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# The temporal dynamics of inflected word recognition: A masked ERP priming study of French verbs ☆

Phaedra Royle [a,b,*], John E. Drury [c], Nicolas Bourguignon [b,d], Karsten Steinhauer [b,e]

[a] École d'orthophonie et d'audiologie, Université de Montréal, C.P. 6128, Succursale Centre-Ville, Montréal, Quebec, Canada H3C 3J7
[b] Centre for Research on Brain Language and Music, Montreal, Canada
[c] Linguistics, Stony Brook, University, NY, USA
[d] Linguistique et traduction, Université de Montréal, Canada
[e] Communication Sciences and Disorders, McGill University, Montreal, Canada

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ABSTRACT

Morphological aspects of human language processing have been suggested by some to be reducible to the combination of orthographic and semantic effects, while others propose that morphological structure is represented separately from semantics and orthography and involves distinct neurocognitive processing mechanisms. Here we used event-related brain potentials (ERPs) to investigate semantic, morphological and formal (orthographic) processing conjointly in a masked priming paradigm. We directly compared morphological to both semantic and formal/orthographic priming (shared letters) on verbs. Masked priming was used to reduce strategic effects related to prime perception and to suppress semantic priming effects. The three types of priming led to distinct ERP and behavioral patterns: semantic priming was not found, while formal and morphological priming resulted in diverging ERP patterns. These results are consistent with models of lexical processing that make reference to morphological structure. We discuss how they fit in with the existing literature and how unresolved issues could be addressed in further studies.



## 1. Introduction

The nature of the organization of the mental lexicon enabling us to link sound patterns and written words to their meaning has long been debated in psycholinguistics (e.g., Bates & Godham, 1997; McQueen & Cutler, 1998). Of particular interest is the status of morphology during word processing. By morphology we mean the structure of complex words and the dynamic processes that allow us to decompose them into simple units (morphemes) that can be recombined with other morphemes to create new words (Aronoff & Fudemann, 2011). We distinguish between (i) *stem* morphemes that carry the core conceptual meaning (e.g., the verb 'inform'), (ii) *derivational* morphemes that (can) change the word's syntactic category and may dramatically change its meaning (e.g., '-ative' can change a verb into an adjective: 'inform-ative'), and (iii) *inflectional* morphemes that primarily mark syntactic information without changing the word category or the core meaning (e.g., '-s' for the third person singular present tense: 'inform-s').

In the present study we address a number of questions: How is the processing of inflectional morphology integrated in the time course of visual word recognition? What *are* "morphological effects" found in behavioral and electrophysiological studies of lexical access? Can we distinguish morphological from semantic and orthographic effects? And which models can best account for these? Using event-related brain potentials (ERPs) to investigate orthographic (formal), semantic, and morphological priming effects on the processing of French verbs in a visual lexical decision task, we contrasted two views on the role of morphology in the organization of the mental lexicon: morphological and eliminativist.

## 2. Background

### 2.1. Lexical processing models

Many psycholinguists regard morphological structure as an indispensible level of linguistic representation (Baayen, Schreuder,

☆ Neurocognition of Language Lab, School of Communication Sciences and Disorders, McGill University, 1266 Pine Avenue West, Montreal, Quebec H3G 1A8, Canada.

* Corresponding author at: École d'orthophonie et d'audiologie, Université de Montréal, C.P. 6128, Succursale Centre-Ville, Montréal, Quebec, Canada H3C 3J7. Tel.: +1 514 343 6111x0925.
*E-mail addresses:* phaedra.royle@umontreal.ca (P. Royle), john.drury@stonybrook.edu (J.E. Drury), nicolas.bourguignon@umontreal.ca (N. Bourguignon), karsten.steinhauer@mcgill.ca (K. Steinhauer).

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& Sprodt, 2000; Domínguez, de Vega, & Barber, 2004; McQueen & Cutler, 1998). It is used in real-time language processing where comprehension and production of forms like 'kicked' involves (de)composition of constituent morphemes 'kick' and '-ed' (e.g., Clahsen, 2006; Stockall & Marantz, 2006). Evidence supporting this comes from priming studies where complex target words (e.g., 'inform-ative') are easier to process when preceded by another word sharing the same base morpheme (e.g., 'inform-s'). Priming effects have also been reported in electrophysiological studies (Brown & Hagoort, 1993; Lavric, Clapp, & Rastle, 2007; Morris, Frank, Grainger, & Holcomb, 2007; Morris, Grainger, & Holcomb, 2008).

However, other views suggest that the link between the orthographic or phonological pattern of a word and its meaning does not require morphological representations (Bates & Godham, 1997; Devlin, Jamison, Matthews, & Gonnerman, 2004; Seidenberg & Gonnerman, 2000, see also Hay & Baayen, 2005 for a critical review). According to this eliminativist stance, morphology is epiphenomenal and has no role to play in lexical representation and processing. This approach claims that there is no theoretical or empirical requirement for morphological representations, nor to putative relationships between morphemes. Morphological effects are argued to be the result of co-activation of *formal* (orthographic/phonological) and *semantic* information (the "convergence of codes"; Seidenberg & Gonnerman, 2000, see also Bates & Godham, 1997; Devlin et al., 2004; Seidenberg & McClelland, 1989). Apparent "morphological" priming effects (see Section 2.2) are simply a combination of (i) orthographic priming (due to the shared letters 'i-n-f-o-r-m', possibly supported by co-activated phonological representations) and (ii) semantic priming due to the conceptual-semantic overlap between the two word meanings.

