Morphological Processing of Printed Nouns and Verbs:

Cross-Class Priming Effects

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RUNNING HEAD: Cross-class morphological priming

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Abstract

Despite grammatical class being a fundamental organizing principle of the human mental lexicon, recent morphological models of visual word identification remain silent as to whether and how it is represented in the lexical system. The present study addresses this issue by investigating cross-class morphological priming (i.e., the effect obtained when nouns prime verbs sharing the same root, or vice versa) to clarify whether morphological stems subserving the formation of both nouns and verbs (e.g., depart-) have a unique, grammatical class independent representation. Experiment 1 and 2 suggest this to be the case, as they show that morphological priming crosses grammatical class boundaries in overt paradigm conditions. Experiment 3 show that, in masked priming conditions, cross-class facilitation emerges both for genuine derivations and pseudo-related pairs with a homographic stem (e.g., *port-e*, doors, and *port-are*, to carry), which is taken to suggest that grammatical-class free stem representations are located at a pre-lexical level of morphological processing.

Keywords: reading, word identification, grammatical class, priming, linguistic morphology.

It has long been known that the morphological structure of written words affects the cognitive processes that are necessary for their identification (e.g., Grainger, Colé & Segui, 1991; Taft & Forster, 1975, 1976; but see also Butterworth, 1983). This view is supported by two key facts that have been repeatedly demonstrated over the last 30 years: (a) the time taken to identify a morphologically-complex word depends on the frequency of its root[1] (e.g., Bradley, 1979; Baayen, Dijkstra & Schreuder, 1997; Luke & Christianson, 2013; New, Brysbaert, Segui, Ferrand & Rastle, 2004) and (b) the identification of a base word (e.g., *deal*) is facilitated by the prior presentation of a morphological relative (e.g., *dealer*) to a greater extent than what would be expected on the basis of semantic and orthographic similarity alone (e.g., Drews & Zwitserlood, 1995; Rastle, Davis, Marslen-Wilson & Tyler, 2000).

However, how exactly morphology is addressed by the visual identification system remains a key issue still open to debate. Over the years, several different views have been proposed. The connectionist approach to morphology states that this latter *"is a characterization of the learned mapping between the surface forms of words (orthography, phonology) and their meanings (semantics)"* (Plaut & Gonnermann, 2000; p. 448). There would be no need for explicit morphological representations, given that morphological relationships would emerge, in fact, from the joint effect of an orthographic (or phonological) and a semantic liaison. Because the consistency of form-to-meaning mapping vary continuously from completely opaque cases (e.g., *corner* and *corn*) to perfectly transparent relationships (e.g., *dealer* and *deal*), morphological effects are predicted to be graded, according to how much words are similar *both* semantically *and* orthographically (or phonologically; see Gonnermann, Seidenberg & Andersen, 2007). Other, non-connectionist theoretical proposals have gone along a similar way (Baayen, Milin, Filipovic Durdevic, Hendrix, & Marelli, 2011), and have stressed the idea the morphology reflects a "*fully compositional probabilistic memory"* (Baayen et al., 2011; p. 440) that learns correlations between units of form (orthography, in this case) and units of meaning.

On a rather different pathway, other scholars have proposed that the reading system develops explicit representations for morphemes (just as much as it does for letters and words), and morphological effects emerge when these representations are contacted during processing (e.g., Crepaldi, Rastle, Coltheart & Nickels, 2010; Grainger & Ziegler, 2011; Taft, 1994). An intense debate between proponents of this theoretical approach concerns the exact location of the morphological level of representation within the visual word identification system. Over the years two main views have been proposed: in one account, morphological decomposition occurs pre-lexically, i.e., before word identification has taken place (e.g., Rastle, Davis & New, 2004), in the other account post-lexically, i.e., after word identification has taken place (e.g., Giraudo & Grainger, 2001). According to the pre-lexical account of morphology, complex written stimuli are firstly decomposed into their constituent morphemes, and on the basis of this analysis they are either identified as existing words or rejected as pseudowords. So, if the word identification system is presented with *kindness*, it first recognizes the morphemes *kind* and *ness*, and then identifies the word *kindness* as the combination of these two units. In a similar way, when the word identification system is presented with the non-word *shootment*, it identifies the morphemes *shoot* and *ment*, but then finds out that the combination of these units does not exist and thus rejects the stimulus as a non-word. In the post-lexical[2] account of morphology instead, written stimuli are identified in terms of letters, and their morphological structure becomes available upon lexical identification. So, when the word identification system is presented with *kindness*, it recognizes this word as the letter combination *k* + *i* + *n* + *d* + *n* + *e* + *s* + *s*, and only after lexical identification has taken place it becomes aware that the word contains the morphemes *kind* and *ness*. It is clear that on this latter account morphemes would never be identified within pseudowords: morphological analysis is triggered by lexical identification, but lexical identification does not occur for non-words.

However, several studies have reported the emergence of morphological effects in non-words. Taft and Forster (1976) found in a lexical decision task that non-words made up of an existing prefix and an existing root (e.g., *dejuvenate*) are rejected more slowly than non-words made up of the same prefix and a non-existing root (e.g., *depertoire*); this shows that morphological decomposition is independent of the lexical status of written stimuli and existing morphemes are indeed recognized by the word identification system also within non-words. This conclusion was further strengthened over the years by several experiments that discovered morphological effects in pseudo-derived, suffixed pseudowords (e.g., Burani, Dovetto, Spuntarelli, & Thornton, 1999; Crepaldi, Rastle & Davis, 2010) and in pseudo-inflected pseudowords (Caramazza, Laudanna & Romani, 1988). All these findings point towards the existence of a pre-lexical level of morphological analysis.

Pre-lexical and post-lexical morphological processing are not mutually exclusive though. In line with this consideration, the debate between pre-lexical and post-lexical accounts of morphology has been recently reconciled by data showing that masked priming occurs between irregularly inflected words (e.g., *fell*) and their roots (e.g., *fall*; Crepaldi et al., 2010; see also Forster, Davis, Schoknecht & Carter, 1987; Kielar, Joanisse, & Hare, 2008; and Pastizzo & Feldman, 2002). Since the pre-lexical segmentation routine described by Rastle et al. (2004) requires written stimuli to be decomposable into morphemes that are orthographically identifiable (e.g., *corn*-*er*, *deal*-*er*, *eat*-*s*), and since irregularly inflected forms do not satisfy this constraint (e.g., *fell*, *bought*, *women*), masked priming with irregularly inflected words cannot be explained at the pre-lexical morphological level. Consequently, the *fell*-*fall* priming effect was interpreted as a post-lexical phenomenon, and triggered the proposal of a formal model featuring both a pre-lexical and a post-lexical level of representation that accommodate for morphological effects (Crepaldi et al., 2010; see also Grainger & Ziegler, 2011; Taft & Nguyen-Hoan, 2010).

One issue that has not yet been addressed in this debate is how (and whether) grammatical class is represented within the word identification system (e.g., Baayen et al., 2011; Gonnerman et al., 2007; Rastle et al., 2004; Taft & Kougious, 2004). This is surprising given the primacy of this factor in linguistics (e.g., Chomsky, 1995; Embick & Noyer, 2007), neuropsychology (e.g., Berndt, Mitchum, Haendiges & Sandson, 1997; Crepaldi et al., 2006), neuroimaging (e.g., Berlingeri et al., 2008; Perani et al., 1999; Tyler, Russell, Fadili & Moss, 2001) and psycholinguistics (e.g., Mahon, Costa, Peterson, Vargas & Caramazza, 2007). All this evidence suggests that grammatical class is a fundamental organizing principle in the mental lexicon; still, morphological models of visual word recognition take no stance on how it informs lexical identification.

