g., *boil-boil*), but irregular forms with low orthographic overlap (e.g., *taught-teach*) do not offer significant target facilitation compared to an unrelated prime. The MEG data, however, show a similar M350 latency for regular word pairs (e.g., *jump-jumped*), irregulars with high overlap, and irregulars with low overlap. Importantly, the M350 latency was not significantly earlier for word pairs that had orthographic and semantic overlap (e.g., *boil-broil*) compared to unrelated word pairs. The authors interpret the neurological results of the study as indicating that both regular and irregular complex forms are decomposed into morphological constituents, and that lexical access involves the root activation via a morpheme-based processing pathway.

Support for a morphological model: dual-mechanism approach

Other *morphological* models posit that the morpheme-based route is available only to a select set of words, and words outside this set are processed via a whole-form storage route. Models that take this dual-route view of lexical processing differ in which lexical properties dictate whether a word will be processed via a morpheme-based route or a whole-form storage route. Baayen, Dijkstra, & Schreuder (1997) claim that affix functionality and surface frequency can influence how a complex word is processed. They used lexical decision tasks (without priming) to examine how the processing of Dutch verbs and nouns is affected by the *–en* inflection and by surface-form frequency. In Dutch, the inflection *–en* is used to pluralize some nouns (e.g., *kelk-kelken*, ‘chalice’), but it appears much more often with verb stems as an infinitive marker (e.g., *lopen*, ‘to walk’), and as a pluralizing verbal inflection (e.g., *liep-liepen*, ‘walked’). In a series of experiments, Baayen et al. compared lexical decision times for high-frequency and low-frequency nouns that are biased to appear either in their singular form or in their plural (*-en*) form, and verbs that are marked with the *–en* inflection. The results of their tasks show that when a verb is inflected with *–en*, it is recognized equally fast as when it appears in its stem form. This result is interpreted to indicate that the verbal inflection is quickly segmented from the stem, allowing equally fast stem access when the target is inflected or uninflected. For nouns, however, stems that are biased to appear in their singular form take significantly longer to recognize when presented with the pluralizing *–en* than when presented in the singular form, whereas nouns biased to appear in the plural form are recognized equally fast when presented in either the singular or plural form. That is, the presence of the *–en* inflection on a noun stem is detrimental to recognizing a noun stem when the stem is most frequently found in its singular form. However, if a noun is most frequently encountered in its plural form, the presence of the inflection does not hinder stem recognition. The authors take the results to indicate that plural nouns marked with *–en* are stored in their whole-form, whereas inflected verbs are decomposed into their stem and affix. They claim that the fact that *–en* is polyfunctional leads to costly subcategorization difficulties when the suffix is segmented from a noun stem, and consequently these inflected plural nouns are stored in their whole-form to avoid these costly post-segmentation stem analyses. The results of this study provide support for dual-mechanism *morphological* models where lexical properties, here specific to the affix and lexical category, as well as specific types of surface frequency, contribute to a word being accessed via its whole-form rather than a morphological representation (cf. Taft, 2004, for a study that accounts for surface frequency effects under a full-decomposition morphological model).

Other dual-mechanism *morphological* models of lexical access claim that regularity is the distinguishing property that dictates how a dichotomous processing system handles lexical access. In his *Words and Rules* theory of lexical processing, Pinker (1991; 1999) posits that regularly formed complex words are processed in a qualitatively different way than complex words with irregular morphology. Support for such a model of lexical access has been found in a number of studies (e.g., Allen & Badecker, 2002; Clahsen, 1999; Marslen-Wilson & Tyler, 1997; Marslen-Wilson et al., 1993).

Other recent studies have investigated how semantic transparency influences the availability of the morphological level of representation. Diependaele, Sandra, & Grainger (2005) conducted 2 priming tasks, in 2 languages. The first experiment included an intramodal (visual prime, visual target) and a cross-modal (visual prime, auditory target) priming lexical decision study with Dutch words that varied in their semantic transparency of the morphological structure. The prime presentation duration was 53 ms for all trials. The results of this task showed that only semantically transparent morphologically structured words (e.g., *gegil-gil*, 'screaming-scream') primed their root compared to unrelated word pairs (e.g., *paprika-dom*, 'pepper-stupid'). Semantically opaque items (e.g., *gebed*-bed, 'prayer-bed') showed some facilitation of target recognition, but only when compared to orthographically related (e.g., *dominee-dom*, 'preacher-stupid') word pairs (which in fact showed inhibitory effects). The authors interpret the results as showing that only semantically transparent words showed target recognition facilitation.

The second experiment in the study was conducted in French and was similar in that it used visual primes for either visual targets or auditory targets, but it also included different prime presentation durations (13 ms, 40 ms, or 67 ms). The stimuli included semantically transparent morphologically related words (e.g., *clochette-cloche*, 'small bell-bell') and semantically opaque words (e.g., *baguette-bague*, 'French bread-ring'). The results showed an effect of prime duration in addition to an effect of modality and prime type. Similar to the results of experiment 1, the semantically transparent primes showed facilitation of visual target recognition with a prime duration of 40 ms. However, when the prime was presented for 67 ms, there was facilitation for both semantically transparent and opaque prime words. When target words were auditory, both semantically transparent and opaque words elicited faster lexical decision times, but only when the visual prime was presented for 67 ms. The fact that semantic transparency effects are found in a masked-priming task, even when the prime was presented for only a very brief time (40 ms), poses problems for sublexical morphological models that posit that semantic transparency should not influence morphological priming in a masked-priming task. Such models posit a form-then-meaning process, where semantic information is not available early enough in masked-priming tasks to influence priming effects. The findings in this study also pose problems for supralexical morphological models that posit that semantic transparency should influence morphological priming, even in a masked-priming task, because semantic information is available early on in lexical activation. The authors account for their findings by proposing that morphological processing involves two distinct mechanisms that work in parallel: a morpho-orthographic component that uses orthographic information to exhaustively segment words into potential morphological constituents, and a morpho-semantic component that maps a decomposable root onto a representation of the root, which only yields semantic priming when there is shared semantic information between the visually presented word that contains the root and the root representation. This hybrid approach to morphological processing thus posits a model where the lexical system does make recourse to a morphological level of representation, but semantic information influences the activation of morphological representations. It is important to note, however, that the debate on the effects of semantic information in masked-priming remains unsettled (e.g., Davis & Rastle, 2010; Feldman, O'Connor, & Moscoso del Prado Martín, 2009; Rastle & Davis, 2008).

Support for a non-morphological model

The studies discussed above all posit that the language processing system can make recourse to a morpheme level of representation at least some of the time. Other studies, however, provide support for models of lexical access where a morpheme-based route of processing is claimed not to be needed to explain priming effects. In fact, some researchers posit that the effects of morphological relatedness found in the above studies can be attributed to effects of form and meaning overlap. That is, morphological processing is not a discrete level of processing, but is instead the result of form and meaning overlapping in morphologically related words. Gonnerman et al. (2007) used a series of cross-modal priming tasks with lexical decision to investigate if varying degrees of form and semantic overlap affect target recognition of morphologically related words. The results of the study showed that when semantic relatedness is kept constant, priming effects are larger when there is greater overlap in form. For example, semantic similarity ratings showed that word pairs such as *teacher-teach* and *idea-notion* were equally similar in meaning, but the priming effect was greater for *teacher-teach* than *idea-notion* due to the additional form overlap. Form overlap, however, cannot offer facilitation in the absence of semantic overlap. That is, despite the orthographic overlap between *hardly* and *hard*, the lack of semantic overlap between the two words blocks facilitation. The study also showed that priming effects are larger with greater phonological overlap between word pairs. For example, *acceptable* primed *accept* to a greater extent than *criminal* primed *crime*. Gonnerman et al. take their results as support of a connectionist model of lexical access where the representation of complex words does not involve morphological structure or morpheme representations, but instead involves lexical representations organized via shared form and meaning features. Such a model would predict greater priming effects from word pairs that have more overlap of form and meaning compared to word pairs that have less overlap.

That is, when the links of the various lexical properties are stronger, the activation of one word in local network would offer greater activation of the connected forms.