Although there is abundant data bearing on this theoretical opposition, a neutral observer can reasonably characterize the empirical evidence as inconclusive (see Seidenberg & Gonnerman, 2000 for some relevant discussion). Behavioral data in particular have often been argued to equally support both accounts (Feldman & Prostko, 2002; Rueckl, Mikolinski, Raveh, Miner, & Mars, 1997; Rueckl, 2010). However, data from such experiments (i.e., response latency and accuracy, which are mediated by motor responses) provide only *indirect* evidence for underlying cognitive processes. In contrast, ERP data enable us to tap brain processes involved in lexical access in real time, and continuously across the entire trial, i.e., long before a motor response has been initiated.

### 2.2. Event-related potentials and the study of lexical processing

A number of electrophysiological studies have shown that different ERP priming effects can be observed that are likely to reflect specific cognitive processes at distinct time periods during word recognition. First, a classic finding in ERP research using *semantic* priming (i.e., presentation of *doctor* before the target *nurse*) is the attenuation of the N400 component, a negative-going waveform believed to reflect processing costs during lexical access and semantic integration. While reductions of the N400 amplitude are the best known ERP correlates of semantic priming at the word level (Bentin, McCarthy, & Wood, 1985; Koivisto & Revonsuo, 2001), repetition priming (e.g., *face-face*) has an even stronger effect in reducing the N400 and, importantly, also affects the ERP signal in both earlier and later time windows than semantic priming (e.g., Rugg, 1987). Rugg's priming study demonstrated that repetition priming of both words and non-words affected processing as early as 200 ms and as late as 600 ms. Whereas early differences were similar in both priming conditions, the late effect was significantly larger for repeated words than non-words, suggesting that it may be attributable to the words' pre-existing representations in lexical memory (Rugg, 1987). As our review of ERP studies will highlight, morphological priming, similarly to repetition priming, also leads to modulation of negativities in an extended latency range.

ERP studies focusing on morphological relationships between words are relatively rare, in particular those investigating inflectional – as compared to derivational – morphology. Whether results obtained in derivational morphology studies can be generalized to inflectional morphology remains unclear. Using an unmasked priming paradigm (see Section 2.3 for a discussion of masking), Domínguez et al. (2004) reported a series of experiments on lexical access using morphologically related inflected primes (*hijo-hija* 'son-daughter'). They provide evidence for morphological priming that is distinct from semantic priming and cannot be attributed solely to formal priming. Spanish regular nouns appear with a noun marker suffix (*-a* or *-o*, for feminine and masculine nouns, respectively). Contrasts were made between these and three other types of pairs: stem homographs with similar word-initial orthographic CVC[1] overlap but no morphological relationship (*foco-foca* 'floodlight-seal'), orthographic-neighbor words with partial orthographic overlap (CV_V) such as *rasa-rana* ('flat-frog') as well as (semantic) synonym pairs (*cirio-vela* 'candle.m-candle.f').[2] All conditions were compared to unrelated prime–target pairs (ex. *pavo-meta* 'turkey-goal'). Results showed that morphological pairs resulted in a strong and long-lasting attenuation of the N400 amplitude (250–650 ms). In the homograph condition, an early N400 attenuation (250–350 ms) was observed, but this was followed by a *more* negative amplitude in the 450–650 ms time-window (a delayed N400). Orthographic neighbors did not show any signs of priming, while synonym priming showed only late N400 amplitude reductions (in the 450–650 ms time window). The authors interpreted their ERPs as evidence for three stages relevant to morphological processing, all resulting in relative positivities (reduced negativities): (1) effects of word segmentation into stem and affix (*hij-o*) and form priming at the lexeme level (250–350 ms), which were also found for stem homographs; (2) effects of lemma contact activating syntactic and semantic stem information (350–450 ms), which were absent for homographs; and (3) effects of semantic integration (450–650 ms), which were also observed for synonyms. As only morphological priming reduced the N400 amplitude across all three stages, the authors concluded that models lacking a morphological level of representation would be unable to explain these data.

Münte, Say, Clahsen, Schiltz, and Kutas (1999) studied the effects of (long-lag) morphological priming in English inflected regular (*walked-walk*) and irregular (*went-go*) verb pairs, for both real and novel (e.g., *broded-brode*) verbs. They observed reduced N400s for regular as opposed to irregular verbs. The effect, later replicated with Spanish verbs (Rodriguez-Fornells, Münte, & Clahsen, 2002), was restricted to real (as opposed to novel) word pairs. The results of these two studies were interpreted as showing differential access to (decomposable) regular and (non-decomposable) irregular verbs, illustrating how the N400's can be modulated by morphological structure. However, the authors simply assumed the existence of morphology and did not attempt to justify its status as an independent level of representation. Note that these studies did not have semantic priming control conditions, although Münte et al. use orthographic priming to control for formal overlap effects. A more recent study by de Diego-Balaguer, Sebastián-Gallés, Díaz, and Rodríguez-Fornells

[1] CVC = a consonant–vowel–consonant sequence.

[2] The '.m' in candle.m indicates it is a masculine noun in Spanish (.f = feminine).