Models that locate morphological analysis at a post-lexical level – which is typically thought to be informed by semantic and lexical-syntactic factors – might be more prone to suggest that morpheme representations incorporate syntactic and semantic information (e.g., Giraudo & Grainger, 2001); consequently, morpheme representations would be marked for grammatical class, with the result that morphological stems sub-serving the formation of both nouns and verbs (e.g., *hammer*) would have separate, grammatical class-specific representations (*hammer*$_N$ vs. *hammer*$_V$). On these grounds, one might predict that nouns and verbs sharing their stem should not yield morphological priming[3]. On the contrary, those who suggest the existence of an early, pre-lexical level of morphological analysis – which is typically thought to be purely morpho-orthographic, i.e., insensitive to semantic and lexical-syntactic information – might argue there is only one representation for stems like *hammer*, which would be contacted when reading either a noun or a verb that includes such stem. The prediction would thus be that nouns and verbs sharing their stem should facilitate each other just as much as words from the same grammatical class.

The question of whether morphological priming is insensitive to grammatical class remains intricate when one considers the experimental findings obtained so far. Some evidence on priming effects in sentence reading seems to suggest that morphologically related nouns and verbs do facilitate each other. Feldman and Andjelkovic (1992) reported shorter response times when Serbian participants read aloud sentences like *vodiči plivaju* (the guides swim) after being exposed to prime sentences such as *vodi plivača* (he guides the swimmer). However, no semantic control was employed in this experiment to attest that the priming effect was genuinely morphological in nature. There are also data on long-lag priming in lexical decision that seem to suggest cross-class morphological facilitation. Feldman and Bentin (1994) reported that the visual identification of Hebrew words is facilitated equally by the previous presentation (7 to 13 items prior to the critical target) of inflectionally or derivationally related words. Since inflectionally related primes always shared their grammatical class with the target, while this was never the case for derivationally-related primes, data seem to show equivalent cross-class and within-class morphological facilitation. However, as for the previous study by Feldman and Andjelkovic (1992), no semantic control was included in the experimental design.

Neuropsychological data seem to go in the opposite direction, i.e., the evidence available is more suggestive of nouns and verbs having different and functionally independent representations. For example, aphasic patients have been described who suffered from lexical impairments that were more pronounced on either nouns or verbs (e.g., Damasio & Tranel, 1993; Luzzatti et al., 2002), thus implying that the two word classes are represented separately in the lexical system. Some of these patients were found to have dissociated performance on nouns and verbs in written lexical decision (Hillis & Caramazza, 1995), which is direct evidence that the two grammatical categories are represented somewhat differently already in the word identification system.

Evidence that nouns and verbs are differently represented in the mental lexicon has also emerged in unimpaired individuals, both in picture naming tasks (e.g., Mahon et al. 2007) and – more relevantly for the purpose of the present paper – in word naming and lexical decision tasks (e.g., Laudanna, Badecker & Caramazza, 1989; Laudanna, Voghera & Gazzellini, 2002; Frost, Forster & Deutsch, 1997; Melinger & Koenig, 2007).

Laudanna, Badecker and Caramazza (1989) carried out a double lexical decision experiment where two stimuli were displayed simultaneously on a screen and participants had to decide whether both were existing words. They found longer response times when the two words to be judged were nouns and verbs with homographic roots (e.g., *port-e*, doors, and *port-are*, to carry) than when they were a noun and a verb with similar orthography (e.g., *cort-a*, short, and *cont-are*, to count). These data seem to indicate that homographic roots subserving the formation of both nouns and verbs do not share their morphological representations, but rather inhibit each other, at least at some level of processing. Further data along these lines were reported by Laudanna, Voghera and Gazzellini (2002) in a standard priming study with lexical decision. With an SOA of 200 ms, a homographic-root noun prime (e.g., *stil-e*, style) slowed down lexical decision on target verbs (*stil-are*, to draft) as compared to an orthographic (*stim-e*, $\text{estimates}_{\text{N}}$) or an unrelated baseline (*grad-i*, degrees).

Although there is no formal account for these data in current models of complex word identification, one possible explanation for this evidence relates to the fact that Laudanna and colleagues tested homographic, rather than truly identical roots. Their results would thus fit with the widely supported idea that close lexical competitors inhibit each other during word identification (e.g., Coltheart, Rastle, Perry, Langdon & Ziegler, 2001; Davis, 2010; McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). Of course, this hypothesis raises the prediction that facilitation, rather than inhibition, should emerge when testing genuine morphological relatives belonging to different grammatical classes (e.g., *involve* and *involvement*).

Quite surprisingly, this has never been tested directly, to the best of our knowledge. However, some relevant evidence in this respect was provided by Frost, Forster and Deutsch (1997) in an attempt to investigate the mental representation of roots and affixes in Hebrew. The morphological system in this language is very different from that of Indo-European languages such as Italian or English. Roots are in fact made up of a consonant skeleton (e.g., *klt*) that is interwoven with a word pattern – a set of letters equivalent to affixes in Indo-European languages (e.g., *ta_ _i_*) – in order to form an existing word (e.g., *taklit*, a record). Frost and colleagues demonstrated in a masked priming experiment that nouns sharing a common root (e.g., *ta**kl**i**t***, a record, and *ha**kl**a**t**a*, the recording) facilitate each other. They also demonstrated that priming does not emerge when nominal primes and nominal targets share an identical morphological word pattern, but have different roots (e.g., ***taklit***, a record, and ***ta**rgil*, an exercise). Deutsch, Frost and Forster (1998) investigated the same effects in Hebrew verbs and found a different pattern of results: in both lexical decision and word naming, masked priming emerged among verbs when primes and targets shared *either* a root *or* a morphological word pattern. In order to account for these results, Deutsch and colleagues proposed a model of the visual identification of complex words in which printed stimuli are processed in parallel along both a lexical, non-morphological route – whereby written words directly activate word representations – and a sub-lexical, morphological route – whereby written words activate morpheme representations, which in turn address word representations. The morphological level of analysis includes representations for morphological roots and verb patterns, but not for nominal patterns; this is what allows Deutsch et al.'s (1998) model to account for the lack of priming between nouns sharing a word pattern. In our perspective, the critical feature of this model is that word roots subserving the formation of both nouns and verbs have a unique representation, which is unmarked for grammatical class (see Figure 1 in Deutsch et al., 1998). This seems to imply that nouns and verbs sharing the same root would address the same morphological representation during word identification, thus raising the prediction that they should facilitate each other in a priming paradigm. Crucially, however, this prediction was not tested directly in either Frost et al. (1997) or Deutsch et al. (1998), nor in any other study that we are aware of.

In sum, current morphological theories remain silent as to how grammatical class is represented within the visual word identification system, particularly for what concerns concatenative languages. This issue is far from being trivial, both because there is vast evidence that grammatical class is a key organizing principle in the human lexicon and because pre–lexical and post–lexical theories of morphological analysis would naturally produce opposite predictions in this respect. In addition, the experimental evidence available suggests that homographic noun and verb roots have separate representations in the word identification system (Laudanna et al., 1989; 2002), which would already call for a modification of most recent theories concerning the visual identification of complex words. However, these data do no speak as to what happens when nouns and verbs are genuine morphological relatives, i.e., truly share their root (e.g., *involve-involvement*). Experiment 1 is a first attempt at taking up this issue by investigating whether morphological priming crosses grammatical class boundaries.