The present study

The present study aims to investigate the nature of lexical representations of regularly formed French verbs. More specifically, this study aims to test if morphologically complex words carrying the *–ons* inflection are decomposed into morphological constituents, leaving the verb stem to be activated at a morphological level of representation in the lexicon. Additionally, this study includes test primes that do not share morphology with their target, but do share orthography or semantic information. Including these items allows this study to investigate if morphological processing can be explained by the overlap of orthography and semantics between prime and target, or if lexical activation does in fact include a morphological level of representation independent of form and meaning. The present study on native French morphological processing is also part of a larger study investigating how non-native speakers process complex words in French. The stimuli in the present masked-priming study are regularly formed French *–er* (Class I) verbs, and were carefully chosen to use a verbal affix that creates a form with low surface frequency (1st person-plural *–ons*). Including verb forms of low surface frequency is important in a study investigating if morphologically complex words are accessed at a morpheme level of representation because it has been proposed in previous work that complex forms of high enough frequency may be stored in their whole form (e.g., Alegre & Gordon, 1999; Baayen et al., 1997). If this is in fact true, this study will be in a better position to test for decomposition if surface frequency of the test items is kept low. Moreover, the choice of a low frequency form allowed for relatively high frequency verbs (e.g., *parler, manger* 'to talk, to eat') to appear in a low frequency surface form. Given that this study is part of a larger project including non-native French speakers, it was important for the target items to be common enough words that non-native speakers will be able to recognize them as French words. A final point on the affix choice for the present study involves the ability to tease apart *morphological* and *non-morphological* models. Regularly formed complex words with low surface-form frequency offer an ideal test case for teasing apart models that posit a morphemic level of representation from *non-morphological* models of lexical access. *Morphological* models from both single- and dual-mechanism approaches to lexical access predict that regularly formed verbs of low surface-form frequency will be decomposed into stem and affix upon presentation (though there is some disagreement on whether high surface frequency leads to whole-word storage and access, as we discuss in the description of the stimuli below), and any priming of shared morphology will be independent of orthographic and semantic priming. That is, if morphologically complex words are decomposed and the stem is accessed in the lexicon, it should not be the case that the priming facilitation offered by a shared morpheme between prime and target can be matched by prime-target pairs that share form or meaning in the absence of shared morphology. By contrast, *non-morphological* models predict that apparent morphological priming would be attributable to semantic and orthographic overlap of prime and target pairs. The stimuli used are thus in a strong position to test the predictions of morphological versus non-morphological models. In addition to prime-target word pairs that share morphology, additional test conditions have been included to investigate the effect of orthographic overlap and semantic overlap.

While none of the morphological processing models put forward by the studies discussed above predict language-specific differences in lexical organization[1], it is important to first briefly consider how French, the language we focus on in the present study, has been used in recent morphological studies. Coughlin & Tremblay (2015) used a masked-priming speeded-naming task with regularly inflected French verbs to investigate morphological decomposition in native (N=30) and non-native (N=30) French speakers. The non-native French speakers were native English speakers who did not begin their studies in French until puberty (mean age of first exposure was 11.8 years). They completed a cloze test to evaluate their proficiency in French (Tremblay, 2011), and were considered intermediate- or high-proficiency learners. Inflected and stem forms were both used as the targets and were preceded by either an identity prime, a morphologically, orthographically, or semantically related word, or an unrelated word. The morphologically related primes contained the same stem as the target, but differed in inflection. The orthographic, semantic, and unrelated primes appeared with the same inflection as the target. Example stimuli are provided in Table 1 below. The inflected form used in Coughlin & Tremblay (2015) were the first-person plural verbal inflection *–ons* (e.g., *donnons*, '(we) give'). The stem form used in this study was the form used for the first-person singular, and third-person singular (e.g., *donne* '(I/he/she/it) give').

Table 1. Example stimuli from Coughlin & Tremblay (2015)

	Target	Prime Type				
		Identity	Morphology	Orthography	Semantic	Unrelated
Stem	DONNE *'give'*	donne *'give'*	donnons *'give'*	doute *'doubt'*	sert *'serve'*	parle *'speak'*
Inflected	DONNONS *'give'*	Donnons *'give'*	donne *'give'*	doutons *'doubt'*	servons *'serve'*	parlons *'speak'*

For each trial in the experiment, participants saw a mask (#######) for 750 ms, followed by the prime for 50 ms, followed by the target word, which remained on the screen for 2000 ms. Participants wore a head-mounted microphone attached to a digital recorder during the experiment. When the target word appeared on the screen the computer made a 100 ms beep sound (which was audible to the participants). This marked the target onset on the digital recorder. The participants were instructed to say the target word aloud as quickly and accurately as possible. The naming latencies for test items were measured by extracting the time between the onset of the target beep and the onset of target production on the audio recording. There was no effect of target type, nor an interaction of prime type x target type, so the two target types (inflected and stem) were collapsed together for analyses. Naming latencies for both the native French speakers and the L2 French learners showed that target words were named significantly faster when preceded by identity primes and morphologically related words. There was no facilitation from semantically related primes compared to unrelated primes, though there was facilitation of orthographically related primes compared to unrelated primes. Importantly, however, the orthographically related primes offered significantly less facilitation compared to both identity primes and morphologically related primes, indicating that the facilitation from morphologically related primes cannot be solely

[1] Note that some proponents of a non-morphological model of processing have proposed that the morphological richness of a complete language system may influence how semantic information contributes to priming effects (e.g., Plaut & Gonnerman, 2000; cf., Lehtonen et al., 2006)

attributed to orthographic facilitation. This finding of facilitation in the morphological condition was interpreted as indicating that the shared morphology between prime and target allowed for target naming facilitation, and this facilitation cannot be attributed to the orthographic or semantic overlap between the prime and target words. The authors concluded that both native and non-native French speakers were able to quickly decompose morphologically complex words into stem and affix, and the lexical activation of the stem form allowed for faster target word recognition.

Similar findings of morphological decomposition in French speakers were found in another recent study using a neurophysiological methodology. Royle et al. (2012) had native French speakers (N=24) complete a masked-priming lexical decision task while electroencephalographic (EEG) data were recorded from the scalp. The target word stimuli in this task were all regular *–er* French verbs, which were primed by either a morphologically related word (e.g., *cassait-casse*; 'broke-break'), an orthographically related word (e.g., *cassis-casse*, 'black currant-break'), a semantically related word (e.g., *brise-casse*, 'break-break'), or an unrelated word (e.g., *moque-casse*, 'mock-break'). The EEG components of interest in this study were the N250 (a negative-going waveform peaking around 250 ms post-stimulus onset), and the N400 (a negative-going waveform peaking around 400 ms post-stimulus onset). The N250 component is believed to reflect form processing, where the negativity of the waveform is attenuated (i.e., more positive) for a target word that is preceded by a prime similar in form (e.g., teble-TABLE) compared to an orthographically distinct prime (e.g., Holcomb & Grainger, 2006). The N400 component, on the other hand, is believed to reflect lexical access and semantic integration. Previous studies using masked-priming to investigate lexical processing have found that the N400 is significantly attenuated for repeated word forms (e.g., Holcomb & Grainger, 2006; Rugg, 1987). For example, when a word form is repeated (e.g., walk-WALK), the N400 time-locked to the target item is significantly reduced compared to the presentation of different word forms (e.g., walk-READ).

The behavioral results from the lexical decision task in Royle et al.'s study revealed facilitation of target recognition for words preceded by a morphologically related word, but there was no facilitation from orthographically or semantically related words compared to unrelated words. The behavioral results are in line with models of lexical processing that predict facilitation from prime-target pairs that share morphology, but do not predict facilitation in the presence of orthographic or semantic overlap in the absence of morphological overlap (e.g., Rastle et al., 2004).

The EEG data revealed that in the early time-windows of analysis (associated with the N250 component), targets preceded by morphologically related primes and orthographically related primes showed significant attenuation of the negativity compared to unrelated and semantically related primes, but in later time-windows (associated with the N400 component), only morphologically related primes sustained the attenuation of the negativity. The EEG data are in line with previous masked-priming studies using EEG in that the early components show sensitivity to overlap in form (e.g., Holcomb & Grainger, 2006). Royle et al.'s morphological and orthographic prime items shared orthography with the target, so the attenuation of the early negativity associated with the target was expected. In the later time-windows, the attenuation of the negativity (the N400) was only predicted for the morphological prime condition. The N400 has been shown to be attenuated when a form is repeated. The attenuation of the N400 for the morphological items only can be interpreted as showing that the morphologically complex prime was decomposed into stem and affix, and once the target word was presented, it was essentially processed as being a repetition of the stem that was activated by the decomposed prime. Though the orthographic primes had an equal amount of orthographic overlap between prime and target as the morphological primes did, the attenuation from stem repetition was only found for items where the prime and target shared morphology.

