

ELSEVIER

- [Home](#)
- [Products](#)
- [User Resources](#)
- [About Us](#)
- [Support & Contact](#)
- [Elsevier Websites](#)

Search

[Advanced Product Search](#)[Author's Home](#) > Track your accepted article**TRACK YOUR ACCEPTED ARTICLE**Welcome ! [Login](#) to get personalized options. New user? [Register](#) | [Why register?](#)[Help](#)

Your article's details and status are shown in the following table:

Article status

Article title:	THE TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION : A MASKED ERP PRIMING STUDY OF FRENCH VERBS
Reference :	NSY4634
Journal title:	Neuropsychologia
Corresponding author:	Mrs. Phaedra Royle
First author:	Mrs. Phaedra Royle
Received at Editorial Office :	26 Jan 2012
Article revised :	29 Aug 2012
Article accepted for publication :	4 Sep 2012
Received at Elsevier :	5 Sep 2012
Journal publishing agreement sent to author :	7 Sep 2012
Offprint order form sent to author :	7 Sep 2012
PDF offprint:	Yes
Expected dispatch of proofs :	17 Sep 2012
Journal publishing agreement returned :	7 Sep 2012
DOI information :	10.1016/j.neuropsychologia .2012.09.007
Status comment :	At this moment it is not yet possible to give you information about the publication date. This depends on the number of articles lined up for publication in the journal . Citation information will be shown when available .



[Home](#) | [Elsevier Sites](#) | [Privacy Policy](#) | [Terms and Conditions](#) | [Feedback](#) | [Site Map](#) | [A Reed Elsevier Company](#)

Copyright © 2012 **Elsevier B.V.** All rights reserved.

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

THE TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION:
A MASKED ERP PRIMING STUDY OF FRENCH VERBS

Phaedra Royle^{1,2}, John E. Drury³, Nicolas Bourguignon^{2,4}, Karsten Steinhauer^{2,5}

¹*École d'orthophonie et d'audiologie, Université de Montréal, Canada,*

²*Centre for Research on Brain Language and Music, Montreal, Canada*

³*Linguistics, Stony Brook NYU, USA*

⁴*Linguistique et traduction, Université de Montréal, Canada*

⁵*Communication Sciences and Disorders, McGill University, Montreal, Canada*

Author e-mails

phaedra.royle@umontreal.ca

john.drury@stonybrook.edu

nicolas.bourguignon@umontreal.ca

karsten.steinhauer@mcgill.ca

Corresponding author

Phaedra Royle

École d'orthophonie et d'audiologie

Université de Montréal

C.P. 6128, Succursale Centre-Ville

Montréal, Qc, Canada, H3C 3J7

514-343-6111 (0925)

phaedra.royle@umontreal.ca

Work carried out at:

Neurocognition of Language Lab

School of Communication Sciences and Disorders

McGill University

1266 Pine Avenue West

Montreal, Quebec H3G 1A8

Canada

34 PAGES

2 APPENDICES / 4 FIGURES / 3 TABLES

WORD COUNT: 9794 words

Short title: TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

Abstract

1 Morphological aspects of human language processing have been suggested by some to be
2
3 reducible to the combination of orthographic and semantic effects, while others propose that
4
5 morphological structure is represented separately from semantics and orthography and
6
7 involves distinct neuro-cognitive processing mechanisms. Here we used event-related brain
8
9 potentials (ERPs) to investigate semantic, morphological and formal (orthographic)
10
11 processing conjointly in a masked priming paradigm. We directly compared morphological to
12
13 both semantic and formal/orthographic priming (shared letters) on verbs. Masked priming
14
15 was used to reduce strategic effects related to prime perception and to suppress semantic
16
17 priming effects. The three types of priming led to distinct ERP and behavioural patterns:
18
19 semantic priming was not found, while formal and morphological priming resulted in
20
21 diverging ERP patterns. These results are consistent with models of lexical processing that
22
23 make reference to morphological structure. We discuss how they fit in with the existing
24
25 literature and how unresolved issues could be addressed in further studies.
26
27
28
29
30

31 [156 words]

32
33
34
35 Keywords: ERPs, Masked priming, Semantics, Morphology, Orthography, French
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1. Introduction

1 The nature of the organization of the mental lexicon enabling us to link sound patterns and
2 written words to their meaning has long been debated in psycholinguistics (e.g., Bates &
3 Godham, 1997; McQueen & Cutler, 1998). Of particular interest is the status of morphology
4 during word processing. By morphology we mean the structure of complex words and the
5 dynamic processes that allow us to decompose them into simple units (morphemes) that can
6 be recombined with other morphemes to create new words (Aronoff & Fudemann, 2011). We
7 distinguish between (i) *stem* morphemes that carry the core conceptual meaning (e.g., the
8 verb ‘inform’), (ii) *derivational* morphemes that (can) change the word’s syntactic category
9 and may dramatically change its meaning (e.g., ‘-ative’ can change a verb into an adjective:
10 ‘inform-ative’), and (iii) *inflectional* morphemes that primarily mark syntactic information
11 without changing the word category or the core meaning (e.g., ‘-s’ for the third person
12 singular present tense: ‘inform-s’).
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29

30 In the present study we address a number of questions: How is the processing of
31 inflectional morphology integrated in the time course of visual word recognition? What *are*
32 "morphological effects" found in behavioral and electrophysiological studies of lexical
33 access? Can we distinguish morphological from semantic and orthographic effects? And
34 which models can best account for these? Using event-related brain potentials (ERPs) to
35 investigate orthographic (formal), semantic, and morphological priming effects on the
36 processing of French verbs in a visual lexical decision task, we contrasted two views on the
37 role of morphology in the organization of the mental lexicon: morphological and
38 eliminativist.
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53

2. Background

2.1 Lexical processing models

54 Many psycholinguists regard morphological structure as an indispensable level of linguistic
55 representation (Baayen, Schreuder, & Sprodt, 2000; Domínguez, de Vega, & Barber, 2004;
56
57
58
59
60
61
62
63
64
65

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

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 stems 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, et al., 2007; Morris, et al., 2007; Morris, et al., 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 (Seidenberg & Gonnerman, 2000; Bates & Godham, 1997; Devlin, Jamison, Matthews, & Gonnerman, 2004, 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, Jamison, Matthews, & Gonnerman, 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 (Rueckl et al, 1997; Feldman & Protsko, 2002;

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 early and late 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

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

to inflectional morphology remains unclear. Using an unmasked priming paradigm (see section 2.3 for a discussion of masking), Domínguez, de Vega and Barber (2004) reported a series of experiments on lexical access using morphologically related 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 CVC¹ 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.

¹ CVC = a consonant-vowel-consonant sequence.

² The ‘.m’ in candle.m indicates it is a masculine noun in Spanish (.f = feminine).

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

Münte, Say, Clahsen, Schiltz and Kutas (1999) studied the effects of (long-lag) morphological priming in English 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 (Rodríguez-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 (2005) does contain a semantic control as well as a novel-word priming orthographic control condition. They studied regular and irregular verb processing in bilingual Catalan-Spanish speakers, while using an unmasked priming paradigm, with a concurrent letter search on the prime to reduce semantic priming effects. They show that morphological priming is much stronger than semantic priming and that regular and irregular verbs show different priming patterns (stronger reductions of the N400 in regular conditions only). A problem in Rodríguez-Fornells et al.'s (2002) and de Diego-Balaguer et al's (2005) stimuli is a possible confound between orthographic overlap and morphological regularity (i.e., the fact that regular verbs have more orthographic - and phonological - overlap, *walked-walk*, than irregular verbs, *went-go*), making it unclear which of these factors was driving the observed differences.

2.3 Masked priming

Another issue that arises with the studies discussed above is the use of (consciously) perceptible primes. This can affect how the target is processed as participants might develop

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

1 hypotheses about the relationship between the prime and the target (e.g., Lorch, Balota &
2 Stamm, 1986). Semantic priming is highly susceptible to this type of effect in behavioral
3 studies (Neely & Keefe, 1989; Kouider & Dehaene, 2007). An elegant way of addressing this
4 concern is the technique of *masking*, i.e., the combination of a very short prime presentation
5 (in the range of 25-50 ms) that is immediately followed (and often preceded) by a
6 meaningless character string such as “#####”. The backward mask can overwrite the visuo-
7 sensory representation and conscious perception of the prime and its features (also
8 preventing retinal after-images) (Holcomb & Grainger, 2006; Kiefer, 2007).

9
10 Masked priming reduces strategic processing (Forster & Davis, 1984; Forster, 1998).
11 Most importantly, in conjunction with short prime presentation, masking can entirely
12 suppress semantic priming, both behaviorally (Feldman & Probst, 2002; Forster, 1998;
13 Holcomb & Grainger, 2009; see Kouider & Dehaene, 2007 for a review) and in ERPs (Brown
14 & Hagoort, 1993; Lavric et al., 2007; Morris et al., 2007; Morris et al., 2008; Kouider &
15 Dehaene, 2007), while yielding both formal and morphological priming, allowing us to test
16 the putative dissociation of formal and morphological priming effects from semantic ones. A
17 few studies have reported semantic priming with masking and short prime presentation, either
18 with behavioral methods (Draine & Greenwald, 1998; Greenwald, Draine & Abrams, 1996;
19 but see Abrams & Greenwald 2000 for a re-interpretation of their own data), or using brain
20 imaging (Dehaene, Naccache, Cohen, Le Bihan, Mangin, Poline, et al., 2001; Dehaene,
21 Naccache, Le Clec’h, Koechlin, Mueller, Dehaene-Lambertz, et al. 1998; Deacon, Hewitt,
22 Yang, & Nagata, 2000; Kiefer 2002; Kiefer & Spitzer, 2000). However, **semantic priming**
23 **effects** from **a number of** the above-cited behavioural and brain imaging studies are driven
24 by **prime-target congruency**, **by attention being directed to the primes**, or **by strategies**
25 **based on partial perception of the prime** (Abrams & Greenwald 2000; Klinger, Burton &
26 Pitts, 2000; Kouider & Dehaene, 2007; **Kouider & Doupoux, 2007**). Kiefer and Brendel
27 (2006) found that, in masked semantic priming, modulation of the N400 did not reach
28 statistical significance when participants were instructed to focus on the target, even though

priming could appear at short SOAs (67 ms) when they were asked to attend to the prime.