Experiment 1

Experiment 1 tested whether verb and noun targets (e.g., *camminare*, to walk; *partenza*, departure) were primed by morphologically related words belonging to a different grammatical class (e.g., *camminata*, walk$_N$; *partire*, to leave). If nouns and verbs share their root representations, we would expect to observe some facilitation in these conditions compared to an unrelated baseline (*mozzarella – CAMMINARE*, mozzarella – WALK$_V$; *rendere – PARTENZA*, to give back – DEPARTURE). In order to show that this advantage does not depend entirely on the semantic relationship between primes and targets, the same target words were also tested in a condition where the related primes were only semantically related (e.g., *passo – CAMMINARE*, step$_N$ – WALK$_V$; *arrivare – PARTENZA*, to arrive –

DEPARTURE) compared to an unrelated baseline (e.g., *borsa – CAMMINARE*, bag – $WALK_V$; *rimanere – PARTENZA*, to stay – DEPARTURE). Of course, morphological relatives also show some degree of orthographic and phonological overlap[4]; however, in order to keep the experimental design within manageable dimensions and in order to facilitate the best possible match between conditions, this aspect was taken up separately in Experiment 2.

Materials and Methods

Participants

Sixty-one undergraduate students at the University of Milano-Bicocca participated in the study. All volunteered for the task, had normal or corrected-to-normal vision, were native Italian speakers, and had no history of neurological disorders or learning disabilities. Participants were given course credits in exchange for their time.

Materials

The list of stimuli was composed of 45 Italian verbs and 45 corresponding nouns (e.g. *applaudire* and *applauso*, to applaud and applause), selected from the set used by Crepaldi et al. (2006). Nouns and verbs in each pair were genuine morphological relatives, i.e., they were both orthographically and semantically related. The orthographic transparency of the morphological relationship was kept as high as possible: in 32 cases the root was preserved with no orthographic modification (e.g., *cammin-are,* to walk, and *cammin-ata*, $walk_N$); the orthographic change was limited to one letter (e.g., *rid-ere* and *ris-ata*, to laugh and $laugh_N$) in 11 pairs; and only 2 pairs had a more pronounced change (*raccogli-ere* and *raccol-ta*, to harvest and $harvest_N$; *legg-ere* and *lett-ura*, to read and $reading_N$). The verb set was composed of 27 verbs belonging to the first conjugation (*-are* verbs; e.g., *saltare*, to jump), 13 verbs to the second conjugation (*-ere* verbs; e.g., *correre*, to run) and five verbs to the third conjugation (*-ire* verbs; e.g., *dormire*, to sleep). This distribution reflects the proportions of the three conjugations in the entire Italian verb set (*-are* verbs=70%; *-ere* verbs=19%; *-ire* verbs=11%; Thornton, Jacobini & Burani, 1997).

One unfortunate feature of the Italian lexicon is that, similarly to English, several nouns in their morphologically unmarked form (i.e., the singular form) are homophonic (and homographic) to existing verb forms (e.g., *bacio* is both "the kiss" and "I kiss"; *calma* is both "the calm" and "he/she calms"). It was impossible to avoid this type of nouns in our set (16 out of 45 nouns were of this sort), given the other constraints that were imposed on the selection of the stimuli. One option to tackle this issue was to use nouns (or verbs) in morphologically marked forms (e.g., plural); we preferred to avoid this option because this is clearly non-standard in morphological priming studies and would have thus made our results hardly comparable with those reported in the literature. We then took into control this potential confounding factor in two ways. First, we selected for our stimulus set only those nouns that are at least 10 times more frequent as nouns than as verbs. Second, we checked post-hoc that the results did not differ in the non-homophonic noun set and in the homophonic noun set (see below).

Nouns and verbs were matched for log-transformed oral word frequency (2.55 ± .54 vs. 2.29 ± .46; based on De Mauro, Mancini, Vedovelli & Voghera, 1993), log-transformed written word frequency (1.57 ± .55 vs. 1.73 ± .50; based on the COLFIS database, Laudanna, Thornton, Brown, Burani & Marconi, 1995), number of letters (8.07 ± 1.54 vs. 7.64 ± 2.39), number of syllables (3.47 ± .59 vs. 3.07 ± .99), and imageability (4.53 ± .68 vs. 4.31 ± .92; estimated on a sample of 21 normal subjects along a seven-point scale). Given the corpus size that informs De Mauro et al.'s (1993) frequency count (~500,000 tokens), it is impossible to derive sensible estimates on a more standard scale (typically, occurrences per million words). Instead, it is possible to do so for the COLFIS, which is based on 3,982,442 tokens: the log-transformed figures given above correspond to a range of .25 to 9.19 occurrences per million words in written frequency.

Each of the 45 noun-verb pairs was tested in two different conditions: in the noun-primes-verb (NV) condition the noun served as prime and the verb as target, while in the verb-primes-noun (VN) condition the verb served as prime and the noun as target. Therefore, the 45 noun-verb pairs generated 90 trials, 45 in the NV condition (e.g., *applauso* – *applaudire*, applause – to applaud) and 45 in the VN condition (e.g., *applaudire* – *applauso*, to applaud – applause). This design ensured that both targets and related primes were tightly matched across the grammatical class conditions (NV vs. VN) for any relevant aspect.

In order to control for pure semantic effects, a further set of 90 primes was compiled. Each of the 90 targets was paired with a word belonging to the opposite grammatical class that was semantically, but not morphologically related (e.g., *applaudire,* to applaud, was paired with *teatro*, theatre, and *applauso*, applause, was paired with *ammirare*, to admire).

The morphological and semantic sets of primes were matched pairwise for grammatical class, log-transformed oral frequency, log-transformed written frequency, number of letters, and number of syllables with two independent control sets of primes (see Table 1). The control primes were all orthographically, phonologically, and semantically unrelated to their corresponding target words. The complete list of the stimuli used in this experiment is given in Appendix A.

Table 1 about here

A possible problem in this set of stimuli was that primes and targets appeared to be intuitively closer in meaning in the morphological set (e.g., *applaudire – applauso*, to applaud – applause) than in the semantic set (e.g., *applaudire – teatro*, to applaud – theatre). This is due to the fact that the semantic relationship between nouns and their corresponding verbs is of necessity extremely close in Italian; and words in the Italian vocabulary comparably close in meaning, but morphologically unrelated, were not available for all items. In order to assess this factor more formally, we asked 40 Italian undergraduate students (who did not participate in the main study) to rate the strength of the semantic association between each prime–target pair in our set on a 1-to-7 scale (1 = completely unrelated; 7 = strongly related). This allowed us to check whether (i) related primes in both conditions were really semantically closer to the targets than their corresponding control primes; and (ii) morphological primes were as semantically related to the targets as the semantic primes, compared to their corresponding control words. The results of this pre-test are illustrated in Figure 1. With regard to (i), it is easy to see that morphologically related primes are far more semantically related to the targets than their unrelated controls in all four conditions. With regard to (ii), the intuition that morphologically-related pairs are more closely related than semantically-related pairs is only partially confirmed by the association ratings. The distributions of related and unrelated primes are completely separated in the morphological conditions: in Figure 1, the lowest value in the related prime distribution is higher than the highest value in the unrelated prime distribution (Panel A and Panel B). This is not the case in the semantic conditions (Panel C ad Panel D). However, the difference is not as big as it might be expected; in fact, the lowest quartile of the related prime distributions is much higher than the highest quartile in the unrelated prime distributions in both the semantic and the morphological conditions. As the constraints imposed on our set of stimuli did not permit a closer match, we controlled for the possible mismatch between morphological and semantic conditions in the prime-target semantic relationship by including this variable as a covariate in the analysis of the results.

Figure 1 about here

A summary of the experimental conditions is provided in Table 2.

Table 2 about here

Procedure

Cross-class morphological and semantic priming were tested at two different SOAs (100 ms and 300 ms), so as to track the temporal pattern of the effects. In both cases trials began with the display of a crosshair on a computer screen for 500 ms. Then the prime word was presented in lower-case letters for either 50 or 250 ms and was immediately followed by a string of hashmarks that remained on the screen for 50 ms, after which the target word appeared in upper-case letters and the Editor application (E-Prime 1.1; 2004) launched the reaction time (RT) measurement. Participants were required to read aloud the target word, which remained on the screen until the participant gave his/her response or for three seconds. Trials were separated by a 1.5-second inter-stimulus interval. All stimuli were displayed in the middle of the screen, using Arial black characters (font size 24) on a white background.