The EEG results are interpreted as evidence that complex forms (presented as primes) are quickly decomposed into stem and affix, leaving the stem form to activate the morphological representation in the lexicon. When the target word appears, it sustains the activation of the morpheme, which in turn leads to a sustained N400 attenuation in the EEG data, and faster lexical decisions in the behavioral data. Moreover, orthographic similarity between primes and targets allows for a short lived attenuation of the negativity at the target word, but this attenuation tapers off after the target activates its lexical representation.

The results of Coughlin & Tremblay (2015) and Royle et al. (2012) are relevant to the present study in that they show that native French speakers have shown evidence of morphological decomposition of regularly formed words in masked-priming tasks, and this effect is independent of orthographic and semantic priming. Recall that semantic information is a required component in non-morphological models of lexical access, whereas semantic information is not considered as necessary for morpheme activation in morphological models of lexical access. Given the stimuli design of regular verbs of low frequency (i.e., verbs appearing with the *–ons* inflection), and a methodology that blocks semantic information from facilitating target recognition, the present study is able to test if lexical access mechanisms are able to make recourse to a morphemic level of representation. To our knowledge the verbal inflection (1st person plural *–ons*) tested in the present study has only been used in the masked-priming naming task used in Coughlin & Tremblay (2015). The other priming studies in French have focused on derivational affixes (e.g., Meunier & Longtin 2007), or the 3rd person singular imperfect (e.g., Royle et al., 2012). This study is thus in a strong position to offer converging evidence with the results of the masked-priming word-naming results in Coughlin & Tremblay (2015), which first investigated the morphological processing of words inflected with *–ons*.

The present study does include a number of important differences in stimuli design compared to both Coughlin & Tremblay (2015) and Royle et al. (2012). Coughlin & Tremblay (2015) had stem and infected primes, and stem and inflected targets (see Table 1 above). The present study includes only inflected primes and stem targets. The analysis in Coughlin & Tremblay did not reveal an effect of target type, so only one combination of prime and target type was chosen for the present study: inflected primes and stem targets, which will make the findings more easily comparable to other studies. Another difference between this study and Coughlin & Tremblay (2015) is the control found in the orthographic items. Coughlin & Tremblay's orthographic overlap items shared the first two letters only, in addition to the inflection (e.g., *doutons-DONNONS* 'doubt, give'). The stimuli in the present study control the overlap between the prime stem and the target stem, with all but the stem-final letter overlapping (e.g., *arrimons-ARRIVE*, 'dock, arrive'; *aidons-AIME*, 'help-love'). This control in the stimuli will be better able to test the role of orthography in priming. Finally, the task in the present study is different from the task in Coughlin & Tremblay (2015). The task in Coughlin & Tremblay (2015) was masked-priming with speeded word-naming, whereas the present study uses masked-priming with lexical decision. Lexical decision is a commonly used methodology to evaluate lexical activation in priming studies because it is believed to reflect activation of lexical representations. By manipulating the relationship between prime and target, it can be determined if the lexical representation for the target word is activated by the presentation of the prime word. If the prime word does activate the target's representation, the time needed to make a lexical decision at the target word should be decreased compared to trials where the prime does not activate the target's representation. Given that the lexical decision task is the most commonly used task in the current literature on native and non-native morphological processing, the use of lexical decision will place this study in a position to provide new evidence regarding the role of morphemes in lexical processing while using an index of lexical activation (lexical decision RT) that the broader morphological processing literature has converged on as a critical measure for demonstrating access to morphemes.

In addition to differences between the present study and Coughlin & Tremblay (2015), the present study includes important differences compared to the masked-priming lexical decision with EEG in Royle et al. (2012). The present study includes an identity prime-target condition where the exact same form appears as the prime and target (e.g., *reste-RESTE*, 'stay-stay'). Including identity conditions is not common practice in the native speaker literature, but has become essential for cross-study comparisons in the second language (L2) literature. Researchers in the native literature claim that any facilitation offered by morphology but not orthography or semantics is adequate evidence of decomposition and accessing a morphological level of representation in the lexicon, whereas some researchers in the L2 literature argue that decomposition can only be supported if inflected primes offer equal facilitation as stem primes (see, e.g., Jacob, Fleischhauer, & Clahsen, 2013). As the present study is part of a larger study that investigates how L2 leaners of French process morphologically complex words, it is crucial that this condition is included so that the findings of that study can be compared to other studies in the L2 literature. A second difference between the stimuli in the present study and Royle et al. is that all primes (across all conditions, including nonword targets) are inflected with *–ons*. In Royle et al.'s study, orthographically related primes were not necessarily verbs (e.g., *cassis-CASSE*, 'black-currant-BREAK'). The present study aims to keep all primes equal in the presence of an inflection. If complex forms are decomposed into stem and affix, this segmentation will be required in all conditions, allowing for a clearer comparison of how stem forms with different relations to the target word affect word recognition.

It is predicted that if a morpheme-based route of lexical access is available, stem targets that are preceded by a masked morphologically related prime should elicit faster lexical decision times than the same targets when preceded by an unrelated prime. Additionally, the magnitude of any facilitation from morphological overlap is expected to be greater than any facilitation that may be found for orthographically or semantically related primes. If, however, non-morphological models of lexical access are an accurate representation of lexical access, any facilitation from morphological primes would be expected not to exceed the facilitation offered by orthographically and semantically related primes.

Methods

Participants

Thirty-five native French speakers (29 females) living in France at the time of testing participated in this study (mean age = 21.4; range = 18-45). All participants were right handed. The participant gave their informed written consent to participate in the study, and were given course credit for a psychology class they were enrolled in at the time of the study. There was only one participant on the higher end of the age range. This participant's mean reaction times were compared to the mean reaction times of the other participants, and did not stand out as slower than other participants (this participant's mean reaction time was just under the mean for the group of

35 participants). This participant also did not differ in accuracy rates compared to the other participants.