1 Kiefer (2007) concludes that these studies provide "strong evidence that attention to an
2
3 unconsciously perceived masked stimulus is a prerequisite for semantic N400 ERP priming
4
5 effects to occur." (p. 298) **Kouider and Dupoux (2007) concur that "the only situations in
6
7 which semantic priming is found are cases of global [... or] partial awareness. Truly
8
9 unconscious priming is restricted to formal (or morphological) identity priming." (p.
10
11
12
13 81)**

14
15 Lavric, Clapp and Rastle (2007) as well as Morris and colleagues (Morris, Frank,
16
17 Grainger & Holcomb, 2007; Morris, Grainger & Holcomb, 2008) used masked priming in
18
19 ERP studies with English derived words, grouped into three types of pairs: morphologically
20
21 related (and semantically transparent) (e.g. *darkness-DARK*), pairs with no morphological
22
23 relationship (but see discussion below) that could in principle be decomposed into
24
25 pseudomorphs (*corner-CORN*, see 2.4 for a discussion of pseudomorphs), and unrelated (and
26
27 un-analyzable) but formally similar pairs (*brothel-BROTH*). The three studies found similar
28
29 priming effects for the two first conditions. First, an attenuation of the early N250 may
30
31 correspond to the early 'segmentation and form priming' effect reported by Domínguez et al.
32
33 (2004). Interestingly, these effects were weaker for the formal than the morphological
34
35 condition, suggesting at least some modulating role of lexical factors. This is compatible with
36
37 an interpretation of the N250 as indexing access to both sub-lexical phonology and word-
38
39 level orthographic representation at the sub-lexical/lexical interface (Holcomb & Grainger
40
41 2006). Importantly, most authors agree that the contribution of lexical processing on N250
42
43 effects does not implicate semantics (Lavric et al., 2007; Morris et al., 2008). These data are
44
45 in line with similar behavioural experiments (Longtin, Segui & Hallé, 2003; Taft &
46
47 Kougious, 2004).

48
49
50
51
52 More recently two studies using magneto-encephalography (MEG) have focused on
53
54 similar relations. Lehtonen, Monahan and Poeppel (2011) used Rastle et al.'s stimuli in a
55
56 forward masked priming task. They show that an early MEG signature around 220 ms,
57
58
59
60
61
62
63
64
65

1 potentially analogous to the N250 in ERPs, is differently affected by the type of prime-target
2 relationship. Transparent morphological pairs prime more than *opaque* ones and these in turn
3 prime significantly more than orthographic pairs. The latency of the MEG component was
4 also reduced in both morphological conditions, but not the orthographic one. The authors
5 argue that these results show similar prelexical effects of shared form to those of the ERP
6 studies. Likewise, an unmasked priming study for inflected English verbs shows that identity
7 and both regular and irregular verb priming (*jump-jumped*, *teach-taught*) result in shorter
8 M350 latencies (the MEG equivalent of the N400) than either pure formal (orthographic)
9 priming (*curt-cart*) or a priming condition combining formal and semantic but not
10 morphological relationships (*boil-broil*) (Stockall & Marantz, 2006). Taken together, these
11 studies support morphology as a distinct level of representation with an important role in
12 lexical processing, even in the absence of complete formal orthographic overlap. These data
13 converge toward a picture of lexical access that is initially mediated by shared form, followed
14 by morphological effects, and that this second aspect of lexical processing is different from
15 that found for orthography or semantics.

2.4 List effects arising from stimuli

16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41 However, a number of issues remain, partly due to methodological shortcomings of
42 previous studies. For one, a majority of the experiments reported here compared ERP or
43 MEG components elicited by *different* target stimuli in each of their experimental conditions,
44 as is the case with all the studies based on Rastle et al.'s (2004) stimuli lists including Lavric
45 et al. (2007), Morris et al. (2007; 2008) and Lehtonen et al. (2011). This is a recurrent issue in
46 priming studies (Forster, 2000) and can result in 'list effects' that are independent of the
47 manipulation of interest. For example, the priming found for derived forms might be driven
48 in part by the repeated presentation of specific derivational suffixes (Morris et al, 2008). In
49 addition, the linguistic criteria used to create stimuli for different 'morphological' conditions
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

are often problematic. For instance, the stimuli developed by Rastle and colleagues (2004) are divided into three groups based on orthographic overlap and morphological structure. The first group has transparent morphological stems and forms derived from these such as *bake-baker*, the second has pseudo-morphological relations such as *board-boarder*, where the derived word could be decomposed into a pseudo stem (*board*) and a pseudo suffix (*-er*). These are morphologically complex forms only in appearance.³ The third group of stimuli pairs has orthographic overlap with no possible (pseudo- or real) morphological parse, such as in *arse-arsenal*. These distinctions should help us distinguish morphological from orthographic parsing, since the semantic relationship between the stem and derived form in the so-called *opaque* (pseudo-morphological) condition is similar to that of simple orthographic overlap. However, a closer look at these lists raises a number of issues (see also Baayen et al., 2011). First, some of the items in the orthographic condition are in fact true (opaque) morphological pairs (*phone-phonetic*, *append-appendix*, *stamp-stampede*). Many pairs, such as *colon-colonel* do not share phonological structure (contrary to morphological pairs) (see Marslen-Wilson, Bozic & Randall, 2008; and Morris et al., 2008 on this issue). More importantly, in the so-called *opaque* (pseudo-morphological) list, we find true morphologically derived forms (such as *arch-archer*), which cannot therefore be pseudo-morphological. In fact, Rastle et al. (2004) state that “[a]lthough some of the prime target pairs [bore] an etymological relationship [...] *this was not a requirement.*” (p. 1092, our italics). According to our evaluation, some 15 of the 50 pairs in the pseudomorphological list bore a true morphological relationship. Such a stimulus blend is clearly suboptimal if the research question is whether an early automatic parser could recognize potential morphemes and might treat them differently from items having no real or apparent morphological structure. Notice also that there were items in the orthographic (‘non-morphological’) priming pairs that contained pseudomorphemes (*fusel-age*, *iron-irony*). So the case for rapid

³ They are called *semantically opaque* by Rastle and colleagues, although this is a misnomer, as this term usually indicates the presence of a semantically non-transparent morphological relationship, as in *master-mistress*.

and automatic parsing of possible (real or pseudo) morphemes is not clearly established by these studies, as these stimuli confound the linguistic dimensions of interest.

One specific issue in the context of our main research question (i.e., whether morphological effects can be fully explained as formal plus semantic effects) is that none of the reviewed studies, except that of Domínguez and colleagues (2004), compared more than two of the three priming conditions that interest us (morphological, semantic and formal-orthographic). Another concern related specifically to semantic priming is the *type* of pairs used to study this dimension of lexical processing. Many studies use semantic associates or other types of semantic or even collocational relationships (words found together or in close space in the corpus) that are arguably much more variable than the strong and consistent nature of the connections between morphologically related pairs (see Ferrand & New, 2003, for a review). In fact, *associative* relatedness (as in *salt - pepper*) may be of a quite different nature than that between the inflectional forms of a verb stem, given that the latter are much less likely to co-occur within the same sentence. This issue has spawned debate in the behavioral literature. Lucas (2000) argues that genuine semantic priming effects cannot be reduced to association priming, while Hutchison (2003) argues that apparent semantic priming is in fact based on association. In our view, a more stringent test of the semantic relationship in morphological pairs is that found either with synonym pairs or repetition priming (the latter, however, has the obvious problem of a full confound between morphological and formal priming).

Finally, the majority of morphological priming studies has focused on derivational morphology while neglecting inflectional morphology. To understand morphological processing as a whole, it seems necessary to investigate if effects obtained for derivational morphology hold for inflected word processing as well. We decided to replicate effects found for derived words with inflected words, using masked priming in an ERP study. An added advantage in using inflected forms is that they encode regular semantic relationships, allowing for highly constrained semantic similarity measures.

2.5 Predictions for the present study

Based on the literature discussed above, we expected our priming conditions to modulate two ERP components: the N250 and the N400. Formal priming effects on the N250 seem quite robust and have been observed in repetition priming (*table-TABLE*), partial repetition (*teble-TABLE*,⁴ Holcomb & Grainger 2006), and transparent derivation priming (*hunter-HUNT*, Morris et al. 2008). We thus expected N250 reductions for morphological as well as orthographic (formal) priming, with these effects being weaker for orthography, as found by Morris et al. (2008).

Unlike the N250, predictions for later priming effects in the N400 time-range crucially depend on whether (a) masking successfully suppresses semantic priming and (b) an independent status is assumed for morphology. One would expect to find a reduced N400 reflecting morphological priming, as has been found in numerous studies using masked-morphological priming (see, for example, Forster 1998) and in a number of ERP studies (Morris et al, 2007; Diependaele et al, 2005; Lavric et al, 2007). Moreover, the interpretation of such effects also depends on the results for orthographic priming: here we expected to replicate Morris et al.'s (2008) finding that orthographic overlap without semantic relationship (*scandal-SCAN*) yields only weak trends toward N250/N400 effects as compared to morphological priming.