Morphological and semantic priming effects have been studied in an overt (i.e., unmasked) paradigm using either lexical decision (e.g., Rastle et al., 2000) or reading (e.g., Tabossi & Laghi, 1992), while other studies used both tasks (e.g., Deutsch et al., 1998). Results were generally consistent, however in the present work reading aloud was adopted because of its lower sensitivity to response bias (lexical processing interacts heavily with general cognitive factors such as attention or YES/NO bias in forced choice tasks; see, e.g., Wagenmakers, 2009, and Ratcliff & McKoon, 1978).

Before being presented with the experimental stimuli the participants were given 10 practice trials to familiarize them with the task. The familiarization session was rerun if the experimenter noticed any indication that the instructions were not perfectly understood. The experimental session started only when the participants showed a complete understanding of the task by performing perfectly on the practice trials.

Data collection

Reaction times were measured through a microphone connected to a Serial Response Box controlled by E-Prime. The correctness of the responses was judged on-line. The experimental sessions were also recorded in order to allow the experimenter to conduct an off-line evaluation when responses were unclear.

Experimental design

Prime type (morphological vs. semantic) and SOA (100 ms vs. 300 ms) were used as crossed, between-subject variables. Four different trial lists were thus set up, one where morphological priming was assessed with a 300-ms SOA, one where morphological priming was assessed with a 100-ms SOA, one where semantic priming was assessed with a 300-ms

SOA, and one where semantic priming was assessed with a 100-ms SOA. Each participant was tested on only one of the four lists. Since each list contained 180 trials (which adds up to around 16 minutes of testing per subject), trials were split into two blocks that were administered separately with a 10-minutes break. Grammatical class, i.e., noun-primes-verb (NV) vs. verb-primes-noun (VN), and relatedness, i.e., related prime vs. control prime, were used instead as within-subject variables.

This experimental design allowed stimuli to be presented twice in each list. In order to minimize any possible confounding effect that this repetition might cause, trial presentation was pseudo-randomized within each block, so that the time gap between the presentations of two trials containing a same stimulus was maximized. We also guaranteed that any single word appeared either as a prime or as a target once in the first test block and once in the second test block. Moreover, the order in which the trials containing the same stimulus were presented was counterbalanced across subjects: each stimulus was presented as prime in the first block and then as target in the second block to 50% of the participants, and to the other 50% of the participants in the opposite order.

Statistical analysis

Data were analysed through mixed-effect models in order to maximise statistical power and reach a more precise evaluation of the effects of interest. The model included as fixed effects: (i) the four variables of interest (*prime type*: morphological vs. semantic; *SOA*:100 ms vs. 300 ms; *grammatical class*: nouns priming verbs, NV, vs. verbs priming nouns, VN; *relatedness*: related primes vs. control primes), and their interactions; (ii) several target-specific variables, which were inserted into the model as covariates (log written frequency, length in letters, initial phoneme, orthographic neighbourhood size, and imageability); (iii) prime-target semantic association and its interaction with the variables of interest; (iv) the interaction between grammatical class and each target-specific covariate. Fixed effects that did not contribute significantly to the goodness of fit of the model (as assessed through a chi-square test) were removed. The random effect structure included a random intercept for subject, item, and block, so that any subject-specific, item-specific, and block-specific variability was taken into account separately and did not contribute to the overall error variance against which the effects of interest were tested. Models were fitted to log-transformed RTs, so as to make the distribution of the dependent variable more Gaussian-like. The significance of the effects and parameters was evaluated using Wald chi-square tests or bootstrapping (Bates, Maechler, Bolker & Walker, 2013). All analyses were carried out using the statistical software R (version 3.0.1, freely available at http://www.r-project.org), and in particular the packages *car* (version 2.0-19; Fox, Weisberg, Adler et al., 2013) and *lme4* (version 1.0-5; Bates et al., 2013).

Results

The percentage of correct responses was at ceiling (98%) and thus accuracy was not analysed further.

Table 3 about here

Table 3 summarises the mean RTs obtained by the participants in each experimental condition. The statistical analyses showed a significant interaction between *relatedness* and *prime type* (Wald chi-square [df = 1] = 30.31, $p < .001$), a borderline interaction between *relatedness* and *SOA* (Wald chi-square [1] = 3.56, $p = .059$), and an interaction between all four experimental predictors (Wald chi-square [1] = 4.03, p = .04). Importantly, prime-target *semantic association* did not contribute significantly to the goodness of fit of the model (Chi-square [15] = 18.19; p = .25), nor did any of the second level interactions between grammatical class and the target-specific covariates (all p > .45). This indicates that the effects of interest were not influenced by either the strength of the semantic relationship between primes and targets or any of the specific features of the target words. The final model proved to be unbiased (the correlation between residuals and fitted values was .01) and solid (parameters did not change substantially when the model was re-run after excluding outliers[5]; see Baayen, 2008).

In order to check whether the presence of nouns that were homonyms to verbs in our set had any influence on this pattern of results, we ran an additional model that was identical to the best fitting one described above, but also included noun-verb homonymy in interaction with the four experimental variables. We reasoned that, if cross-class morphological priming was influenced by this factor, these interactions should be significant and the overall fit of the model should improve. This turned out not to be true: the extended model did not explain the observed data significantly better than did the original one (Chi-square [15] = 21.82, p = .11).

Results were explored more in depth in a post-hoc analysis, which was carried out by fitting a separate mixed-effect model for each of the experimental conditions determined by the factors *SOA* and *grammatical class* (300 ms SOA–NV; 300 ms SOA–VN; 100 ms SOA–NV; 100 ms SOA–VN). These analyses allowed us to establish whether cross-class morphological priming emerged in all SOA and grammatical class conditions, and whether it was reliably larger than semantic priming. This is in fact what we found: in all four mixed-effect models there was a strong and reliable interaction between *relatedness* and *prime type* (300 ms SOA–nouns priming verbs: Wald chi-square [1] = 66.03, p < .001; 300

ms SOA–verbs priming nouns: Wald chi-square [1] = 33.21, $p < .001$; 100 ms SOA–nouns priming verbs: Wald chi-square [1] = 21.93, $p < .001$; 100 ms SOA–verbs priming nouns: Wald chi-square [1] = 34.45, $p < .001$), indicating that morphological priming was consistently stronger than semantic priming.

Finally, Table 4 reports the significance of morphological and semantic priming in each of the four *SOA-by-grammatical class* combinations. Morphological priming is strong and consistent in each combination, whereas semantic priming is generally weak and more volatile (it is only significant in one condition and close to the threshold in another one).

Table 4 about here

Discussion

The results of Experiment 1 indicate that nouns and verbs sharing a same root mutually facilitate in a priming paradigm where participants were asked to read existing words aloud. Crucially, this phenomenon was genuinely morphological – and not merely due to the semantic relationship between primes and targets – as demonstrated by: (i) the fact that cross-class morphological priming emerged in an analysis that took into account the strength of the semantic relationship between primes and targets, and turned out to be independent of this factor; and (ii) a significant interaction between relatedness and prime type emerged in both the overall analysis and the separate mixed-effects models fitted to the 300 ms SOA–NV, 300 ms SOA–VN, 100 ms SOA–NV, and 100 ms SOA–VN conditions. We also explored the possibility that the pattern of results was dependent on specific target features (e.g., frequency, length), and this turned out not to be the case. This indicates that our results are fairly general (although we have not sampled words from the whole frequency distribution and thus cannot guarantee that they hold consistently across the entire frequency range; see, e.g., Luke & Christianson, 2013).