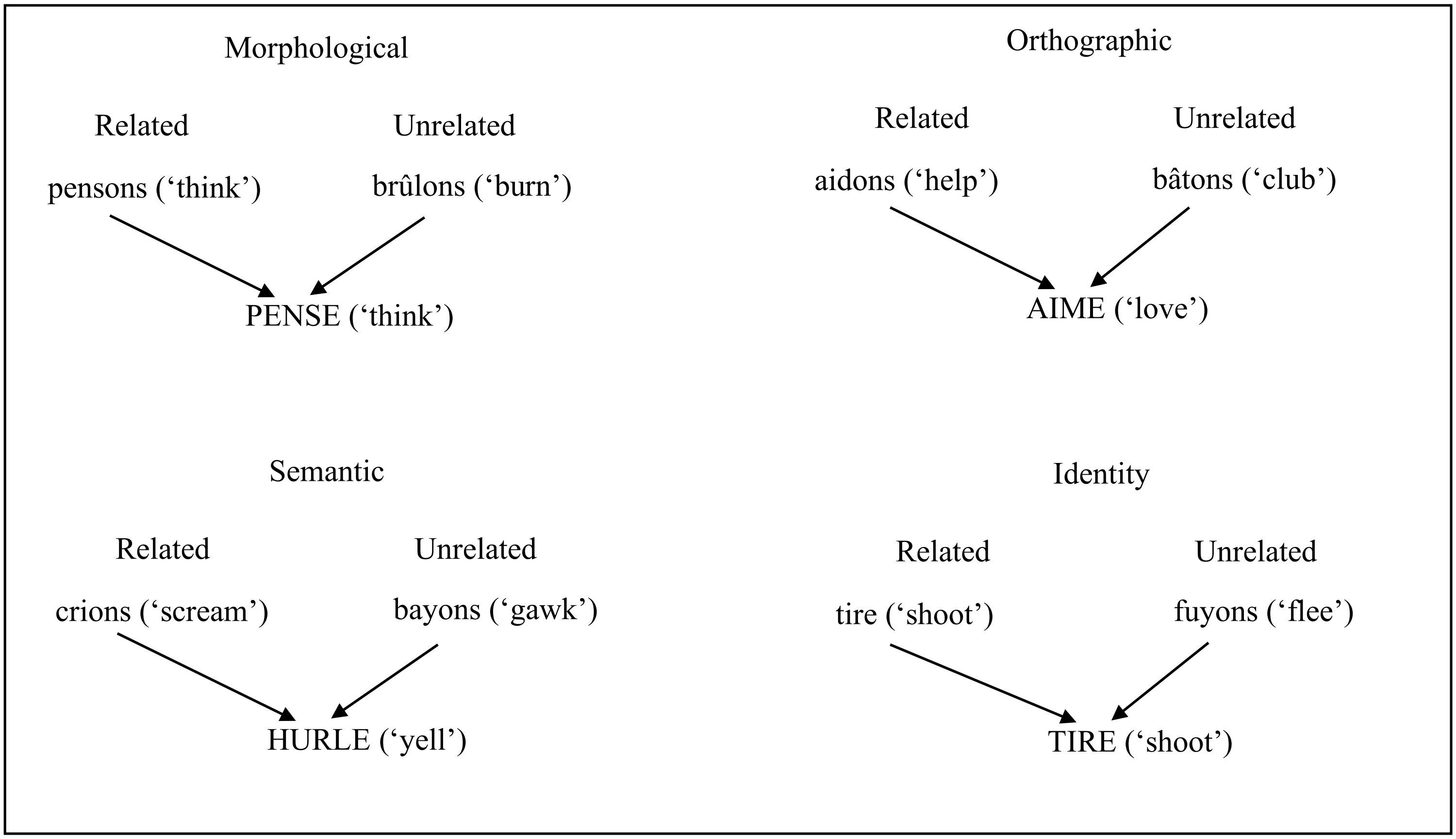
Procedure

This study used a masked-priming lexical decision task. For a given trial, participants first saw a mask (#######) in white Times New Roman font for 750 ms at the center of a black screen, immediately followed by a prime word presented for 50 ms in lower case letters, and then the target word presented in upper case letters. When the target word appeared on the screen the participants indicated whether the target word was a real word in French or not by pressing one of 2 buttons in front of them. The 2 buttons that were used were next to each other on a computer keyboard, allowing participants to use their preferred hand to respond to all targets (all participants were right-handed). For all participants, the "word" response was given with the index finger of the right hand, and the "non-word" response was given with the middle finger of the right hand. They were instructed to respond as quickly as they could, and were told it was better to be fast and make mistakes than to take their time and be accurate. The experiment was broken into 4 blocks to allow for short breaks throughout the experiment. The entire experiment took approximately 15 minutes to complete.

Stimuli

The real-word stimuli in the priming task included 4 prime-target relation conditions with 36 targets each: morphologically related, orthographically related, semantically related, and identity. For every target in a condition there was a related prime and an unrelated prime, yielding 288 total test prime-target pairs. Figure 1 shows example primes and targets for each condition.

Figure 1. Example test stimuli



Two lists of 144 test trials were created so any one participant only saw a given target word in either a related or an unrelated prime condition. Non-word target items were created using 144 nonce targets that were orthographically and phonologically possible French words. Each non-word target was created with two real-word primes, with each experiment list having each nonce target appear once. Half of the 144 non-word targets were created with two unrelated primes, and the other half had one unrelated prime and one orthographically related prime. This allowed the non-word target items to resemble the test items in that one fourth of the targets were preceded by a prime that had orthographic overlap in the absence of semantic overlap. Non-word items were distributed between the two lists using a Latin square design. All primes for the non-word targets were inflected with the 1st person plural *–ons* (like the test primes discussed below), and were controlled for length and surface frequency to match all test conditions. Additionally, all non-word targets were controlled for letter length to match all test condition targets.

All targets and primes were regularly conjugated French -*er* verbs, which is the most common verb class (Class I) in French. The target words were balanced across conditions in letter length and surface form frequency. Prime words were balanced within and across conditions for letter length and surface form frequency. The conjugation forms used in the experiment were 1st/3rd person singular, which served as the stem form for targets, and the 1st person plural, which served as the inflected form for primes. French regular -*er* verbs have five orthographically distinct forms (1st singular and 3rd singular are orthographically and phonologically identical, e.g., *donne* ‘give’), but two of the orthographically distinct forms are phonologically identical, (2nd person singular *donnes;* 3rd person plural *donnent)*. To illustrate, an example verb conjugation paradigm (with phonetic transcription) for the *–er* verb *donner* ('to give') is provided in Table 2 below.

Table 2. French *–er* verb conjugation paradigm (*donner* 'to give')

1st-sg	donne	/dɔn/	1st-pl	donnons	/dɔnɔ̃/
2nd-sg	donnes	/dɔn/	2nd-pl	donnez	/dɔne/
3rd-sg	donne	/dɔn/	3rd-pl	donnent	/dɔn/

The 1st person plural form takes the affix *-ons* (e.g., *donnons*), and is phonologically distinct from all other forms[2]. This form was chosen for its orthographic and phonological saliency and the fact that it allows for the creation of words with very low surface frequency for the inflected forms, even when appearing on frequent verb stems (see frequency differences for stem versus inflected forms in Table 3). Surface frequency for all primes was kept low because it has been proposed that complex forms of a great enough frequency may be stored in their whole form (e.g., Alegre & Gordon, 1999; Baayen et al., 1997). As the aim of the study is to probe whether morpheme-level representations are ever made recourse to, we decided to utilize test items that both morphological models (single- and dual-route) would predict would be decomposed into their morphological constituents. It should be noted that the form used as the target in this study is not monomorphemic itself because it does carry inflection: *-e*. This form was chosen to serve as the target form because the true stem of an *–er* verb is not a French word (e.g., *donn*), and this inflection is the orthographically minimal, and is phonologically null. This same decision was made in Royle et al. (2012) for target items.

Example stimuli from each condition as well as the condition average of letter length and frequency are given in Table 3. Frequency was calculated per million words from the Lexique French database (New et al., 2001). Each condition had 36 different target words and no single surface form appeared more than once (other than items in the identity condition), including items used in the fillers. Student's *t*-tests were used to establish that all target conditions were similar in length and frequency, and that all primes (related and unrelated) were similar within and across conditions. No conditions were significantly different from any other condition on either measurement.

Table 3. Example stimuli with average letter length (SD) & average frequency (SD) for each condition

Condition	Target		Related Prime		Unrelated Prime	
Morph	PENSE 'think'	5.25 (1.02); 22.48 (31.63)	pensons 'think'	7.25 (1.02) 0.86 (1.66)	brûlons 'burn'	7.25 (1.02) 0.27 (0.57)
Orth	MANGE 'eat'	5.03 (0.75); 27.44 (51.26)	mandons 'summon'	7.11 (0.89) 0.59 (2.69)	traçons 'trace'	7.11 (0.88) 0.32 (0.56)
Sem	HURLE 'yell'	5.46 (0.89); 33.44 (44.52)	crions 'scream'	7.31 (1.01) 0.91 (2.14)	bayons 'gawk'	7.33 (0.96) 0.48 (1.57)
ID	DOUTE 'doubt'	5.25 (1.11); 23.98 (37.37)	doute 'doubt'	5.25 (1.11) 23.98 (37.37)	causons 'cause'	7.25 (1.11) 0.65 (0.97)

[2] Note that in the absence of a subject the *–ons* inflected present tense form is used as the adhortative (*let's*) form

Orthographically related primes were created by using *–er* verbs that were orthographically identical to the target except for the letter immediately to the left of the affix (e.g., *aidons- AIME,* 'help-love'). The semantically related primes were created by using synonyms for the target word that were rated by two native French speakers that did not participate in the study. All chosen stimuli were rated at least 4 by both raters on a scale of 1-6, where 1 = unrelated, and 6 = perfect synonym.

A noteworthy feature of the stimuli used in this study is that all target conditions have primes that are morphologically complex. That is, all primes other than the related primes for the identity targets are inflected with *–ons*. Designing the stimuli this way allows the task to evaluate stem priming while keeping morphological structure consistent across conditions.

Analysis & results

All reaction times above 3000ms were removed before calculating mean and standard deviations for each participant. Mean reaction times (and standard deviations) were calculated for each participant (nonce targets were not included in this calculation) Targets with reaction times 2.5 standard deviations above the mean or greater for a given participant were removed from analysis. This resulted in the removal of 3.2% of the data overall.

To get a sense of effect of lexicality on reaction times, nonce targets were returned to the dataset and compared to real word targets in a linear mixed-effects model where target type (word, nonce) and prime type (related, unrelated) were included as fixed variables, and subjects and items were included as random variables. The model revealed a significant effect of target ($t(9902)=-15.94$, $p<.001$), and a marginal effect of relatedness ($t(9902)= 1.896$, $p=.058$). These results indicate that reaction times to nonce targets were significantly longer than reaction times to real word targets.

The analysis of reaction times to investigate the question of morphological processing only included trials with real word targets, and only items where participants correctly identified the target as a real French word. Removing items with inaccurate judgments resulted in the loss of an additional 8.2% of the data. The raw reaction times (in milliseconds) for morphological, orthographic, semantic, and identity conditions are presented visually in Figures 2-5, respectively. Each figure shows the reaction times for prime-target pairs that were related (Rel) as well as the prime-target pairs that were unrelated (Unrel).