The most robust N400 priming effects in previous studies are associated with semantic effects. In our study, morphological and semantic (synonym) primes were matched in their semantic relatedness with the targets, and semantic priming effects attenuating the N400 were expected to be the same for both conditions. According to eliminativist models, this semantic priming effect would be the only source for N400 attenuation in *both* the semantic and – crucially – also in the morphological priming condition. Semantic priming,

⁴ Note that this is in conflict with the absence of effects for orthographic neighbors in Domínguez et al (2004), however, Holcomb and Grainger use a sandwich masking design.

however, was expected to be absent in response latencies and ERP measures due to the masking procedure, as reported by Holcomb and Grainger (2009). This scenario leads to the following predictions for the models outlined above.

(1) According to eliminativist proposals, semantic and formal priming combined should result in a similar pattern to morphological priming. In terms of ERP components, one would expect to see similar early orthographic effects (attenuation of the N250) for the formal and the morphological conditions, and similar late semantic effects (attenuation of the N400) for the semantic and the morphological conditions. Importantly, if semantic priming effects are successfully suppressed by the masking procedure, this should prevent N400 attenuation equally in the semantic and the morphological conditions (resulting in comparable ERPs in the formal and the morphological conditions).

(2) Predictions based on a morphological perspective on word processing are quite different. Morphological priming should result in qualitatively different ERP signatures from formal or semantic priming, and one would also expect the *combined* orthographic and semantic effects to be different from those found for morphological priming. Crucially, successful suppression of semantic priming due to masking is *not* expected to eliminate priming effects on the N400 in the morphological condition. Facilitation for morphological and orthographic priming on the early N250 is also expected.

3. Methods

3.1 Participants

Twenty-four adults (12 women) between 18 and 35 years of age and with no history of neurological or language disorders participated in the experiment. All were right-handed as per the Edinburgh Handedness Inventory (Oldfield, 1971), were native speakers of Quebec French and had (corrected to) normal vision. They read and signed a consent form before the recording session and received 45.00 \$ for their participation. The study was reviewed and approved by the ethics boards of the Faculties of Medicine of McGill and the University of

Montreal, as well as the Centre de recherche CHU Ste-Justine.

3.2 Procedure

Participants were seated in a comfortable chair in a sound-attenuated and electromagnetically shielded recording booth, at a distance of ~ 1m from a computer screen. Participants were presented with one of three lists during the recording session, and were asked to decide if the string of letters on the screen was a French word or not by clicking a mouse key (lexical decision task, LDT). Every prime-target pair was presented following the scheme outlined in Figure 1. Primes, preceded by a (forward) mask for 500 ms, stayed on the screen for 50 ms and were followed by a 20 ms (backward) mask. A target word was then presented for 300 ms and was followed by an LDT response interval of up to one second. As soon as the response key was pressed, a visual prompt (“- -”) was presented for two seconds to indicate the interval allotted for eye blinking (reducing the number of eye-blink contaminated trials).

[-----Insert Figure 1 here-----]

3.2.1 Stimuli

For each verb target, three primes and their controls⁵ were used: Morphological: *cassait* – *CASSE* ‘broke – break’ (control: *disait* ‘said’); Formal: *cassis* – *CASSE* ‘blackcurrant – break’ (control: *dorsal*); Semantic: *brise* – *CASSE* ‘break – break’ (control: *moque* ‘mock’). We used the same targets in all priming conditions, thus allowing direct comparisons across conditions and avoiding list effects. Stimuli are presented in Appendix A. Formal primes were real words of French without internal morphological structure. They did not share any semantic relationship with the target. Morphological and formal primes were matched (item by item) on the amount of formal overlap they shared with the target, as well as on orthographic, syllabic and phonological structure and oral language frequency (New et al,

⁵ Controls were matched with primes in length (syllable and letter) oral surface frequency and morphological structure.

2001). All initial letters and phonemes were the same in these two conditions (e.g., cassait vs. cassis, for target CASSE). Semantic primes were synonyms of the targets, and had no formal overlap with the target. To maximize the similarity of semantic priming strength across the two conditions, semantic and morphological primes were additionally matched on their semantic overlap with the target. We had native speakers rate semantic overlap on all prime-target pairs on a Likert scale from one to six (1 meaning none, 6 meaning complete) presented in pairs of sentences. Because of our stringent criteria for stimuli selection, we ended up with a master list of 42 target items. We decided to repeat targets within presentation lists, considering we wanted to compare responses to the same target primed in different conditions. However, we reduced to four the amount of times a given target was seen within a session. Three presentation lists were generated from this master list. Stimuli lists are in Appendix B (examples of conditions for a given target are shaded in grey). This yielded 28 items for each of the six main priming conditions per list. Each target word repetition within a session appeared in two distinct experimental conditions along with their respective controls. Target word repetitions never occurred within the same $\frac{1}{4}$ of any list. The order of target repetitions (e.g., experimental before control, or vice-versa) was evenly distributed and flipped across lists. Filler items and experimental pairs were pseudo-randomized, with each list arranged into 4 blocks (allowing three breaks), with all conditions equally distributed across the blocks. Finally, to avoid purely formal letter overlap and ERP effects arising from this (Chauncey, Holcomb, & Grainger, 2008), all of the pairs in every list were presented with the primes in lower-case and target word in UPPER CASE, or *vice-versa*, these conditions were counterbalanced across lists and conditions.

3.2.2 EEG data recording and analysis

The EEG was recorded continuously with a 500 Hz sampling rate from 64 cap-mounted electrodes (Electrocap International Inc., Eaton: OH). Four additional electrodes were attached above and below the left eye as well as on both temples to monitor vertical and

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

horizontal eye movement respectively. All impedances were maintained below 5 Ω (impedance for eye electrodes was under 10 Ω). The EEG was amplified using a Neuroscan SYNAMPS2 DC amplifier, referenced to the right mastoid. All subsequent steps of EEG/ERP data processing and analysis were carried out with the EEProbe software package (ANT; Enschede, The Netherlands). Offline, data were re-referenced to linked mastoids and filtered with a bandpass of 0.3 to 40Hz. Trials contaminated with eye blinks and other artifacts were rejected using a 30 μ V criterion (resulting in a data loss of 9 %, evenly distributed across conditions). Only trials in which target words were correctly accepted as real words in the LDT (approximately 500 trials per condition) entered the final analyses. ERP averages were computed in an 800 ms time epoch, including a 100 ms prestimulus baseline interval (-100 to 700 ms). ERP components were quantified in three time windows: 175-275 ms (N250), 350-450 ms and 450-550 ms (early and late N400). Mean amplitude data for each of these time windows were subjected to repeated-measures ANOVAs, separately for 5 midline electrodes (FZ, FCZ, CZ, CPZ, PZ) and 30 lateral electrodes that were organized according to factors *Hemisphere* (2 levels: left, right), *Column* (3 levels: medial [e.g., F1/F2], intermediate [e.g., F5/F6], and lateral [e.g., F7/F8]), and *Anterior-Posterior* (5 levels, see midline electrodes). In addition to these topographical factors, the ANOVAs included the experimental factors *Prime* (2 levels: related vs unrelated) and *prime Type* (3 levels: formal, semantic, morphological).⁶

4. Results

4.1 Behavioral data

As expected, there were no processing differences for targets following synonyms versus unrelated controls on both lexical decision response accuracy (control: 88%, primed: 87%; F

⁶ Note that we also conducted analyses including all 64 EEG electrodes. However, as these more complex analyses did not reveal any relevant additional effects while requiring more follow-up analyses (and space) to identify the actual data pattern, we will report the simpler analyses here for reasons of transparency and efficiency.

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

< 1) and latency (control: 705 ms, primed: 699 ms; $F < 1$). Response accuracy was significantly higher for the formally-primed (89%) versus control (83%) conditions [$F(1, 23) = 10.85, p < 0.01$]. The formally-primed condition (687 ms) was also numerically faster than its matched control (701 ms), but this difference did not reach significance [$F(1, 23) = 2.42, p = 0.12$]. There were no differences in response accuracy for morphologically-primed and control conditions (both 86%; $F < 1$). Decision times, however, demonstrated a significant priming effect: the morphologically primed conditions (693 ms) were 29 ms faster than control ones (722 ms; [$F(1, 23) = 8.23, p < 0.01$]).

[-----Insert Figure 2 here-----]

[-----Insert Figure 3 here-----]

4.2 Event-related potentials

Grand average waves for each of the three comparisons (semantic, formal, and morphological) are shown in Figures 2 and 3. As expected, in the semantic comparison the primed and control conditions demonstrated similar waveforms throughout the entire measurement epoch, suggesting that masking successfully suppressed semantic priming. In contrast, for both the formal and morphological comparisons the primed and control condition waveforms diverged between approximately 200-450 ms post-target word onset (with controls more negative-going). While this priming effect continued in the morphological priming condition until after 500 ms, the formal priming condition displayed an inverse pattern in this late time range (with controls more *positive*-going). Corresponding difference waves (primed minus control) and scalp voltage maps for each of these two conditions in all three time windows are shown in Figure 4.

4.2.1 Standard analyses of ERP priming effects

Consistent with these observations, the global ANOVA revealed Type \times Prime (\times topography) interactions in the N250 (175-275 ms) and N400 (350-450 and 450-550 ms)

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

time-windows, confirming significant ERP differences among the three priming conditions.