The fact that semantic effects are weaker than morphological effects – in priming experiments using SOAs that were comparable to ours – is certainly not new: this was already shown to be the case both in lexical decision (e.g., Rastle et al., 2000) and naming tasks (Feldman & Prostko, 2002). The novelty of our results lies in the fact that primes and targets were chosen systematically from different grammatical classes, which was not the case in any previous priming experiment of which we are aware, and shows that this factor does not affect morphological and semantic priming.

In fact, semantic priming turned out to be quite unstable across conditions, and very weak in general. Although this might sound somewhat surprising, similar data were also reported by Feldman and Prostko (2002), who showed that semantic priming does not emerge in a naming task at SOAs of 32, 66 and 300 ms. It is also important to note that the absence of any semantic priming *per se* has little to say about the core question of the paper. In the present study we were interested in assessing whether morphological roots that sub-serve the formation of both nouns and verbs have a unique, grammatical class-free representation, and cross-class morphological priming was taken as the experimental diagnostic for this to be the case. The semantic condition was included in the experimental design to guarantee that morphological priming could not be entirely explained by the semantic relationship that unavoidably holds between genuine morphological relatives: we were only interested in checking that morphological priming was significantly larger than semantic priming, irrespective of the size of semantic priming *per se*.

Thanks to mixed-effects models, we also took into account a number of other variables that might have affected the between-target comparison of the VN and the NV conditions and, more generally, we accounted for any variance that might have come from imperfect matching between the noun and the verb targets. The fact that all relevant effects emerged in this tight test indicates that results are solid and replicable.

As anticipated while introducing Experiment 1, the cross-class morphological effect observed here may also depend on the orthographic and phonological relationship between primes and targets. The presentation of *applauso*, applause, as a prime could implicitly pre-activate its initial phoneme(s) in output and this could speed up the reading of the target word *applaudire*, to applaud. This phonological-orthographic overlap between prime and target was absent in the control conditions of Experiment 1, which was focused on extricating morphological and semantic effects. Therefore, it was necessary to provide some experimental evidence that the cross-class effect emerged in this experiment was not entirely due to orthography and phonology: this evidence is offered in Experiment 2.

Experiment 2

In this experiment we contrasted morphological priming with orthographic and phonological priming using noun primes and target verbs, and vice versa. Since (i) cross-class morphological priming was stronger than semantic priming in Experiment 1, and (ii) target and related primes were identical in the two experiments, we did not include a semantic condition in this experiment.

Materials and Methods

Participants

Twenty-eight undergraduate students of the University of Milano-Bicocca participated in Experiment 2. None of them had participated in Experiment 1. They all volunteered to participate, had normal or corrected-to-normal vision, were native Italian speakers and had no history of neurological disorders or learning disabilities. Participants were given course credits in exchange for their time.

Materials

Target stimuli were identical to those used in Experiment 1 (45 nouns and 45 verbs). Each of the targets was paired with two different primes: (i) the same morphologically related primes used in Experiment 1, and (ii) an unrelated word that had the same initial syllable of the morphologically related primes and, consequently, of the target (e.g., cammello, camel, was chosen as control condition for *camminata*, walk$_N$, in priming *camminare*, to walk). Because of the very shallow phoneme-to-grapheme correspondence in Italian, the phonological prime-control matching also implied an orthographic matching. In 13 items a complete match of the first syllable was not possible, so a control word was chosen that matched both the first phoneme and the syllable structure (e.g., *esplodere*, to explode, was paired with *esclamare*, to exclaim). As a further control over the possible role of orthographic and phonological overlap between primes and targets, this variable was included in the statistical model as an additional covariate. We calculated orthographic overlap values according to the spatial coding approach (Davis, 2010) using the MatchCalc program (Davis, 2004).

Related and control primes were matched listwise for log-transformed oral frequency, log-transformed written frequency, number of letters and number of syllables (see Table 5).

Table 5 about here

Procedure, data collection, experimental design and statistical analysis

The trial timeline, procedure, apparatus, and experimental design were the same as those used in Experiment 1. In line with the change in experimental design, the variables considered as fixed effects in the model were: (i) SOA (100 ms vs. 300 ms), grammatical class (nouns priming verbs, NV, vs. verbs priming nouns, VN), relatedness (related primes vs. control primes), and their interactions; (ii) log written frequency, length in letters, initial phoneme, orthographic neighbourhood size, and imageability as target-specific covariates; (iii) the interaction between grammatical class and each target-specific covariate; (iv) prime-target semantic association and its interaction with the variables of interest; (v) prime-target orthographic overlap and its interaction with the variables of interest.

Results

As 99% of the responses were correct, accuracy was not analysed further. Mean response times in the experimental conditions are reported in Table 6.

Table 6 about here

The statistical analyses showed a significant main effect of *relatedness* (Wald chi-square [1] = 31.39; $p < .001$), which did not interact with the other variables of interest (all $p > .16$).

The strength of the semantic relationship between primes and targets did not contribute to the model goodness of fit (Chi-square [7] = 7.71, p = .36). *Prime-target orthographic overlap* improved the fit of the model (Chi-square [1] = 9.43; p = .002); however, its interaction with the variables of interest did not (Chi-square [6] = 9.53; p = .15). None of the second level interactions between grammatical class and target covariates contributed significantly to the model fit (all p > .09). As for Experiment 1, the final model turned out to be unbiased (residuals were uncorrelated with fitted values; r = .01) and robust (parameters were unaffected when the model was re-fitted after excluding outlying data-points; Baayen, 2008).

We also carried out a combined analysis of Experiment 2 data with data coming from the morphological condition in Experiment 1: this allowed us to assess more directly the role of phonological and orthographic factors in the cross-class morphological effects, as we compared in a same analysis trials where primes and targets were morphologically related (e.g., *camminata – CAMMINARE*, walk_N – to walk; Experiment 1 and Experiment 2), orthographically and phonologically related (*cammello – CAMMINARE*, camel – to walk; Experiment 2), or unrelated (*mozzarella – CAMMINARE*, mozzarella – to walk; Experiment 1). Here again, mixed-effects models allowed us to keep under control any spurious variance that might have come from: (i) different unrelated primes being used in the two different experiments; and (ii) different subjects participating in the two experiments. This was done by nesting random intercepts for subjects and items within the factor Experiment. A further random intercept for experiment was inserted into the model to capture any variability that might have come from the different overall difficulty of Experiment 1 and Experiment 2 (list effects). The analysis was identical to that described for Experiment 1 in all other aspects.

Results showed a borderline effect of *grammatical class* (Wald chi-square [1] = 3.57; p = .059) and, most importantly, a strong effect of *relatedness* (Wald chi-square [2] = 90.23; p <

.001). *Prime-target semantic association* did not contribute to explain the data (Chi-square [10] = 12.17; p = .28), nor did any of the interactions between grammatical class and target-specific covariates (all p > .18). The prime type effect emerged from the fact that the morphological condition elicited faster reading times than the unrelated condition (95% confidence interval of the relevant model parameter: −. 13 to −. 08, which in turn elicited reading times that were comparable to those of the unrelated condition (95% confidence interval of the relevant model parameter: −. 04 to +.03).

Discussion

Experiment 2 replicated the core results of Experiment 1. Nouns and verbs sharing their root mutually facilitate in a word naming task, even when unrelated control primes share their initial syllable with morphologically related primes -- i.e., *camminata–camminare*, walk_N–to walk, was compared with *cammello–camminare*, camel–to walk. These results show that the priming effect observed in Experiment 1 could not be entirely attributed to either (i) the pre-activation of the initial phonemes of the target word or (ii) the fact that related primes entertained a closer orthographic and phonological relationship with the targets than with the unrelated primes. The cross-experiment analysis additionally showed that sharing an orthographic/phonological onset was not enough in our data for primes to speed up the reading of their corresponding targets – pairs like *cammello*-*CAMMINARE* (camel – to walk) elicit similar reading times as pairs like *mozzarella*-*CAMMINARE* (mozzarella-to walk) (e.g., Dimitropoulou, Duñabeitia & Carreiras, 2010; Feldman, 2000; Forster & Davis, 1991; Rastle et al., 2000). This result suggests again the genuine morphological nature of the priming effect observed in Experiment 1.