Figure 2. Reaction times (ms) for morphological targets

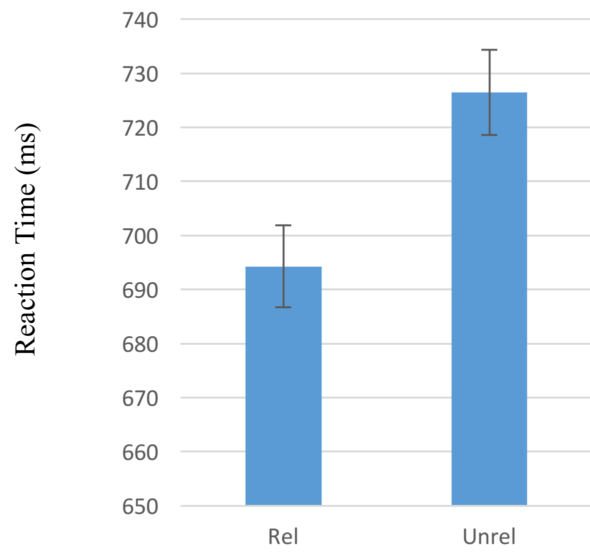


Figure 3. Reaction times (ms) for orthographic targets

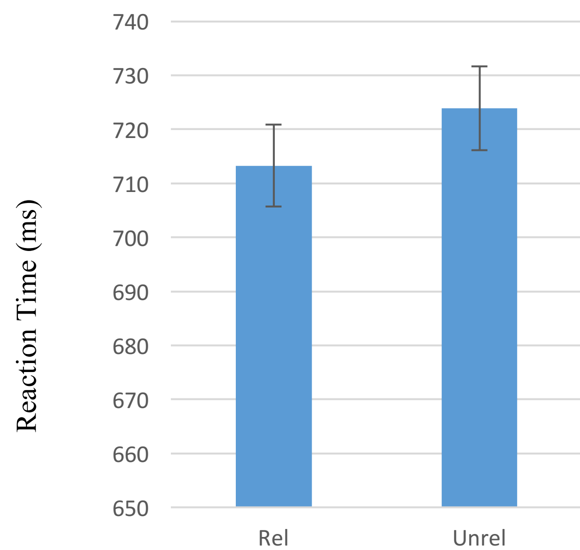


Figure 4. Reaction times (ms) for semantic targets

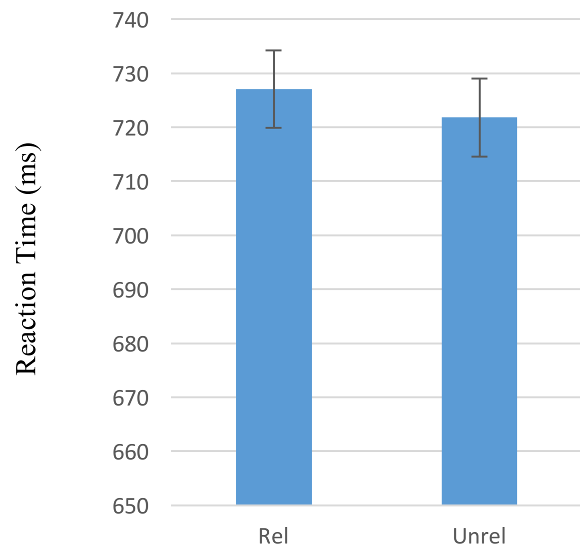
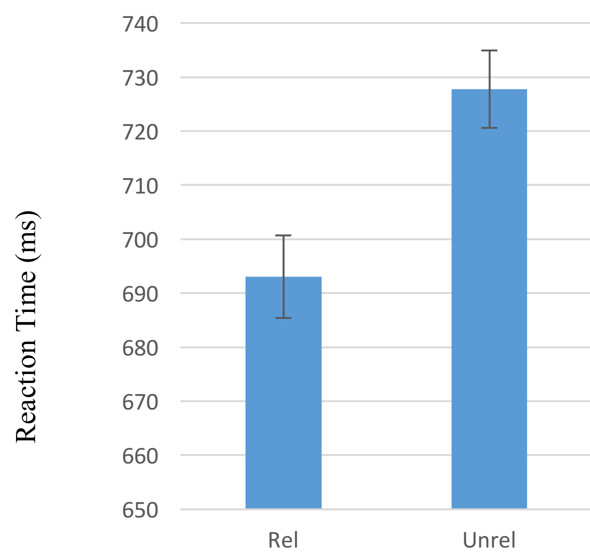


Figure 5. Reaction times (ms) for identity targets



The data were analyzed with linear mixed-effects models using the lme4 package in R (Bates & Maechler, 2009). The dependent variable in the analyses was the log-transformed reaction times for the lexical decision. The model that best accounted for the data included condition (Identity Morphology, Orthography, Semantic), relatedness (related, unrelated), and log-transformed target frequencies as fixed variables, as well as the two-way interaction of condition x relatedness. Item and subject were included in the model as random variables. The ID condition was treated as the baseline to which all other conditions were compared, and unrelated was treated as the baseline for the relatedness variable. Given the Latin square design of the test items, List was included in earlier analyses, but there was no effect of list, nor did including it as a predictor improve the overall model, so it was not included in the final model. Additionally, the target words contain some items (N=77) that are ambiguous with regard to their syntactic category (marked with '*' in the Appendix). For example, *fume* ('smoke') can be either a finite verb form or a noun, as in English. The data were dummy coded for category ambiguity, and included in an earlier model. There was no effect of category ambiguity, nor did including it improve the model, so it was not included in the final model.

The results of the final model show an effect of relatedness (t (4459) = -4.97, p < .001), an effect of log-transformed target frequency (t (4469) = -7.69, p < .001), an interaction of condition x relatedness for the orthographic condition (t (4469) = 2.459, p = .014), and an interaction of condition x relatedness for the semantic condition (t (4469) = 4.10, p < .001). The results of this model indicate that targets with related primes are responded to more quickly than targets with unrelated primes in the baseline condition (ID), and targets with higher surface-form frequency are responded to more quickly than targets with lower surface-form frequency. Recall that the ID condition was treated as the baseline, meaning that the interaction of condition and relatedness for orthographic and semantic conditions indicates that when comparing only two conditions (ID and either orthography or semantic), there is an interaction between condition and relatedness. The effect of relatedness and the lack of interaction between condition and relatedness for the morphological condition indicates that the ID related primes were equally facilitatory as the morphologically related primes in responding to targets compared to unrelated primes. In other words, target words are recognized equally quickly when preceded by either an identity prime or a morphologically related prime compared to when preceded by an unrelated prime. This result of equal facilitation indicates morphological priming was found. This finding will be discussed in greater detail below.

To understand the interaction of condition x relatedness for the orthographic and semantic conditions, subsequent models were used to analyze the effect of relatedness for each condition separately. For each of the subsequent models, relatedness and log-transformed target frequency were included as fixed variables, and item and subject were included as random variables. The model including only the orthographic condition shows no significant effect of relatedness (t (1057) = 1.253, p >.2), but there was an effect of log-transformed target frequency (t (1057) = -5.24, p <.001). These results indicate that targets in the orthographic condition with higher surface-form frequency were responded to more quickly when compared to targets with lower surface-form frequency, but there was not facilitation in target responses when the prime was orthographically related to the target compared to when the prime was unrelated to the target. In other words, there was no evidence of orthographic priming. The results from this model indicate that the interaction found in the larger model was driven by an effect of relatedness for the ID condition only, which will be discussed in further detail below.

The model including only the semantic condition also showed no significant effect of relatedness (t (1133) = -.922, p >.3), but there was an effect of log-transformed target frequency (t (1133) = -4.066, p <.001). Again, targets with higher surface-form frequency are responded to more quickly than targets with lower surface-form frequency. Similar to the model for the orthographic condition, the results of this model show no facilitation in target responses for semantically related primes compared to unrelated primes. In other words, there was no evidence of semantic priming. Like the orthographic model, the semantic model indicates that the interaction of condition and relatedness in the larger model was driven by an effect of relatedness in the ID condition only.