1 First, the N250 latency range yielded, in the lateral analyses, T × P interactions with
2 topographic factors Hemisphere [$F(1, 23) = 3.24, p < 0.05$] and Hemisphere × Column [$F(2,$
3 $46) = 4.02, p < 0.05$]. Main effects of Prime were also obtained in lateral and midline
4 analyses [*lateral*: $F(1, 23) = 5.81, p < 0.05$; *midline*: $F(1, 23) = 5.84, p < 0.05$]. Second, T × P
5 interactions also manifested in the two N400 time-windows in the lateral analyses [*350-450*
6 *ms*, T×P: $F(1, 23) = 3.55, p < 0.05$; *450-550 ms*, T×P×H: $F(1, 23) = 3.38, p < 0.05$], with
7 corresponding trends towards T × P interactions on the midline [*350-450 ms*: $F(1, 23) = 2.98,$
8 $p < 0.10$; *450-550 ms*: $F(1, 23) = 2.64, p < 0.10$].
9

10 These Type × Prime interactions were followed up in two steps. First, we confirmed
11 the absence of semantic priming effects on the ERPs by examining that comparison in a
12 separate ANOVA for the semantic condition. Consistent with the pattern evident in the grand
13 average waves (Figure 2), there were no statistically detectable effects of synonym priming
14 on ERPs in any of the time-windows tested.⁷
15

16 [-----Insert Figure 4 here-----]
17

18 Second, given the apparent pattern of partly shared and partly divergent ERP effects
19 across the formal and morphological comparisons (see voltage maps in Figure 4), these
20 conditions were compared in a further ANOVA (excluding the semantic prime/control
21 conditions). Results are shown for all time-windows in Table 1. Consistent with the visual
22 inspection of the data, main effects of priming were evident in the N250 and in the early
23 N400 (350-450 ms) time-windows at both lateral and midline electrodes. Additionally, there
24 was a significant T x P interaction in the lateral analysis in the late N400 (450-550 ms) time
25 window (and a corresponding trend at midline electrodes), as well as a four-way interaction
26

27 ⁷ These analyses did reveal Prime × Hemisphere interactions in the 175-275 ms and 450-550
28 ms time-windows. However, neither of these interactions corresponded to main effects of
29 priming in either hemisphere [all F 's < 1]. These interactions were due to slight trends in
30 opposite directions across the hemispheres (see Figure 2).
31

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

involving the factors Column and Hemisphere in the 175-275 ms range. Follow-up analyses conducted separately for the morphological and formal priming conditions in the N250 and in the N400 time-windows are presented in Table 2.

[-----Insert Table 1 here-----]

[-----Insert Table 2 here-----]

Here we observe that the Morphological condition shows a main effect of Prime at the lateral electrodes for both N400 time-windows and corresponding trend and significant effect at midline electrodes, while a trend toward a Prime effect is observed in the 175-275 window for both lateral and midline analyses. A Prime x Column interaction is also found in the 175-275 time-window, pointing to a larger priming effect at medial rather than more lateral electrodes (see voltage map in Fig. 4).

In the Formal condition, there is a trend for a Prime x Column x Hemisphere effect in the N250 time window, pointing to a weak and somewhat left-lateralized positivity. In the early N400 interval (350-450 ms), a trend for main effect of Prime is observed at midline electrodes along with an interaction of Prime x Anteriority at both midline and lateral electrodes. Trends for interactions of Prime with topographic factors Column are observed in the lateral analysis. Between 450 and 550 ms, a Prime x Anteriority effect at midline electrode reflected the inverse effect of priming in orthographic conditions alluded to in 4.2.

4.2.2 Additional ERP analyses using a common control condition

One potential concern regarding the results reported above has to do with the use of different control conditions for each priming condition. Recall that prime words in the control conditions were individually matched with the prime words of their respective priming conditions (see Appendix A). This procedure is standard in sophisticated psycholinguistic research on lexical priming (Feldman & Protsko, 2002) and was purposefully adopted here in order to control for systematic differences that necessarily exist between the prime words in

our three priming conditions. For instance, primes in the morphological (and the formal) condition were inevitably slightly longer than synonyms in the semantic condition. By matching the length of the prime and its respective control within a given priming condition we ensured that any effects in the behavioral or ERP data could not be attributable to word length. This rationale also holds for *differences* observed between the priming conditions. We believe this is the best approach to our research question. However, it could be argued that the differences in priming effects reported above may be driven by differences of the control rather than the experimental priming conditions. Even though we do not agree with this view, the strongest evidence supporting our findings would be to demonstrate that the findings are robust even when the three priming conditions are compared to the same control condition. To this end, we computed a new ‘common control’ condition by averaging across the ERPs of the three original control conditions. In a second step, we compared the ERPs of each priming condition with this common control (Table 3). These statistical analyses replicated the pattern reported above. Most importantly, whereas the morphological priming condition displayed significant main effects of priming in all three time windows (at lateral and midline electrodes), both the semantic and the orthographic condition did not show any significant main effect. There was only a tendency for orthographic priming at midline electrodes in the early N400 time interval and two complex interactions of prime by anteriority by hemisphere (by column) in lateral electrodes for semantic priming in the two N400 time intervals.⁸

[-----Insert Table 3 here-----]

5. Discussion

The data from our experiment show that the three priming conditions result in three distinct patterns of lexical activation. That is, semantic priming is not observed either behaviorally or in the ERPs, whereas formal and morphological priming elicit different ERP signatures and

⁸ See footnote 7. Neither of these interactions corresponded to main effects of priming in either hemisphere [all F's < 1]. These interactions were due to slight trends in opposite directions across the hemispheres.

behavioral results. We discuss these in turn.

1 *First*, the fact that semantic priming does not obtain is not surprising, given that a
2
3 considerable number of different masking studies have shown that this type of priming can be
4
5 suppressed with short presentation times, short SOAs, masking and the absence of directed
6
7 attention to the primes. As Kiefer (2007) suggests in his review of masked semantic priming,
8
9 primes must be attended in order for a significant semantic modulation of the N400 to
10
11 emerge. Although some complex interactions were found in the statistical analyses, these do
12
13 not occur in the midline electrodes, where N400s typically surface, and appear to reflect
14
15 slight differences in relative positive and negative going waves in the two hemispheres.
16
17
18
19

20 Our present study extends similar previous results in that it shows that sandwich-
21
22 masking entirely suppresses the facilitation effects for one of the strongest possible types of
23
24 semantic prime: synonyms. As we have argued above, synonyms can be viewed as a much
25
26 better semantic match (or control) for morphological primes than associative primes. The
27
28 absence of synonym priming cannot be explained by our types of pairs (i.e., the possibility
29
30 that French synonyms may not be reliable primes), since we did observe large and significant
31
32 N400 reductions in a concurrent study on *unmasked* synonym priming in French, partly
33
34 involving the same participants as in the present study (Steinhauer, Nadeau-Noel, Drury &
35
36 Royle, 2008; Steinhauer et al, in preparation). As we will see below, the absence of any
37
38 synonym priming in our study allows us to draw much more specific conclusions regarding
39
40 the nature of (late) morphological priming effects than studies that either did not use masking
41
42 (e.g., Domínguez et al., 2004) or did not include a corresponding synonym prime condition
43
44 (this is the case for most of the studies discussed above).
45
46
47
48
49
50

51 *Second*, we observed that formal (orthographic) priming facilitated word recognition
52
53 behaviorally and slightly reduced the amplitude of negative-going ERPs between
54
55 approximately 200 and 450 ms, which resulted in non-significant trends in the N250 and
56
57 early N400 time-windows. This is similar to effects found for orthographic priming in a
58
59 number of studies reported above, where shared orthography resulted in early N250 effects
60
61
62
63
64
65

and a short-lived attenuation of the N400. However, in contrast to at least some of those studies, we made sure that the orthographic overlap was always word-initial (all first letters up to the suffix, see e.g., Domínguez et al. 2004), was equal to that found in morphological priming (no more and no less), and never created a phonological mismatch (as, e.g., *colon - COLONEL* would; Lavric et al., 2007; Morris et al., 2007; 2008; Lehtonen et al., 2011). Our data support previous interpretations according to which N250 attenuations can occur in the absence of any semantic or morphological overlap. However, they also suggest that purely formal priming effects in ERPs can extend into the early N400 time range, even under masked priming conditions⁹.

Third, in the morphological priming condition, we found two consecutive patterns. The first one, an attenuated negative-going wave, occurred in an early time window (in the N250 time range) and was broadly distributed with a fronto-central maximum near the midline. This effect resembles, in terms of timing and scalp distribution, the pre-lexical orthographic N250 effects previously reported in a considerable number of priming studies for morphologically-related derived words (e.g., Holcomb & Grainger in 2006). The effect is similar to that in our formal condition, but was more robust for morphological than orthographic primes. This finding (although not reflected by a significant interaction) may be viewed as support for the notion that the N250 does not exclusively reflect formal (pre-lexical) overlap between prime and target, but is instead modulated by lexical processes (Domínguez et al., 2004; Morris et al., 2007; 2008). Interestingly, the absence of any semantic priming effects in the N250 time window confirms previous suggestions that the contributions at a lexical level are, in fact, independent of semantic representations. In line with Domínguez et al.'s (2004) argument, a plausible account for this finding would locate the lexical contribution to N250 effects at the (morphologically motivated) level of word

⁹ Recall that a shared main effect of priming between 350 and 450 ms was found across orthographic and morphological conditions (Table 2). In absence of a significant interaction with prime type, this pattern is best interpreted as an N400 reduction in both conditions (see Nieuwenhuis et al., 2011).

segmentation for inflection (*cass-ait* -> *cass-e*).¹⁰ The main difference between the two

1 conditions would then point to a successful segmentation/decomposition in the morphological
 2
 3 (*cass-ait*) but not the formal condition (*cassis* with no possible morphological parse *pseudo* or
 4
 5 otherwise).
 6