This evidence complements the data obtained by Laudanna and colleagues (1989, 2002) – who showed that nouns and verbs with homographic roots (e.g., *port-e*, doors, and *port-are*, to carry) inhibit each other in a lexical decision task – and refine their explanation. Namely, these data show that nouns and verbs compete for selection (thus inhibiting each other) when they are lexical competitors, that is, when they feature a homographic root, but are otherwise unrelated. However, nouns and verbs yield facilitation when their orthographic similarity also brings along semantic similarity, that is, when they genuinely share the same morphological root. In other words, morphological root priming holds across grammatical class, but only for semantically transparent derivations.

As already suggested in the Introduction, existing morphological theories of visual word identification imply nothing on grammatical class representation. However, models featuring both pre-lexical and post-lexical levels of morphological processing (Crepaldi et al., 2010; Grainger & Ziegler, 2011) can accommodate these results rather easily with some appropriate modifications. Building on the established body of evidence showing that early (pre-lexical) morphological processing is primarily guided by form, i.e., written stimuli are decomposed into their morphemes irrespective of whether (and how) these morphemes contribute to word meaning (e.g., Davis & Rastle 2010; Kazanina, Dukova-Zheleva, Geber, Kharlamov, & Tonciulescu, 2008; Longtin, Segui, & Hallé, 2003; Marslen-Wilson, Bozic, & Randall, 2008; Rastle & Davis, 2008; Rastle et al., 2000, 2004), we may hypothesize that, at this level, *port-e*, doors, *port-atore*, carrier, and *port-are*, to carry, would all be parsed into their morphemes and would all contact a unique, form-based representation for the stem *port-*. At this stage, we might thus expect equivalent priming for transparent and opaque derivations. However, when processing comes to post-lexical levels of analysis in the word identification system (which incorporate semantic and syntactic information), *port-atore* and *port-are* would contact the same (or strongly related) representations, whereas *port-e* and *port-are* would address unrelated (thus competing) entries: therefore, the facilitation based on pre-lexical processing would remain in place for the former pair, but would turn into inhibition for the latter. Because both in our and in Laudanna et al.'s experiments participants had sufficient time to process prime words up to the semantic level (i.e., SOA was long), this account justifies the different results obtained with transparent derived words and pseudo-derived, homographic-root words.

Of course, accounting for cross-class facilitation between genuine morphological relatives and cross-class inhibition between pseudo-derived, homographic-root words does not require *necessarily* the existence of a pre-lexical, semantics-free shared representation of (pseudo-)stems. One might just suggest the existence of a (unique) level of morphological processing where genuinely related nouns and verbs (e.g., *dealer* and *deal*) facilitate, and homographic-root nouns and verbs compete (e.g., *inventory* and *invent*). The model proposed by Taft and Nguyen-Hoan (2010) seems to belong to this class as it suggests separate representations for homographic stems with different meanings at a morphological level (the lemma). (Note, however, that grammatical class was not addressed in Taft and Nguyen-Hoan's (2010) model.)

One nice feature of the model including a pre-lexical, grammatical-class free representation is that it raises a straightforward and easily testable prediction, namely, that because homographic and truly identical roots would be processed in the same way at a pre-lexical level, they should determine the same behavioural pattern of results in experimental paradigms that tap primarily into pre-lexical processing, such as masked priming.

Experiment 3

This experiment was designed to test the prediction raised by an account for Experiment 1 and 2 featuring a grammatical-class independent, pre-lexical representation for roots subserving both nouns and verbs (e.g., hammer), i.e., that nouns and verbs genuinely sharing their stem (e.g., *port-atore*, carrier, and *port-are*, to carry) yield equivalent masked priming as nouns and verbs sharing a pseudo-stem (e.g., *port-e*, doors, and *port-are*, to carry). We thus devised a 2×2 experiment, where genuine morphological relatives and pseudo-related nouns and verbs are contrasted with a matched, control prime condition in a masked priming paradigm. Because the vast majority of the masked priming literature has used lexical decision, we switched to this task in this experiment.

Materials and Methods

Participants

Fifty students at the University of Milano Bicocca participated in Experiment 3. None of them had participated in either Experiment 1 or Experiment 2. They had all normal or corrected-to-normal vision, were native Italian speakers and had no history of neurological disorders or learning disabilities. Participants were given either course credits or a small cash payment (4 Euros) in exchange for their time.

Materials

Seventy-six Italian derived nouns were selected to serve as target words in this masked priming experiment. Thirty-eight were primed by morphologically related verbs (e.g., *ruggito*, $roar_N$, was primed by *ruggire*, to roar), whereas 38 were primed by verbs that shared a homographic stem (e.g., *forn-aio*, baker, was primed by *forn-ire*, to provide). We only tested nouns primed by verbs in this Experiment in order to comply with previous literature (where the vast majority of the target words were nouns), and because Experiments 1 and 2 did not show any difference between the VN and NV conditions.

Targets included in the two conditions were matched as tightly as possible for length in letters (8.21 ± 1.88 vs. 8.50 ± 1.14), written frequency (1.05 ± .62 vs. .57 ± .68) and number of orthographic neighbours (1.58 ± 1.48 vs. .71 ± 1.12). Likewise, related primes were matched across conditions for length in letters (8.00 ± 1.45 vs. 7.29 ± 1.21) and frequency (.88 ± .62 vs. 1.11 ± .83); opaque, homographic-stem primes had more orthographic neighbours than transparent primes (2.08 ± 1.88 vs. .84 ± 1.01).

Each target was also paired with a control prime to serve as a baseline; as for Experiment 2, control primes were orthographically and phonologically similar, but semantically unrelated to the targets, (e.g., *marcire-MARINAIO*, to go rotten-SAILOR), and were matched with related primes for length (transparent, related primes: 8.00 ± 1.45; transparent, control primes: 8.16 ± 1.20; opaque, related primes: 7.29 ± 1.21; opaque, control primes: 7.79 ± 1.03), log written frequency (transparent, related primes: .88 ± .62; transparent, control primes: 1.13 ± .71; opaque, related primes: 1.11 ± .83; opaque, control primes: 1.28 ± .63), and orthographic neighbourhood size (transparent, related primes: .84 ± 1.01; transparent, control primes: .63 ± 1.13; opaque, related primes: 2.08 ± 1.88; opaque, control primes: 1.29 ± 1.30).

As for Experiment 2, we calculated the orthographic overlap between primes and targets according to the spatial coding approach (Davis, 2010) using the MatchCalc program (Davis, 2004). Related primes had similar orthographic overlap with their targets in the two conditions (.68 ± .12 vs. .57 ± .10). Moreover, the difference in prime-target overlap between related and control primes was comparable in transparent and opaque prime-target pairs (.24 ± .14 vs. .14 ± .12).

The assignment of word targets to the two priming conditions (related vs. unrelated) was counterbalanced over participants, so that all participants received primes from each condition, but saw each target only once. This was achieved by creating two experimental lists, which were presented to different subsets of participants.

The stimulus set also included 76 orthographically and phonologically legal nonwords, which were used as targets in the NO trials. Pseudoword targets were matched pairwise with word targets for length, and were paired with a real word prime. Mirroring the structure of the YES trial set, half of the prime words were orthographically and phonologically similar to the target pseudowords, whereas half were not. Word primes in NO trials were roughly matched to word primes in YES trials for length (8.20 ± 1.21 vs. 7.81 ± .38), log written frequency (.72 ± .64 vs. 1.10 ± .18) and orthographic neighbourhood size (.68 ± 1.09 vs. 1.21 ± .64).