These two subsequent models show that neither the related orthographic nor the related semantic primes were facilitatory compared to the unrelated primes for the same targets. To ensure that the interaction in the first model was in fact driven by the ID condition, a model was run on the ID condition only, with relatedness and log-transformed target frequencies as fixed variables, and item and subject as random variables. The results of this model showed an effect of relatedness (t (1120) = 5.094, p <.001), and an effect of log-transformed target frequency (t (1120) = -3.023, p <.01). These results indicate that, again, targets of higher frequency elicit faster responses than targets of lower frequency. Additionally, targets that were preceded by an identity prime were responded to more quickly than targets preceded by an unrelated prime, indicating repetition priming was found. Recall that the first model showed no interaction of condition and relatedness for the morphological condition, indicating that the pattern we see in the ID condition does not differ from the pattern in the morphological condition. To demonstrate the magnitude of the effect of relatedness in the morphological condition, a subsequent model was run on the morphological condition items only, with relatedness and log-transformed target frequencies included as fixed variables, and item and subject as random variables. The results of the model showed an effect of relatedness (t (1149) = -3.597, p <.001, and an effect of log-transformed target frequencies (t (1149) = -2.260). These results indicate that increased target frequency elicits faster lexical decisions. The effect of relatedness indicate that, like the ID condition, targets preceded by a morphologically related prime are recognized faster than targets preceded by an unrelated prime.

To summarize the data analysis, the results show evidence of morphological priming in the absence of orthographic and semantic priming. The lack of orthographic and semantic priming indicate that the facilitation of morphologically related primes cannot be attributed to the facilitation of orthographic or semantic overlap. These results are in line with predictions made by morphological models of lexical access, and are inconsistent with predictions made by non-morphological models.

The mean accuracy for all test items was 91%. Mean accuracy for targets preceded by a related prime was 92%, whereas targets preceded by an unrelated prime was 91%. Accuracy rates were analyzed using a logistic mixed-effects model with condition and relatedness as fixed variables and item and subject as random variables using the lme4 package in R (Bates & Maechler, 2009). While this difference in mean accuracy rates for related and unrelated primes is very small numerically, it is significant (z(4863) = 2.102, p < 0.05). There was no effect of condition on accuracy, nor an interaction of condition and relatedness. The results of the model indicate that participants were more accurate in their lexical decision for target words when preceded by a related word compared to when preceded by an unrelated word, and this effect was not affected by the type of relation between prime and target.

The accuracy rates for rejecting the nonword targets were also analyzed. Participants rejected nonword targets with 91% accuracy. Accuracy rates for nonword targets were analyzed using a logistic mixed-effects model with condition (orthographic or unrelated word primes) as a fixed variable, and subjects and items as random variables. There was no effect of prime condition for the nonword target accuracy rates. Another logistic regression model was used to compare accuracy across target types (words, nonce). The model included target type (word, nonce) and relatedness (related, unrelated) as predictor variables. The results of the model revealed no effect of target type or relatedness (p>.1), indicating that participants were equally accurate in identifying word targets as real French words and identifying nonce targets as nonwords

Discussion

The present study aimed to investigate if morphologically complex French verbs (carrying the *–ons* inflection) are decomposed into stem and affix, and accessed at a morphological level of representation in the lexicon. This study aimed to test the predictions of *morphological* and *non-morphological* models of lexical processing by examining how morphologically, orthographically, and semantically related primes affected recognition of target words compared to unrelated primes.

The present study was able to test predictions made by morphological models of lexical access to predictions made by non-morphological models by using regular French verbs that are inflected with an affix that creates a low-frequency form. While some morphological models posit a whole-form storage route to access some complex forms (e.g., Baayen et al., 1997), no morphological model (to our knowledge) predicts regularly inflected forms with low surface frequency to be processed as a whole-form. It was predicted that if the language processing system makes recourse to a morphological level of representation, the prime words that share morphology will be decomposed into stem and affix, and the stem activation from the prime word will allow for faster recognition of the target word compared to when an unrelated word is presented as the prime word. Importantly, the size of this morphological priming effect was predicted to be independent of any facilitation offered by orthographic or semantic priming. That is, it was predicted that the orthographically and semantically related primes would not offer similar facilitation in target recognition, nor would their combined priming effect resemble the facilitation offered by shared morphology. By contrast, if the language processing system does not have a morpheme-based pathway to lexical representations, it was predicted that any facilitation from a morphologically related prime would not differ from either orthographic or semantic facilitation.

The results of the present study provide evidence in line with predictions of morphological models by showing that the language processing system can make recourse to a morpheme level of representation when recognizing complex word forms. The results from this study showed lexical decision facilitation from morphological primes that equaled the facilitation offered by identity primes, similar to the findings in the speeded word-naming task used Coughlin & Tremblay (2015). The present study had more strongly controlled stimuli than Coughlin & Tremblay (2015), but the effect of identity and morphological primes was similar. In other words, it did not matter if a prime and target were the exact same word, or if they were the same stem with different inflections, the target word was recognized equally quickly. This result is interpreted as indicating that the inflected primes were decomposed into stem and affix, leaving the stem to activate the morpheme's representation in the lexicon. These results are in line with previous studies arguing for a morphological approach to lexical access (e.g., Rastle et al., 2004; Stockall & Marantz, 2006). Recall that both a morphological and a non-morphological model may predict priming effects from morphologically related primes, but crucially, morphological models predict that this priming effect would be tapping a level of processing that is independent of form and meaning, whereas a non-morphological model would predict this priming can best be explained by form and meaning facilitation. The results from the present study showed no significant facilitation from orthographically related or semantically related primes compared to unrelated primes, similar to previous findings (e.g., Royle et al., 2012). The stimuli in the present study differed from those in Royle et al. in that all primes were verbs carried the *–ons* inflection, and the orthographic items were controlled differently in that the stems of the primes and target overlapped in all but one letter (as compared the stem being embedded in a larger monomorphemic word in Royle et al., 2012). The differences in stimuli design in the present study and Royle et al. (2012)

did not lead to different effects of orthographic overlap between primes and targets. That is, in both studies, the presentation of a prime that has a high degree of orthographic overlap with the target word offered no more facilitation than a prime with no orthographic overlap. Additionally, prime words that were judged as synonyms of the targets offered no more facilitation than primes that shared were semantically unrelated to the target. The results of the present study also showed an effect of log-transformed target frequency showing that more frequent forms elicited faster lexical decision times. The effect of frequency did not interact with the relatedness of the prime, and is thus interpreted as being independent of any priming. The effect of frequency is consistent with the predictions of both a morphological model (e.g., Taft, 2004) and a non-morphological model (e.g., Gonnerman et al., 2007), and consequently will not be discussed further. The results of the present study are interpreted as evidence that lexical access in native French speakers involves access to a morpheme-based processing route. This study was designed to test if native French speakers are able to use a processing mechanism that makes recourse to morphological representations during processing, but it was not designed to investigate if native speakers *always* use a morphological processing route when processing morphologically complex words. While the latter question is an important one, our focus on regular morphology both allowed us to contrast morphological and non-morphological models on a point of fundamental difference (whether morpheme representations are *ever* utilized) and positions us to extend this research to address a related theoretical debate in the second language acquisition literature that centers on regular morphology, The study was successful in showing that morphological-level representations are indeed available in the processing of regular inflected forms in French native speakers.

References

Alegre, M., & Gordon, P. (1999). Frequency effects and the representational status of regular inflections. *Journal of Memory and Language*, 40, 41–61.

Allen, M., & Badecker, W. (2002). Inflectional regularity: Probing the nature of lexical representation in a cross-modal priming task. *Journal of Memory and Language*, 46, 705–722.

Baayen, R. H., Dijkstra, T., & Schreuder, R. (1997). Singulars and plurals in Dutch: Evidence for a parallel dual-route model. *Journal of Memory and Language*, 37, 94–117.

Balota, D. & Chumbley, J. (1984). Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage. *Journal of Experimental Psychology: Human perception and Performance*, 10, 340–357.

Bates, D., & Maechler, M. (2009). lme4: Linear mixed-effects models using S4 classes [Computer software manual]. Available from http://CRAN.R-project.org/package=lme4

Clahsen, H., & Felser, C. (2006). Grammatical processing in language learners. *Applied Psycholinguistics*, 27, 3–42

Clahsen, H., Balkhair, L., Shutter, J.-S., & Cunnings, I. (2013). The time course of morphological processing in a second language. *Second Language Research*, 29, 7–31.

Clahsen, H. (1999). Lexical entries and rules of language: A multidisciplinary study of German inflection. *Behavioral and Brain Sciences*, 22, 991–1060.

Coughlin, C.E., & Tremblay, A. (2015). Morphological decomposition in native and non-native French speaker. *Bilingualism: Language and Cognition*, 18, 524–542.

Davis, M. H., & Rastle, K. (2010). Form and meaning in early morphological processing: Comment on Feldman, O'Connor and Moscoso del Prado Martin. *Psychonomic Bulletin & Review,* 17, 749–755.

Diependaele, K., Sandra, D., & Grainger, J. (2005). Masked cross-modal morphological priming: Unraveling morpho-orthographic and morpho-semantic influences in early word recognition. *Language and Cognitive Processes*, 20, 75–114.