7
 8 The second – and most important – effect in the morphological condition, a broadly
 9
 10 distributed and significant attenuation of the negative going wave, was observed in the
 11
 12 primed versus unrelated condition between 350 and 550 ms post onset (resembling a classic
 13
 14 N400). This effect most probably reflects co-activation of the morphological stem or root
 15
 16 form, from the prime to the target. A direct comparison of the formal and orthographic
 17
 18 priming conditions (see Figure 4) reveals that these two result in significantly different
 19
 20 patterns in late time windows, such that morphological priming causes long-lasting
 21
 22 reductions of the N400, while the effects of formal priming are more transient. This late
 23
 24 N400 attenuation for morphological priming is especially remarkable, as no indication for a
 25
 26 similar effect was seen in the semantic condition. If anything, the primed semantic condition
 27
 28 showed a *larger* N400 in the second (combined control) analysis. Since we used synonyms,
 29
 30 the absence of any N400 effect for these primes shows that our masking procedure
 31
 32 successfully eliminated even the slightest tendencies of semantic priming. In other words, in
 33
 34 contrast to certain ambiguities in previous studies, the present morphological N400 effect
 35
 36 cannot be attributed to, or confounded with, semantic facilitation. We believe it is best
 37
 38 characterized as a genuine morphological priming effect, as predicted by traditional linguistic
 39
 40 theory. In our opinion, eliminativist models, according to which morphology is viewed as an
 41
 42 ‘emergent’ description that can be entirely accounted for in terms of (i) orthographic (or
 43
 44 phonological) and (ii) semantic similarities among words, are unable to explain our pattern of
 45
 46 results.
 47
 48
 49
 50
 51
 52
 53
 54
 55
 56

57 In conclusion, there were no semantic priming effects on any measure, while both

58
 59 ¹⁰ As our formal primes (*cassis* [ka.sis]) had similar but not always identical syllable
 60
 61 structures as the morphological primes (*cassait* [ka.se]), a phonological effect in terms of
 62
 63 syllable structure cannot be ruled out.
 64
 65

morphological and orthographic facilitation effects were observed. Morphological priming using inflected forms yielded robust N250 and N400 effects. Orthographic priming yielded a weak N250 effect and a short-lived weak N400 reduction. Direct comparisons of the two types of priming in the early N250 time-window yielded no significant interactions with the factor prime-type, suggesting a shared (and graded) effect related to orthographic overlap. In contrast, the subsequent N400 effect had a significantly longer duration for morphology (375-575 ms) than orthography (375-425 ms), and robust priming by type interactions were obtained at 475-575 ms post target onset.

5.1 Models

Some eliminativists have recently suggested that formal overlap may be helpful in word recognition *only* (or significantly more so) if there is *also* a semantic relationship between the prime and the target (Seidenberg & Gonnerman, 2000; Morris & Grainger, 2009)¹¹. This stance is, however, indistinguishable from a classical morphological view. Thus it is quite difficult to imagine any pattern of results that would *not* be explainable (at least post-hoc) according to at least some eliminativist accounts. Nevertheless, we propose that, differences in the ERP waves and time-courses for different priming conditions for morphological pairs as compared to orthographic and semantic pairs would be grounds for a morphologically based model. In particular, if semantic priming is suppressed while orthographic and morphological priming are maintained, and these two last priming types show different time-courses and/or topographies in target processing, we believe this is related to the activation of different levels of processing in the mental lexicon (i.e., orthographic and morphological).

These patterns are consistent with a picture of morphology as having both pre- and post-lexical responses (indexed by both N250 and N400 effects). The early effect likely

¹¹ Since these models argue all information is available, the argument could go the other way around: that semantic overlap may be helpful in word recognition *only* if there is *also* a formal relationship between the prime and the target

reflects automatic processing of orthographic overlap between prime and target as well as the parsing of potential morphological constituents, as has been shown in previous ERP and psycholinguistic experiments (e.g., Morris et al., 2008; Longtin et al., 2003). The most important result of our study is the difference between all priming types at later time windows, in particular, strong modulation of the N400 by morphological but not by either orthographic or semantic priming. These results converge with data from Spanish showing that orthographic overlap (even in the case of Spanish homographic stems) is not sufficient to produce effects similar to morphological priming (Domínguez, et al., 2004). These data also converge with studies of derivational and inflectional morphology showing morphological modulation of the N400 (e.g., Münte et al., 1999; Rodríguez-Fornells et al, 2002; de Diego-Balaguer et al., 2005; Lavric et al., 2007; Morris et al., 2007, 2008). However, under the assumption that semantics, even in the absence of main effects, can interact with orthographic effects such that they elicit quantitatively and qualitatively distinct ERP patterns, it is theoretically possible that eliminativist approaches could also account for our data. Our experiment cannot provide a clear-cut answer regarding this issue, however we can address this question based on a synthesis of the present and other work. In particular, it has been shown that semantically and orthographically related pairs (*broil-boil*) do not pattern like morphological pairs in MEG priming (see discussion of Stockall & Marantz, 2005, in 2.3 above). Thus, in conjunction with our data, the experiments on Spanish and English seem to point to the existence of morphologically based parsing of words during lexical access.

We project to develop studies using similar (*broil-boil*) pairs in French, and we expect non-morphological priming of this type to pattern similarly to orthographic priming in our task, and differently from morphological priming, if morphology is truly cognitively represented. In addition we would expect orthographic priming effects to be modulated by prime presentation duration or interstimulus intervals between prime and target, in particular, we should be able to completely suppress orthographic priming (or make it inhibitory) by providing a longer inter-stimulus interval or by making the prime more perceptible to participants. We would expect

morphological priming to maintain facilitatory priming effects even under these conditions.

1
2
3 5.2 Conclusion
4

5 In conclusion, our data are consistent with evidence from a large body of work in
6 psycholinguistics and a growing body of neurolinguistic data showing evidence for abstract
7 knowledge of morphological organization in the lexicon (Domínguez et al., 2004; McQueen
8 & Cutler, 1998). However, further research, is needed to refine our understanding of the
9 issues raised relative to the clear interpretation of these data in light of different models of
10 visual word processing.
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

References

- 1 Abrams, R. L., & Greenwald, A. G. (2000). Parts Outweigh the Whole (Word) in
 2 Unconscious Analysis of Meaning. *Psychological Science*, *11*(2), 118-124.
- 3 Aronoff, M., & Fudemann, K. (2011). *What is Morphology?* (2nd ed.). Oxford: Wiley-
 4 Blackwell.
- 5 Baayen, H., Milin, P., Filipović Đurđević, D., Hendrix, P., & Marelli, M. (2011). An
 6 amorphous model for morphological processing in visual comprehension based on
 7 naive discriminative learning. *Psychological Review*, *118*, 438-482.
- 8 Baayen, H., Schreuder, R., & Sprodt, R. (2000). Morphology in the mental lexicon: A
 9 computational model for visual word recognition. In R. v. Eynde & D. Gibbon (Eds.),
 10 *Lexicon development for speech and language processing*. Dordrecht: Kluwer
 11 Academic Publishers.
- 12 Bates, E., & Godham, J. C. (1997). On the inseparability of grammar and the lexicon:
 13 Evidence from acquisition, aphasia, and real-time processing. *Language and*
 14 *Cognitive Processes*, *12*(5-6), 507-584.
- 15 Chauncey, K., Holcomb, P. J., & Grainger, J. (2008). Effects of stimulus font and size on
 16 masked repetition priming: An event-related potentials (ERP) investigation. *Language*
 17 *and Cognitive Processes*, *23*(1), 183-200.
- 18 Clahsen, H. (2006). Linguistic Perspectives on Morphological Processing. In D. Wunderlich
 19 (Ed.), *Advances in the Theory of the Lexicon* (pp. 355-388). Berlin: Mouton de
 20 Gruyter.
- 21 Colé, P., Beauvillain, C., & Segui, J. (1989). On the Representation and Processing of
 22 Prefixed and Suffixed Derived Words: A Differential Frequency Effect. *Journal of*
 23 *Memory and Language*, *28*, 1-13.
- 24 Deacon, D., Hewitt, S., Yang, C.-M., & Nagata, M. (2000). Event-related potential indices of
 25 semantic priming using masked and unmasked words: evidence that the N400 does
 26 not reflect a post-lexical process. *Cognitive Brain Research*, *9*, 137-346.
- 27 de Diego-Balaguer, R., Sebastián-Gallés, N., Díaz, B., Rodríguez-Fornells, A. (2005).
 28 Morphological processing in early bilinguals: an ERP study on regular and irregular
 29 verb processing. *Cognitive Brain Research*. *25*:312-327
- 30 Dehaene, S., Naccache, L., Cohen, L., Le Bihan, D., Mangin, J.-F., Poline, J.-B., et al.
 31 (2001). Cerebral mechanisms of word masking and unconscious repetition priming.
 32 *Nature Neuroscience*, *4*, 752-758.
- 33 Dehaene, S., Naccache, L., Le Clec'H, G., Koechlin, E., Müller, M., Dehaene-Lambertz, G.,
 34 et al. (1998). Imaging unconscious semantic priming. *Nature*, *395*, 597-600.
- 35 Devlin, J. T., Jamison, H. L., Matthews, P. M., & Gonnerman, L. M. (2004). Morphology and
 36 the internal structure of words. *Proceedings of the National Academy of Science*,
 37 *101*(41), 14984-14988.
- 38 Diependaele, K., Sandra, D., & Grainger, J. (2005). Masked cross-modal morphological
 39 priming: Unravelling morpho-orthographic and morpho-semantic influences in early
 40 word recognition. *Language and Cognitive Processes*, *1*/2(75-114).
- 41 Domínguez, A., de Vega, M., & Barber, H. (2004). Event-related Brain Potentials Elicited by
 42 Morphological, Homographic, Orthographic, and Semantic Priming. *Journal of*
 43 *Cognitive Neuroscience*, *16*(4), 598-608.
- 44 Draine, S. C., & Greenwald, A. G. (1998). Replicable unconscious semantic priming. *Journal*
 45 *of Experimental Psychology General*, *127*, 286-303.
- 46 Feldman, L. B., & Prostko, B. (2002). Graded aspects of morphological processing: Task and
 47 processing time. *Brain & Language*, *81*(1-3), 12-27.
- 48 Ferrand, L., & New, B. (2003). Semantic and Associative Priming in the Mental Lexicon. In
 49 P. Bonin (Ed.), *Mental lexicon: Some words to talk about words*. Hauppauge, NY:
 50 Nova.