The complete list of the stimuli used in this Experiment is reported in Appendix C.

Procedure

Participants were tested in a dimly lit room. They were seated in front of a computer screen and instructed to decide whether or not the letter strings appearing on the screen were existing Italian words. They were also told that the letter strings would be preceded by a string of hash marks as a warning signal, but no mention was made of the presence of the prime words. Participants were given six practice trials to familiarize with the task; as a further control over outlier responses due to unfamiliarity with the task, each experimental session began with four warm-up filler trials that were not analysed.

Trials began with the display of a string of uppercase “X” at the centre of a computer screen for 500 ms. Then the prime word was presented in lower-case letters for 48 ms and was immediately followed by the target word, which was displayed in uppercase. The target word remained on the screen until the participant gave his/her response, or for two seconds. Trials were separated by a half second inter-stimulus interval. All stimuli were displayed in white (Arial font, size 32) against a black background.

Stimulus presentation and data recording were accomplished via MatLab Psychtoolbox (MathWorks Corporation, 2011). A two-button response box was used to record lexical decisions. As they came into the lab, participants were asked about their hand dominance; for those who reported being left handed (N=7), the button box was turned upside down so that the YES response button was always controlled by the dominant hand. Trial presentation within lists was pseudo-randomized, so that no more than eight consecutive word or pseudoword targets could occur in a row; this design also ensured that no more than four experimental items were presented in eight consecutive trials.

Statistical analysis

Statistical analyses were performed as for the previous experiments. In line with the change in experimental design, the variables considered as fixed effects in the model were: (i) morphological structure (transparent vs. opaque primes), relatedness (related vs. control primes), and their interaction; (ii) length in letters, log written frequency and orthographic neighbourhood size as target-specific covariates; (iii) the interaction between relatedness and each target-specific covariate; (iv) prime-target orthographic overlap, so as to partial out this factor from the evaluation of the priming effect.

Results

Because of a technical error, eight targets were presented twice to each participant; we then first cleaned the dataset by excluding the second presentation of these targets to each reader. We also excluded three target words from any further analysis because their mean accuracy was below 70%.

After trimming, mean response times in the experimental conditions were as follows: transparent, related primes, 675 ± 176 ms; transparent, control primes, 707 ± 187 ms; homographic-stem, related primes, 713 ± 210 ms; homographic-stem, control primes, 736 ± 210 ms.

The statistical analyses showed a significant main effect of *relatedness* (Wald chi-square = 29.60, $p < .001$) and no interaction between *relatedness* and *morphological structure* (Wald chi-square = .084, $p = .77$). Neither *prime-target orthographic overlap* nor any interaction between target-specific covariates and *relatedness* increased the model goodness of fit (all $p > .27$). As for Experiments 1 and 2, the final model turned out to be unbiased (residuals were uncorrelated with fitted values; $r = .04$) and robust (parameters were unaffected when the model was re-fitted after excluding outlying data-points; Baayen, 2008).

Discussion

The results of Experiment 3 clearly confirm the prediction based on our interpretation of the results of Experiment 1 and 2. When priming is tested under masked conditions – i.e., in a paradigm that taps primarily onto very early steps in visual word identification – both transparent (e.g., *ruggito*, roar_N, for *ruggire*, to roar) and opaque, homographic-stem primes (e.g., *forn-aio*, baker, for *forn-ire*, to provide) yield time savings in the identification of their (pseudo-)related base words, even when these latter belong to a different grammatical class.

Therefore, data further constrain the interpretation offered in the Discussion of Experiment 2, namely, that morphological roots sub-serving the formation of both nouns and verbs have a unique, grammatical class-free representation at a pre-lexical level, but contact separate, grammatical class-specific representations post-lexically.

General Discussion

The results of the three experiments described in this paper show that: (i) nouns and verbs sharing their stem (e.g., *ruggito*, roar_{N} and *ruggire*, to roar) prime each other as it is normally the case for morphologically related words belonging to the same grammatical class; (ii) this effect is genuinely morphological in nature, as it also emerges when orthographic and phonological overlap between prime and target is appropriately controlled; (iii) this effect emerges irrespectively of whether nouns prime verbs or verbs prime nouns, and irrespectively of SOA, although it strengthens as SOA grows; (iv) this effect holds independently of whether the prime word is presented under unmasked or masked conditions; (v) under masked conditions, nouns and verbs with homographic, but otherwise unrelated stems (e.g., *forn-aio*, baker, and *forn-ire*, to provide) yield the same amount of time advantage that is brought about by genuinely related nouns and verbs.

In a joint interpretation with the results reported by Laudanna et al. (2002), the present data are taken to support morphological models of visual word identification featuring levels of representation that accommodate morphological effects *both* pre-lexically *and* post-lexically. This account is based on the (widely shared) assumption that at the pre-lexical level, form dominates semantic and syntactic factors (and thus pseudo-derived words are equivalent to genuine derivations), whereas at the post-lexical level, syntax and semantics become relevant (and thus genuine derivations are treated differently from pseudo-derived words). There are two such models in the current landscape of theories on complex words identification, namely, the lemma theory by Crepaldi et al. (2010) and the dual-route model by Grainger & Ziegler (2011). The fundamental difference between these models – leaving aside orthographic coding, which is important in particular for the latter theory, but is outside the scope of this study – is that Grainger and Ziegler (2011) postulate the existence of a second processing route that connects letter representations to word representations with no mediation by morphological analysis. The present data do not seem to speak to this aspect of the model, so the task of adjudicating between these theories is left to new research.

The latest model by Taft and colleagues (Taft & Nguyen-Hoan, 2010) is also seemingly able to account for the present data. Although, formally, there is no morpho-orthographic segmentation in the model, *"the orthographic units representing a polymorphemic word correspond to its individual morphemes"* (Taft & Nguyen-Hoan, 2010, p. 279). As it becomes clear in Figure 1 (p. 280), this implies that *"in the process of recognising the pseudo-affixed word 'corner', the same* [as for genuine affixed words] *structural decomposition will blindly occur, leading to the priming of corn"* (ibid., p. 279). As for Crepaldi et al.'s (2010) and Grainger and Ziegler's (2011) model, this mechanism would account for the results of Experiment 3: because *port-e*, doors, and *port-are*, to bring, are both parsable into form-based morphemes, their representation at the form level overlap, thus yielding masked priming effects. In a longer-SOA paradigm, instead, processing would go more deeply into the system, thus leaving syntactic and semantic factors to play their role, differentiating genuine derivations (which would produce facilitation) and homographic-root words (which would produce inhibition, as in Laudanna et al., 2002).

Of course, these accounts of the present data are tenable only if Crepaldi et al.’s (2010), Grainger and Ziegler’s (2011), and Taft and Nguyen-Hoan’s (2010) models are extended by incorporating explicit information about grammatical class. This is one important aspect where the data presented in this paper extend our knowledge; namely, they attest that early morphological representations are insensitive to grammatical class, which is clearly not the case for “late” (post-lexical) morphological representations. This conclusion strengthens the idea -- somewhat contested (e.g., Feldman et al., 2009) -- of the existence of a morpho-orthographic level of representation that plays a strong role during the early steps in visual word identification (e.g., Kazanina, 2011; Longtin et al., 2003; Rastle et al., 2004).