Diependaele, K., Sandra, D., & Grainger, J. (2009). Semantic transparency and masked morphological priming: The case of prefixed words. *Memory & Cognition*, 37, 895–908.

Embick, D., Hackl, M., Schaeffer, J., Kelepir, M., & Marantz, A. (2001). A magnetoencephalographic component whose latency reflects lexical frequency. *Cognitive Brain Research*, 10, 345–348.

Feldman, L. B., O'Connor, P. A., & Moscoso del Prado Martín, F. (2009). Early morphological processing is morphosemantic and not simply morpho-orthographic: A violation of form-then-meaning accounts of word recognition. *Psychonomic Bulletin & Review, 16,* 684–691.

Gonnerman, L., Seidenberg, M., & Andersen, E. (2007). Graded semantic and phonological similarity effects in priming: Evidence for a distributed connectionist approach to morphology. *Journal of Experimental Psychology: General*, 136, 323–345.

Hay, J., & Baayen, H. (2005). Shifting paradigms: Gradient structure in morphology. *Trends in Cognitive Sciences*, 9, 342–348.

Holcomb, P. J. and J. Grainger. 2006. The time-course of masked repetition priming: An event-related brain potential investigation. *Journal of Cognitive Neuroscience* 18, 1631–1643.

Jacob, G., Fleischhauer, E., & Clahsen, H. (2013). Allomorphy and affixation in morphological processing: A cross-modal priming study with late bilinguals. *Bilingualism: Language and Cognition*, 16, 924–933.

Lehtonen, M., Vorobyev, V., Hugdahl, K., Tuokkola, T., & Laine, M. (2006). Neural correlates of morphological decomposition in a morphologically rich language: An fMRI study. *Brain and Language*, 98, 182–193.

Marslen-Wilson, W., & Tyler, L. (1997). Dissociating types of mental computation. *Nature*, 387, 592–594.

Marslen-Wilson, W. D., Hare, M., & Older, L. (1993). Inflectional morphology and phonological regularity in the English mental lexicon. *Proceedings of the 15th annual conference of the cognitive science society* (pp. 693–698). Hillsdale, NJ: Erlbaum

Marslen-Wilson, W. D., Tyler, L., Waksler, R., & Older, L. (1994). Morphology and meaning in the mental lexicon. *Psychological Review*, 101, 1–33

Meunier, F. & Longtin, C.M. (2007). Morphological decomposition and semantic integration in word-processing. *Journal of Memory and Language*, 56, 457–471.

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

Pinker, S. (1991). Rules of language. *Science*, 253, 530–535.

Pinker, S. (1999). Words and rules: the ingredients of language. New York: Basic Books.

Rastle, K., Davis, M. H., Marslen-Wilson, W. D., & Tyler, L. K. (2000). Morphological and semantic effects in visual word recognition: A time-course study. *Language and Cognitive Processes*, 15, 507–537.

Rastle, K., Davis, M. H., & New, B. (2004). The broth in my brother's brothel: Morpho-orthographic segmentation in visual word recognition. *Psychonomic Bulletin and Review,* 11, 1090–1098.

Rastle, K., & Davis, M. (2008). Morphological decomposition based on the analysis of orthography. *Language and Cognitive Processes*, 23, 942–971.

Royle, P., Drury, J. E., Bourguignon, N., & Steinhauer, K. (2012). The temporal dynamics of inflected word recognition: A masked ERP priming study of French verbs. *Neuropsychologia*, 50, 3542–3553.

Rugg, M. (1987) Dissociation of semantic priming, word and non-word repetition by event-related potentials. *Quarterly Journal of Experimental Psychology* 39A:123–48

Rumelhart, D., & McClelland, J. (1986). On learning the past tense of English verbs: Implicit rules or parallel distributed processing? In J. McClelland, D. Rumelhart & the PDP Research Group (eds.), Parallel distributed processing: Explorations in themicrostructure of cognition, pp. 318–362. Cambridge, MA: MIT Press.

Stockall, L., & Marantz, A. (2006). A single-route, full-decomposition model of morphological complexity: MEG evidence. *The Mental Lexicon*, 1, 85-123.

Taft, M. (2004). Morphological decomposition and the reverse base frequency effect. Quarterly *Journal of Experimental Psychology*, 57A, 745-765.

Taft, M. (1979). Recognition of affixed words and the word frequency effect. *Memory & Cognition,* 7, 263–272.

Appendix
Stimuli

'*'= Ambiguous syntactic category

Condition	**Target**	**Related Prime**	**Unrelated Prime**
Morph	ACCUSE 'accuse'	accusons 'accuse'	louchons 'squint'
Morph	AJOUTE* 'add'	ajoutons 'add'	épousons 'marry'
Morph	AMUSE 'amuse'	amusons 'amuse'	suivons 'follow'
Morph	ARME* 'arm'	armons 'arm'	lisons 'read'
Morph	BLESSE 'bless'	blessons 'bless'	échouons 'fail'
Morph	BOUFFE* 'eat'	bouffons 'eat'	convions 'invite'
Morph	BRISE* 'break'	brisons 'break'	luttons 'fight'
Morph	CASSE* 'break'	cassons 'break'	voilons 'veil'
Morph	CHASSE* 'hunt'	chassons 'hunt'	scrutons 'scan'
Morph	CHERCHE 'search'	cherchons 'search'	bénissons 'bless'
Morph	CITE 'cite'	citons 'cite'	filons 'fly by'
Morph	CLOUE 'nail'	clouons 'nail'	topions 'shake hands'
Morph	DÉCIDE 'decide'	décidons 'decide'	brillons 'shine'
Morph	ÉCHAPPE 'escape'	échappons 'escape'	résistons 'resist'
Morph	ENTRE 'enter'	entrons 'enter	jugeons 'judge'
Morph	ERRE* 'roam'	errons 'roam'	gênons 'disturb'
Morph	EXPRIME 'express'	exprimons 'express'	regagnons 'win back'
Morph	FONDE 'melt'	fondons 'melt'	méfions 'suspect'
Morph	FROTTE 'rub'	frottons 'rub'	daignons 'deign'
Morph	GAGNE* 'win'	gagnons 'win'	offrons 'offer'
Morph	IMPOSE 'impose'	imposons 'impose'	pelotons 'paw'
Morph	JOUE* 'play'	jouons 'play'	potons 'putt'
Morph	LOUE 'rent'	louons 'rent'	plions 'fold'
Morph	MONTRE* 'show'	montrons 'show'	écrasons 'press'
Morph	MOQUE* 'mock'	moquons 'mock'	nommons 'name'
Morph	OSE* 'dare'	osons 'dare'	suons 'sweat'
Morph	PENSE 'think'	pensons 'think'	brûlons 'burn'
Morph	PLEURE 'cry'	pleurons 'cry'	assurons 'assure'
Morph	POSE* 'place'	posons 'place'	fêtons 'celebrate'
Morph	POUSSE* 'push'	poussons 'push'	croulons 'sag'
Morph	PROUVE 'prove'	prouvons 'prove'	choppons 'stumble'
Morph	SERRE* 'tighten'	serrons 'tighten'	avouons 'confess'
Morph	SIGNE* 'sign'	signons 'sign'	testons 'test'
Morph	SOIGNE 'treat'	soignons 'treat'	couchons 'sleep'
Morph	TUE 'kill'	tuons 'kill'	ôtons 'remove'