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

- Forster, K. I. (1998). The Pros and Cons of Masked Priming. *Journal of Psycholinguistic Research*, 2(2), 203-233.
- Forster, K. I. (2000). The Potential for Experimenter Bias Effects in Word Recognition Experiments. *Memory & Cognition*, 28(7), 1109-1115.
- Greenwald, A. G., Draine, S. C., & Abrams, R. L. (1996). Three cognitive markers of unconscious semantic activation. *Science*, 273, 1699-1702.
- Hay, J. & Baayen, R. H. (2005). Shifting paradigms: gradient structure in morphology. *Trends in Cognitive Sciences* 9(7), 342-348.
- Holcomb, P. J., & Grainger, J. (2006). On the Time Course of Visual Word Recognition: An Event-related Potential Investigation Using Masked Priming. *Journal of Cognitive Neuroscience*, 18(10), 1631-1643.
- Holcomb, P. J., & Grainger, J. (2009). ERP effects of short interval masked associative and repetition priming. *Journal of Neurolinguistics*, 22, 301-312.
- Hutchison, K. A. (2003). Is semantic priming due to association strength or feature overlap? A micro-analytic review. *Psychonomic Bulletin & Review*, 10, 785-813.
- Kiefer, M. (2002). The N400 is modulated by unconsciously perceived masked words: Further evidence for an automatic spreading activation account of N400 priming effects. *Cognitive Brain Research*, 13, 27-39.
- Kiefer, M. (2007). Top-down modulation of unconscious 'automatic' processes: A gating framework. *Advances in Cognitive Psychology*, 3(1-2), 289-306.
- Kiefer, M., & Brendel, D. (2006). Attentional modulation of unconscious 'automatic' processes: Evidence from event-related potentials in a masked priming paradigm. *Journal of Cognitive Neuroscience*, 18, 184-198.
- Kiefer, M., & Spitzer, M. (2000). Time course of conscious and unconscious semantic brain activation. *NeuroReport*, 11, 2401-2407.
- Klinger, M. R., Burton, P. C., & Pitts, G. S. (2000). Mechanisms of unconscious priming I: response competition not spreading activation. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 26, 441-455.
- Koivisto, M., & Revonsuo, A. (2001). Cognitive representations underlying the N400 priming effect. *Cognitive Brain Research*, 12(3), 487-490.
- Kouider, S., & Dehaene, S. (2007). Levels of processing during non-conscious perception: a critical review of visual masking. *Philosophical Transactions of the Royal Society B*, 362, 857-875.
- Kouider, S., & Dupoux, E. (2007). Partial awareness creates the "Illusion" of subliminal semantic priming. *Psychological Science*, 15(75-81).
- Landauer, T. K., & Dumais, S. T. (1997). A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction, and representation of knowledge. *Psychological Review*, 104, 211-240.
- Lavric, A., Clapp, A., & Rastle, K. (2007). ERP Evidence of Morphological Analysis from Orthography: A Masked Priming Study. *Journal of Cognitive Neuroscience*, 19(5), 866-877.
- Lehtonen, M., Monahan, P. J., & Poeppel, D. (2011). Evidence for early morphological decomposition: combining masked priming with magnetoencephalography. *Journal of Cognitive Neuroscience*, 23(11), 3366-3379.
- Longtin, C.-M., Segui, J., & Hallé, P. A. (2003). Morphological priming without morphological relationship. *Language and Cognitive Processes*, 18(3), 313-334.
- Lorch, R. F., Balota, D. A., & Stamm, E. G. (1986). Locus of inhibition effects in the priming of lexical-decisions: pre- or postlexical access? *Journal of Memory and Cognition*, 14, 95-103.
- Lucas, M. (2000). Semantic priming without association: A meta-analytic review. *Psychonomic Bulletin & Review*, 7, 618-630.
- Marslen-Wilson, W. D., Bozic, M., & Randall, B. (2008). Early Decomposition in Visual Word Form Recognition: Dissociating Morphology, Form, and Meaning. *Language*

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

and Cognitive Processes, 23(3), 394-421.

- 1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
- McQueen, J. M., & Cutler, A. (1998). Morphology in Word Recognition. In A. Spencer & A. M. Zwicky (Eds.), *The Handbook of Morphology* (pp. 406-427). Oxford: Blackwell.
- Morris, J., Frank, T., Grainger, J., & Holcomb, P. J. (2007). Semantic transparency and masked morphological priming: An ERP investigation. *Psychophysiology*, 44, 506-521.
- Morris, J., Grainger, J., & Holcomb, P. J. (2008). An electrophysiological investigation of early effects of masked morphological priming. *Language and Cognitive Processes*, 23(7-8), 1021-1056.
- Münte, T. F., Say, T., Clahsen, H., Schiltz, K., & Kutas, M. (1999). Decomposition of morphologically complex words in English: Evidence from event-related brain potentials. *Cognitive Brain Research*, 7, 241-253.
- Nieuwenhuis, S., Forstmann, B. U., & Wagenmakers, E.-J. (2011). Erroneous analyses of interactions in neuroscience: a problem of significance. *Nature Neuroscience*, 14, 1105-1107.
- Steinhauer, K., Drury, J., & Royle, P. (in preparation). The priming of priming in French.
- Steinhauer, K., Nadeau-Noel, K., Drury, J. E., & Royle, P. (2008). The priming of priming: A cross-linguistic ERP study. *Journal of Cognitive Neuroscience*, 20, 216.
- Neely, J. H., & Keefe, D. E. (1989). Semantic context effects on visual word processing: a hybrid prospective retrospective processing theory. In G. H. Bower (Ed.), *The Psychology of Learning and Motivation: Advances in Research and Theory* (Vol. 23, pp. 207-248). New York: Academic Press.
- Oldfield, R. C. (1971). The Assessment and Analysis of handedness: The Edinburgh Inventory. *Neuropsychologia*, 9, 97-115.
- Rastle, K., Davis, M. H., & New, B. (2004). The broth in my brother's brothel: Morpho-orthographic segmentation in visual word recognition. *Psychonomic Bulletin & Review*, 11(6), 1090-1098.
- Rueckl, J. G. (2010). Connectionism and the role of morphology in visual word recognition. *The Mental Lexicon*, 5(3), 371-400.
- Rueckl, J. G., Mikolinski, M., Raveh, M., Miner, C. S., & Mars, F. (1997). Morphological priming, connectionist networks, and masked fragment completion. *Journal of Memory and Language*, 36, 382-405.
- Rodriguez-Fornells, A., Münte, T. F., & Clahsen, H. (2002). Morphological priming in Spanish verb forms: An ERP repetition priming study. *Journal of Cognitive Neuroscience*, 14(3), 443-454.
- Rugg, M. D. (1987). Dissociation of semantic priming, word and non-word repetition effects by event-related potentials. *The Quarterly Journal of Experimental Psychology Section A*, 39(1), 123-148.
- Seidenberg, M. S., & Gonnerman, L. M. (2000). Explaining derivational morphology as the convergence of codes. *Trends in Cognitive Sciences*, 4(9), 353-361.
- Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychol Rev*, 96(4), 523-568.
- Stockall, L., & Marantz, A. (2006). A single route, full decomposition model of morphological complexity MEG evidence. *The Mental Lexicon*, 1(1), 85-123.

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

Appendix A: Attributes of primes and targets for the task (standard deviations in parentheses)

	Type of Prime						
		<i>Semantic</i>		<i>Morphological</i>		<i>Formal</i>	
	Target	Prime	Control	Prime	Control	Prime	Control
	<i>casse</i>	<i>brise</i>	<i>moque</i>	<i>cassait</i>	<i>disait</i>	<i>cassis</i>	<i>dorsal</i>
	'break'	'break'	'mock'	'broke'	'said'	'blackcurrant'	'dorsal'
Surface	51.14	38.02	38.15	38.98	39	39.04	39.06
Frequency ^a	(11.7)	(9.03)	(9.14)	(8.27)	(8.32)	(9.91)	(9.9)
p^b		0.94		0.99		0.99	
Length in	1.1	1.5	1.64	2.1	2.1	2.14	2.14
Syllables ^c	(0.34)	(0.51)	(0.53)	(0.37)	(0.37)	(0.52)	(0.52)
p^b		0.21		1		1	
Length in Letters	4.6	6.19	6.17	6.79	7.02	6.67	6.69
	(1.08)	(1.17)	(1.21)	(0.9)	(0.81)	(1.12)	(1.26)
p^b		0.93		0.2		0.93	
Formal overlap with target		0.12	0	3.74	0.24	3.95	0.1
		(0.32)	(0)	(0.89)	(0.53)	(0.99)	(0.3)
p^d				0.3			
Phoneme overlap with		0.12	0	3.24	0.19	3.17	0.05
target ^c		(0.32)	(0)	(0.73)	(0.4)	(0.73)	(0.22)
p^d				0.65			
Semantic relatedness to		5.13	1.44	5.79	1.64	1.06	1.22
target		(1.01)	(1.01)	(0.19)	(1.05)	(0.12)	(0.32)
Difference in semantic		3.46		3.95		- 0.16	
relatedness (P - C)		(1.22)		(1.05)		(0.42)	
p^e		= 0.049				= 5.26 E-30	

^a In thousands, taken from *Frantexte* (New *et al.*, 2001)

^b Two-tailed t-test for independent samples

^c Quebec French phonological and syllabification rules apply here (e.g., *casse* and *brise* are both monosyllabic)

^d Two-tailed t-test for independent samples, comparison between M-F primes.

^e Two-tailed t-test for independent samples, comparison of mean differences in semantic relatedness between primes and controls for M-pairs versus S-pairs, and M-pairs versus F-pairs.

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

Appendix B Master list of prime-target pairs used in experiment

Primes						
Targets	Se	Sc	Fe	Fc	Me	Mc
cerne	entoure	entiche	cerneau	pectine	cernait	restait
ferme	obture	informe	ferraille	rongeur	fermait	feutrait
casse	brise	moque	cassis	dorsal	cassait	disait
fourre	flanque	tremble	fourrure	désastre	fourrait	haussait
barre	biffe	offre	barrot	casbah	barrait	gantait
fane	fripe	pleut	fanal	loyal	fanait	teintait
mure	enferme	suppose	murmure	famille	murait	rusait
pave	tapisse	entasse	pavillon	mocassin	pavait	paumait
cache	couvre	repent	cachemire	bonniche	cachait	pouffait
pompe	puise	berce	pompeux	cageot	pompait	palpait
bride	freine	démêle	bridge	phoque	bridait	blairait
campe	loge	mate	campus	coquine	campait	suivait
bute	accule	récure	butane	cafard	butait	cognait
chipe	attrape	utilise	chipote	crevage	chipait	guindait
brave	risque	flotte	bravo	excès	bravait	trônait
farde	maquille	traverse	fardeau	boudeur	pardait	pilait
cale	assure	irrite	calibre	horaire	calait	lisait
bourre	remplit	moleste	bourrique	calebasse	bourrait	poquait
croque	bouffe	pouffe	croquet	châssis	croquait	effilait
ferre	chausse	tripote	ferret	secret	ferrait	donnait
sue	transpire	troisième	sublime	foulard	suait	sautait
rate	avorte	excite	raton	bonus	ratait	savait
boude	rechigne	ronronne	boudin	nadir	boudait	minait
fige	cloue	chipe	figaro	judoka	figeait	plongeait
hale	tire	aime	haleine	aneth	halait	gainait
attire	charme	craque	attirail	bottillon	attirait	guettait
larde	pique	trie	lardon	moulin	lardait	heurtaït
aspire	souhaite	convoite	aspirine	rétinite	aspirait	admirait
trame	brasse	brette	tramway	échelle	tramait	juchait
bave	salive	colore	bavard	colloque	bavait	aérait
coupe	supprime	visionne	coupon	bottin	coupait	soudait
vire	pivote	apaise	virus	libraire	virait	nommait
gare	parque	souque	garde	rame	garait	rotait
sangle	bride	érige	sanglier	laminage	sanglait	bondait
lie	noue	jase	lierre	marron	liait	jouait
noue	arrime	cajole	nougat	subtil	nouait	rouait
oriente	dirige	relaxe	oriental	capuccino	orientait	humiliait
loupe	bousille	pardonne	loupot	coursier	loupait	laissait
couve	protège	suggère	couvent	oeillet	couvait	votait
pue	empeste	absorbe	punit	sauna	puait	pansait
hume	flaire	pivote	humecte	frileuse	humait	frisait
fuse	gicle	vient	fuseau	fondeur	fusait	notait

Notes: shaded cells for priming conditions on targets for each 1/3 of the list represent one of three possible sets of target repetitions within given presentation lists (see main text for details). Se: semantic experimental; Sc: semantic control; Fe: formal experimental; Fc: formal control; Me: morphological experimental; Mc: morphological control.

Acknowledgements

1 The first and last authors give special thanks to Marie-Do, Mair and family for hosting them
2 in Vientiane during the final stages of writing this paper. The first author acknowledges
3 funding from a Université de Montréal seed grant (SSHRC-UdeM, 2005). The last author
4 acknowledges funding from the Canadian Foundation for Innovation, Canada Research
5 Chairs, and a SSHRC grant on semantic processing (SSHRC, 410-2007-1501). These
6 agencies had no controlling impact on the paper.
7
8
9

10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

Table 1: Global repeated measures ANOVA results comparing Formal and Morphological priming only

		df	0-175	(N250)	(N400)	
				175-275	350-450	450-550
Lateral	Prime	(1, 23)	—	6.23*	9.24**	—
	P x A/P	(4, 92)	—	—	3.57†	3.50†
	P x Col	(2, 46)	—	3.63†	5.32*	—
	P x Hemi	(1, 23)	—	—	—	—
	P x A x C	(4, 92)	—	—	—	—
	P x A x H	(4, 92)	—	—	2.56†	3.03*
	P x C x H	(2, 46)	—	—	—	—
	P x A x C x H	(4, 92)	—	—	—	—
Midline	Prime	(1, 23)	—	6.41*	9.20**	—
	P x A	(4, 92)	—	—	3.62*	3.43*
Lateral	Type x Prime	(1, 23)	—	—	—	4.77*
	T x P x A/P	(4, 92)	—	—	—	—
	T x P x Col	(2, 46)	—	—	—	3.21†
	T x P x Hemi	(1, 23)	—	—	—	3.09†
	T x P x A x C	(4, 92)	—	—	—	—
	T x P x A x H	(4, 92)	—	—	—	—
	T x P x C x H	(2, 46)	—	4.32*	2.47†	—
	T x P x A x C x H	(4, 92)	—	—	—	—
Midline	T x P	(1, 23)	—	—	—	4.08†
	T x P x A	(4, 92)	—	—	—	—

Notes: P = Prime (prime vs. control); T = Type (morphological vs. orthographic); A/P = Anterior/Posterior; C = Column; H = Hemisphere; † p < 0.10, * p < 0.05, ** p < 0.01

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

Table 2: Repeated measures ANOVA results by Condition for morphological and orthographic priming

Morphological		df	(N250)	(N400)	
			175-275	350-450	450-550
Lateral	Prime	(1, 23)	3.56†	5.62*	7.77*
	P x A/P	(4, 92)	—	—	—
	P x Col	(2, 46)	4.56*	—	—
	P x Hemi	(1, 23)	—	—	—
	P x A x C	(4, 92)	—	—	—
	P x A x H	(4, 92)	—	—	2.60†
	P x C x H	(2, 46)	—	—	—
	P x A x C x H	(4, 92)	—	—	—
Midline	Prime	(1, 23)	3.25†	4.13†	5.98*
	P x A	(4, 92)	—	—	—
Orthographic					
Lateral	Prime	(1, 23)	—	—	—
	P x A/P	(4, 92)	—	3.16†	2.88†
	P x Col	(2, 46)	—	3.42†	—
	P x Hemi	(1, 23)	—	—	—
	P x A x C	(4, 92)	—	—	—
	P x A x H	(4, 92)	—	—	—
	P x C x H	(2, 46)	2.97†	—	—
	P x A x C x H	(4, 92)	—	—	—
Midline	Prime	(1, 23)	—	4.07†	—
	P x A	(4, 92)	—	3.70*	3.69*

Notes: P = Prime (prime vs. control); A/P = Anterior/Posterior; C = Column; H = Hemisphere; † $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Table 3: Global repeated measures ANOVA results comparing Formal, Morphological and Semantic priming to all control conditions

Morphological		<i>df</i>	(N250)	(N400)	
			175-275	350-450	450-550
Lateral	Prime	(1, 23)	4.93*	5.72*	5.10*
	P x A/P	(4, 92)	—	—	4.36*
	P x Col	(2, 46)	4.49*	5.23*	3.73*
	P x Hemi	(1, 23)	—	—	—
	P x A x C	(8,184)	—	—	—
	P x A x H	(4, 92)	—	2.80†	—
	P x C x H	(2, 46)	4.94*	—	—
	P x A x C x H	(8,184)	—	—	—
Midline	Prime	(1, 23)	4.79*	5.20*	4.58*
	P x A	(4, 92)	—	—	3.83*
Orthographic					
Lateral	Prime	(1, 23)	—	—	—
	P x A/P	(4, 92)	—	—	—
	P x Col	(2, 46)	—	—	—
	P x Hemi	(1, 23)	—	—	—
	P x A x C	(8,184)	—	—	—
	P x A x H	(4, 92)	—	2.81†	—
	P x C x H	(2, 46)	—	—	—
	P x A x C x H	(8,184)	—	—	—
Midline	Prime	(1, 23)	—	2.99†	—
	P x A	(4, 92)	—	2.34†	—
Semantic					
Lateral	Prime	(1, 23)	—	—	—
	P x A/P	(4, 92)	—	—	—
	P x Col	(2, 46)	—	—	—
	P x Hemi	(1, 23)	—	3.58†	2.95†
	P x A x C	(8,184)	—	—	—
	P x A x H	(4, 92)	—	—	—
	P x C x H	(2, 46)	—	3.52*	—
	P x A x C x H	(8,184)	—	—	2.98*
Midline	Prime	(1, 23)	—	—	—
	P x A	(4, 92)	—	—	—

Notes: P = Prime (prime vs. control); A/P = Anterior/Posterior; C = Column; H = Hemisphere; † $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Figure 1

[Click here to download Figure: SFM Figure 1.pdf](#)