Morph	VALSE*‘waltz’	valsons ‘waltz’	cordons ‘tie up’
Orth	AIME ‘love’	aidons ‘help’	bâtons ‘club’
Orth	ARRIVE ‘arrive’	arrimons ‘dock’	cinglons ‘whip’
Orth	ARROGE ‘assume’	arrosons ‘water’	traquons ‘track’
Orth	ASSURE ‘assure’	assumons ‘assume’	trottons ‘trot’
Orth	BASE* ‘base’	bavons ‘gawk’	volons ‘steal’
Orth	BOUGE* ‘move’	boudons ‘stay away’	tissons ‘weave’
Orth	BOULE* ‘roll’	boutons ‘set’	tondons ‘mow’
Orth	BRASE ‘braze’	bramons ‘roar’	surfons ‘surf’
Orth	BRÛLE ‘burn’	brumons ‘mist’	collons ‘glue’
Orth	CHANGE* ‘change’	chantons ‘sing’	refusons ‘sing’
Orth	CHARGE* ‘charge’	charmons ‘charm’	amassons ‘amass’
Orth	COMMENCE ‘start’	commentons ‘comment’	encombrons ‘block’
Orth	COUPE* ‘cut’	coulons ‘sink’	donnons ‘give’
Orth	DUPE* ‘trick’	durons ‘last’	levons ‘raise’
Orth	ÉCOUTE ‘listen’	écoulons ‘sell’	désirons ‘desire’
Orth	ÉGALE ‘equal’	Égarons ‘lose’	ballons ‘dangle’
Orth	ÉVITE ‘avoid’	évidons ‘hollow out’	portons ‘carry’
Orth	EXPLORE ‘explore’	explosons ‘explode’	supplions ‘beg’
Orth	FERME* ‘close’	ferrons ‘hook’	glaçons ‘chill’
Orth	FIGE ‘set’	fixons ‘attach’	gelons ‘freeze’
Orth	FORGE* ‘forge’	formons ‘form’	ciblons ‘target’
Orth	GARE* ‘park’	gavons ‘feed’	visons ‘aim at’
Orth	JUGE* ‘judge’	jurons ‘swear’	humons ‘sniff’
Orth	LANGE* ‘change clothes’	lançons ‘throw’	chopons ‘catch illness’
Orth	MANGE ‘eat’	mandons ‘summon’	traçons ‘draw’
Orth	MONTE* ‘climb’	mondons ‘blanch’	cernons ‘surround’
Orth	PANSE* ‘bandage’	pannons ‘miss’	calmons ‘calm’
Orth	PARIE ‘bet’	parlons ‘speak’	adorons ‘adore’
Orth	PLACE* ‘place’	planons ‘glide’	vendons ‘sell’
Orth	RASE ‘shave’	ratons ‘miss’	fumons ‘smoke’
Orth	ROULE* ‘roll’	routons ‘direct’	flânons ‘stroll’
Orth	SAUVE ‘save’	sautons ‘jump’	mâchons ‘chew’
Orth	SONGE* ‘think’	sonnons ‘ring’	frayons ‘clear’
Orth	SOUDE* ‘weld’	soupons ‘dine’	tâchons ‘stain’
Orth	TRAITE ‘process’	traînons ‘drag’	récitons ‘recite’
Orth	VOLE* ‘steal’	votons ‘vote’	salons ‘salt’
Sem	ACCEPTE ‘accept’	agréons ‘agree’	campons ‘camp’
Sem	ADORE ‘adore’	aimons ‘love’	vexons ‘vex’

Sem	AIDE* ‘help’	assistons ‘assist’	discutons ‘discuss’
Sem	AVALE ‘swallow’	gobons ‘swallow’	rayons ‘cross out’
Sem	CACHE* ‘hide’	masquons ‘mask’	trompons ‘cheat’
Sem	CLAQUE* ‘smack’	frappons ‘slap’	existons ‘exist’
Sem	COLLE* ‘glue’	adhérons ‘adhere’	mouchons ‘blow’
Sem	DONNE* ‘give’	servons ‘serve’	lardons ‘lard’
Sem	DORE ‘gild’	bronzons ‘bronze’	glissons ‘slip’
Sem	EMPÊCHE ‘prevent’	Inhibons ‘inhibit’	plaisons ‘please’
Sem	EPOUSE* ‘marry’	marions ‘marry’	voguons ‘sail’
Sem	ESPÈRE ‘hope’	comptons ‘count’	penchons ‘tilt’
Sem	FORME* ‘form’	créons ‘create’	optons ‘choose’
Sem	GRIMPE* ‘climb’	montons ‘ascend’	pompons ‘pump’
Sem	HABITE ‘inhabit’	logeons ‘lodge’	captons ‘get’
Sem	HURLE ‘yell’	crions ‘scream’	bayons ‘gawk’
Sem	LANCE* ‘throw’	jetons ‘throw’	nouons ‘tie’
Sem	MÉRITE* ‘merit’	valons ‘cost’	cirons ‘polish’
Sem	NOTE* ‘note’	écrivons ‘write’	invitons ‘invite’
Sem	NOUE* ‘tie’	attachons ‘atttach’	butons ‘trip’
Sem	OUBLIE* ‘forget’	omettons ‘omit’	croquons ‘crunch’
Sem	PASSE* ‘pass’	croisons ‘cross’	résumons ‘resume’
Sem	PERCE* ‘pierce’	piquons ‘scratch’	agitons ‘agitate’
Sem	PORTE* ‘wear’	revêtons ‘wear’	abjurons ‘recant’
Sem	PRIE ‘pray’	implorons ‘implore’	calculons ‘calculate’
Sem	QUITTE ‘leave’	laissons ‘leave’	effaçons ‘erase’
Sem	RACONTE ‘tell’	narrons ‘narrate’	prêtons ‘lend’
Sem	REFUSE ‘refuse’	dénions ‘deny’	saluons ‘greet’
Sem	RINCE ‘rinse’	lavons ‘wash’	topons ‘catch’
Sem	SITUE ‘put’	mettons ‘put’	voulons ‘want’
Sem	TOUCHE* ‘touch’	caressons ‘caress’	apprenons ‘learn’
Sem	TOURNE* ‘turn’	remuons ‘swing’	barrons ‘block’
Sem	TREMBLE* ‘tremble’	vibrons ‘shake’	doutons ‘doubt’
Sem	TROMPE* ‘cheat’	bernons ‘deceive’	frôlons ‘approach’
Sem	TROUVE ‘find’	dénichons ‘find’	observons ‘observe’
Sem	VEXE ‘offend’	choquons ‘offend’	tolérons ‘allow’
ID	ABUSE ‘abuse’	abuse ‘abuse’	gâchons ‘waste’
ID	BORDE* ‘surround’	borde ‘surround’	versons ‘pour’
ID	BOUCLE* ‘curl’	boucle ‘curl’	scellons ‘seal’
ID	CRÈVE ‘burst’	crève ‘burst’	privons ‘deprive’
ID	DANSE* ‘dance’	danse ‘dance’	prônons ‘advocate’
ID	DOUTE* ‘doubt’	doute ‘doubt’	causons ‘cause’

ID	DURE* ‘last’	dure ‘last’	notons ‘note’
ID	ÉTALE ‘spread’	étale ‘spread’	cessons ‘stop’
ID	EXPLIQUE ‘explain’	explique ‘explain’	descendons ‘descend’
ID	FUME* ‘smoke’	fume ‘smoke’	bubons
ID	INVITE* ‘invite’	invite ‘invite’	pouffons ‘explode’
ID	MANIE* ‘handle’	manie ‘handle’	battons ‘club’
ID	MANQUE* ‘miss’	manque ‘miss’	semblons ‘appear’
ID	MÊLE ‘mix’	mêle ‘mix’	parons ‘block’
ID	MOULE* ‘form’	moule ‘form’	imitons ‘imitate’
ID	NAGE* ‘swim’	nage ‘swim’	gitons ‘heel’
ID	OBSERVE ‘observe’	observe ‘observe’	paniquons ‘panic’
ID	PARLE ‘speak’	parle ‘speak’	réglons ‘regulate’
ID	PÈSE ‘weigh’	pèse ‘weigh’	gazons ‘gas’
ID	PLONGE* ‘dive’	plonge ‘dive’	accédons ‘reach’
ID	PRÉPARE ‘prepare’	prepare ‘prepare’	concluons ‘conclude’
ID	PULSE ‘pulsate’	pulse ‘pulsate’	tardons ‘be late’
ID	RAMASSE ‘pick up’	ramasse ‘pick up’	gravitons ‘gravitate’
ID	RATE* ‘fail’	rate ‘fail’	buvons ‘drink’
ID	RÉCITE ‘recite’	recite ‘recite’	évoquons ‘evoke’
ID	RÉPÈTE ‘repeat’	répète ‘repeat’	essayons ‘try’
ID	RESTE* ‘stay’	reste ‘stay’	goûtons ‘taste’
ID	RETOURNE* ‘return’	retourne ‘return’	comprenons ‘understand’
ID	RÊVE* ‘dream’	rêve ‘dream’	misons ‘bet’
ID	SONNE ‘ring’	sonne ‘ring’	dansons ‘dance’
ID	TÂCHE* ‘stain’	tâche ‘stain’	ouvrons ‘open’
ID	TIRE* ‘shoot’	tire ‘shoot’	fuyons ‘flee’
ID	TOMBE* ‘fall’	tombe ‘fall’	enflons ‘inflate’
ID	TRACE* ‘draw’	trace ‘draw’	dormons ‘sleep’
ID	VANTE ‘praise’	vante ‘praise’	évadons ‘escape’
ID	VIDE* ‘empty’	vide ‘empty’	laçons ‘lace’

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