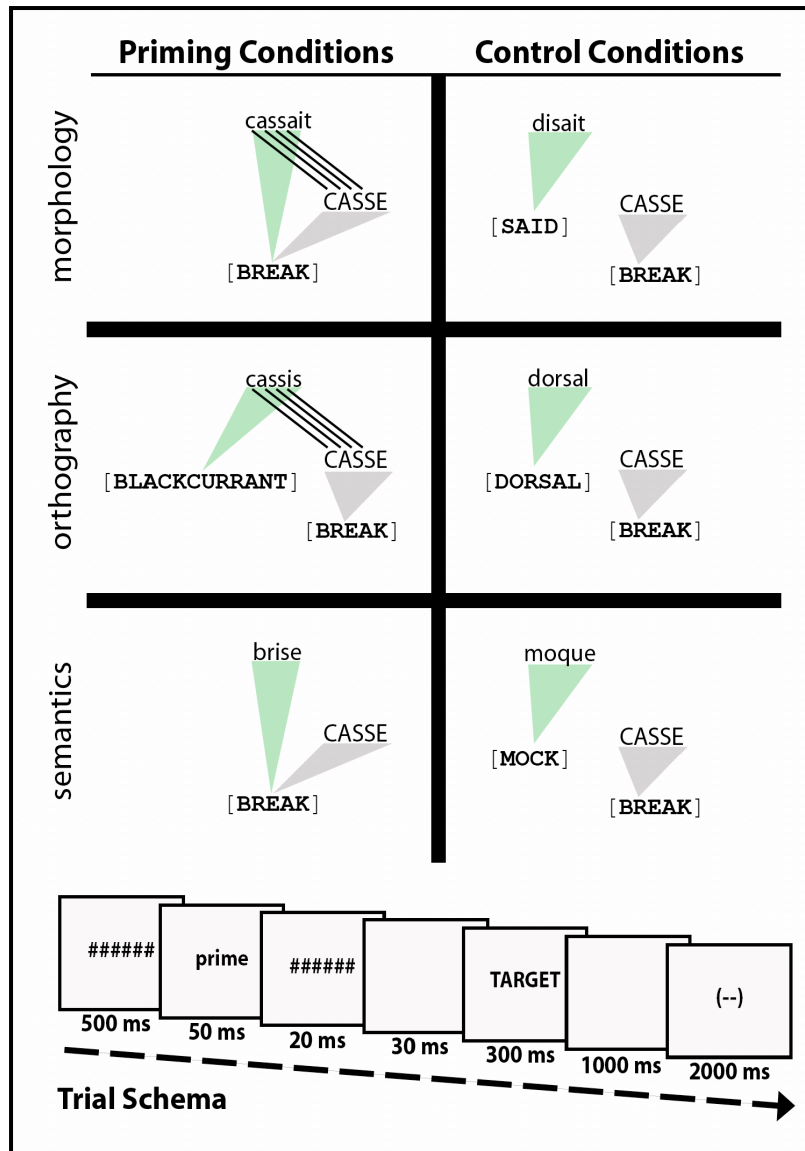


Figure 1: Sample stimuli of the various experimental conditions and stimulus presentation scheme. Green and grey triangles illustrate semantic networks (semantics are in CAPITALS within square brackets); green triangles represent the prime and grey the target semantics. Lines between prime and target represent orthographic overlap. The trial schema shows the time course of the experimental trials. Each trial started with the presentation of a backward mask, followed by a prime that was replaced by a forward mask, and, after a short interval, by the target to which participants made a lexical decision. A blinking period terminated each trial.

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

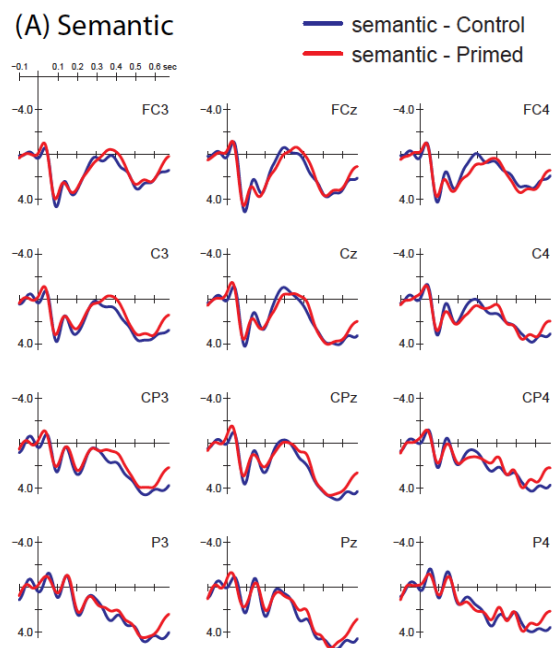


Figure 2. Grand average waves for the semantic priming condition. The masked priming paradigm deployed here successfully inhibited semantic effects, as there were no significant differences in priming conditions for any time-window.

Figure 3

[Click here to download Figure: SFM Figure 3.pdf](#)

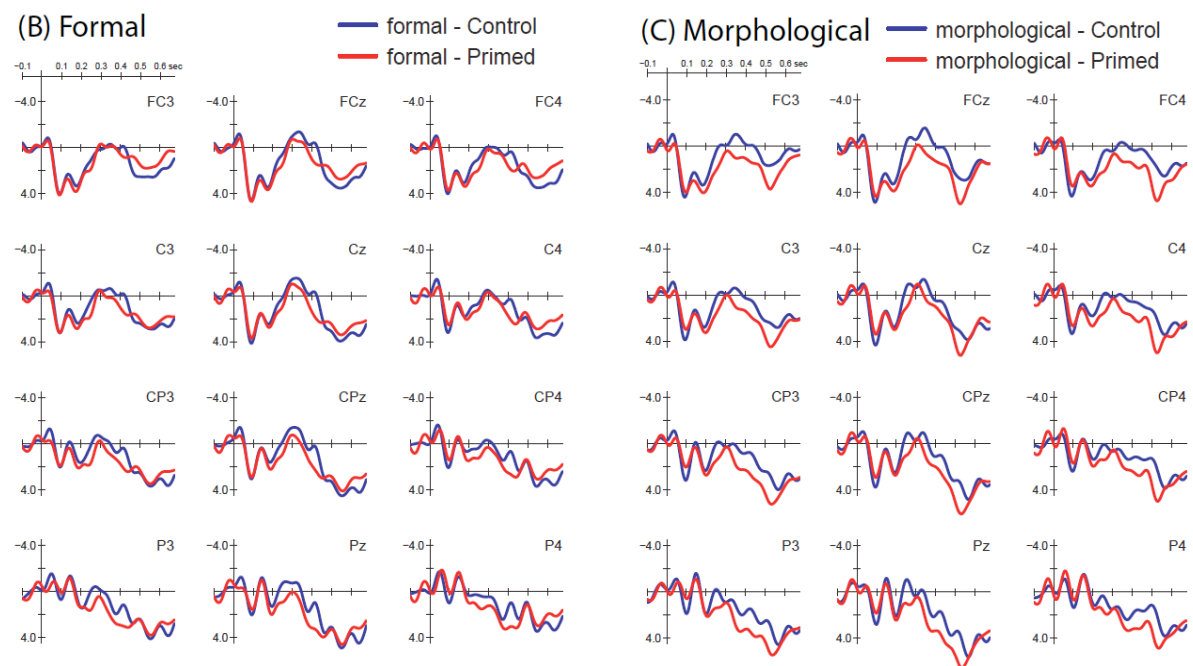


Figure 3. Grand average waves for the morphological and formal priming conditions. Both formal and morphological ERP priming effects were obtained, which overlapped between 175-450 ms. Further, between 450-550 ms only morphological priming effects were evident.

TEMPORAL DYNAMICS OF INFLECTED WORD RECOGNITION

Difference waves (midline)
primed minus control

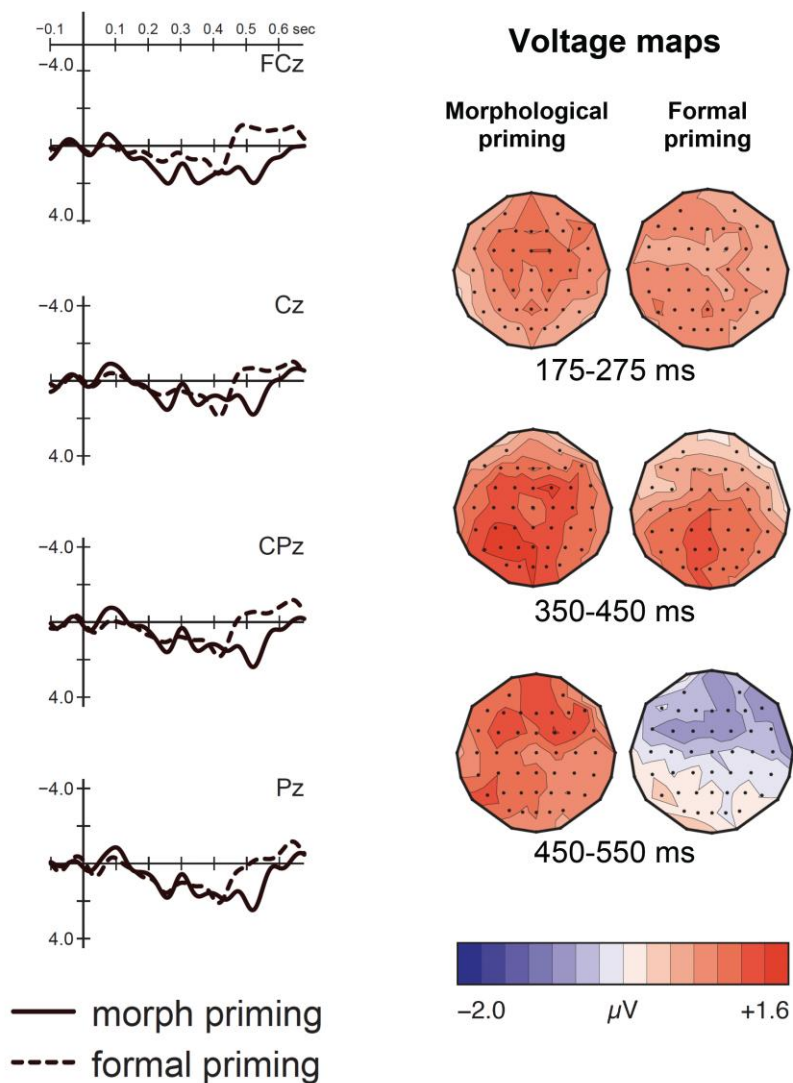


Figure 4. Difference waves (primed minus control) and voltage maps for morphological and formal priming conditions. Effects are presented for midline electrodes FCz, Cz, CPz and Pz (note that waves are low pass filtered at 9 hz for visualization purposes only).