Do these data challenge connectionist models of morphology (e.g., Gonnerman et al., 2007) or, more in general, models that dispense of explicit representations for morphemes (e.g., Baayen et al., 2011)? Surely, these models are not at ease with a time course whereby orthography is more important early and semantics is more important late *during each instance of processing*. In fact, they are not at ease with time course in general, given that time is typically modelled only during learning: the vast majority of non-explicit computational models of morphology do not even produce any time course during individual instances of word identification (but see, e.g., Plaut and Gonnerman, 2000). On a general note, this puts these models into difficulty when it comes to account for time-dependent effects (e.g., frequency; Luke & Christianson, 2013; ERP; e.g., Lavric, Eichlepp & Rastle, 2013). More specifically, morphology is conceived as a set of learned associations between form and meaning: once this knowledge is acquired, there is no assumption (or simulation) as to whether either domain weighs differently as processing unfolds after each presentation of a printed word to the system. Admittedly, some PDP networks do show temporal dynamics in hidden unit activations, which are dominated by orthographic similarity early on, and progressively incorporate semantic information (Plaut & Gonnerman, 2000). In fact, this seems to be a general property of PDP networks that use attractor dynamics (Plaut, 1991). These dynamics, however, emerge during learning, and whether learning dynamics have any direct implications for priming effects in individual instances of processing is not totally clear to us.

On a more general perspective, our results are also relevant in a cross-linguistic perspective. In fact, they are in line with the model proposed by Deutsch, Frost and Forster (1997, 1998) for Hebrew, which suggests that pre-lexical root representations are grammatical-class free, thus subserving the identification of both nouns and verbs. This is notable, given the extreme diversity between the Hebrew and the Italian morphological systems. Morphology is *concatenative* in Italian (as in the majority of Indo-European languages): roots and affixes are attached linearly, one after the other. This is not the case in Hebrew, which features a *template-based* morphology where roots are consonantal skeletons (templates) that interweave with affixes to form other morphologically related words. This difference alone would already make more than likely the idea that morphological processing unfolds differently in Hebrew and Indo-European languages. Moreover, the semantic content of Hebrew roots is generally fuzzy, making the semantic relationship between morphological relatives rather weak in the majority of the cases. This is normally less the case in Italian, where morphological roots have fairly definite meanings, and the semantic relationship between nouns and verbs that are morphologically related is most often strong and, to a great extent, transparent (e.g., a *libr-aio*, bookseller, sells *libr-i*, books, and *libr-etti*, small books, in a *libr-eria*, book-store). Although these differences prevent Deutsch et al.'s (1998) model from being directly generalizable to Italian, our data clearly confirm one of its central tenets, namely, that roots subserving the formation of both nouns and verbs have a unique, shared representation, at least at peripheral levels of processing. This feature might thus be one of those general properties of the human reading system that has been often called for in cross-language (cross-script) psycholinguistic research (e.g., Velan & Frost, 2011; Frost, 2012).

On the other hand one condition that Hebrew and Italian do share is the quite complete lack of free stems, i.e., roots can hardly ever be used in isolation as words. This might be relevant from our perspective as it implies that *per se* roots might not belong themselves to any grammatical class. The Italian root *pesc-*, for example, "becomes" a noun if attached to the affixes *-e* (*pesce*, fish), *-i* (*pesci*, fish$_{\text{plural}}$), or *-atore* (*pescatore*, fisherman), but "becomes" a verb if attached to the affixes *-are* (*pescare*, to fish), *-arono* (*pescarono*, to fish$_{\text{Past-3rd person plural}}$), or *-asse* (*pescasse*, to fish$_{\text{Past-3rd person singular, subjunctive mode}}$). This is also the case for most Hebrew roots, which might explain the consistent results described here, and in Frost et al. (1997) and Deutsch et al. (1998). The case is quite different for, e.g., English roots, which in the majority of the cases are words themselves (e.g., cat, table, ball, hear), although often not unequivocally marked for grammatical class (e.g., hammer, move, bother); it would thus be interesting to see whether the present results generalize to English, perhaps contrasting words whose stem is unequivocally marked for grammatical class and words whose stem serves the formation of both nouns and verbs.

Acknowledgments

The study was carried out at the Department of Psychology, University of Milano Bicocca. We wish to thank Valentina Tobia for her help in the conduction of Experiment 1.

The study was supported by research grants awarded to Davide Crepaldi (RBFR085K98) and Claudio Luzzatti (2005109424_005) by the Italian Ministry of Education, University and Research.

Appendixes

Appendix A. Prime and target words used in Experiment 1.

			Morphological condition				*Semantic condition*			
GC	*Target words*		*Related primes*		*Control primes*		*Related primes*		*Control primes*	
NV	*ABBRACCIARE*	to embrace	*abbraccio*	$embrace_N$	*drappello*	platoon	*bacio*	$kiss_N$	*svago*	amusement
NV	*APPLAUDIRE*	to applaud	*applauso*	applause	*edicola*	newsstand	*teatro*	theatre	*totale*	sum_N
NV	*ARRESTARE*	to arrest	*arresto*	$arrest_N$	*profilo*	profile	*manette*	handcuff	*casello*	toll gate
NV	*BACIARE*	to kiss	*bacio*	$kiss_N$	*svago*	amusement	*amore*	$love_N$	*popolo*	people
NV	*BALLARE*	to dance	*ballo*	$dance_N$	*multa*	fine	*canto*	song	*mappa*	map_N
NV	*BOMBARDARE*	to bomb	*bombardamento*	bombardment	*diplomazia*	diplomacy	*missile*	missile	*formula*	formula
NV	*CADERE*	to fall	*caduta*	$fall_N$	*legame*	tie_N	*gradino*	$step_N$	*assenso*	agreement
NV	*CALCOLARE*	to calculate	*calcolo*	calculation	*missile*	missile	*numero*	number	*persona*	person
NV	*CAMMINARE*	to walk	*camminata*	$walk_N$	*mozzarella*	mozzarella	*passo*	$step_N$	*borsa*	bag
NV	*CANTARE*	to sing	*canto*	song	*suolo*	soil	*ballo*	$dance_N$	*multa*	$fine_N$
NV	*CONVERSARE*	to converse	*conversazione*	conversation	*protocollo*	$protocol_N$	*parola*	$word_N$	*potere*	power

			Morphological condition				Semantic condition			
GC	*Target words*		*Related primes*		*Control primes*		*Related primes*		*Control primes*	
NV	*CORRERE*	to run	*corsa*	run_N	*sorta*	kind	*gara*	competition	*filo*	rope
NV	*COSTRUIRE*	to build	*costruzione*	construction	*democrazia*	democracy	*casa*	house_N	*vita*	life
NV	*CROLLARE*	to collapse	*crollo*	collapse_N	*nebbia*	fog	*edificio*	building	*panorama*	panorama
NV	*ESPLODERE*	to explode	*esplosione*	explosion	*accademia*	academy	*bomba*	bomb_N	*turno*	shift_N
NV	*EVADERE*	to escape	*evasione*	escape_N	*capitano*	captain	*ladro*	thief	*mutuo*	mortgage
NV	*GIURARE*	to swear	*giuramento*	oath_N	*incursione*	incursion	*processo*	process_N	*effetto*	effect
NV	*INTERROGARE*	to examine	*interrogazione*	interrogation	*enciclopedia*	encyclopedia	*maestro*	teacher	*sezione*	section
NV	*LANCIARE*	to throw	*lancio*	throw_N	*stadio*	stadium	*palla*	ball	*duomo*	dome
NV	*LEGGERE*	to read	*lettura*	reading	*autunno*	autumn	*libro*	book_N	*costo*	cost_N
NV	*MASSAGGIARE*	to massage	*massaggio*	massage_N	*discordia*	disagreement	*olio*	oil	*sole*	sun
NV	*MORDERE*	to bite	*morso*	bite_N	*felpa*	jumper	*cane*	dog	*tubo*	tube
NV	*NASCERE*	to be born	*nascita*	birth	*criterio*	criterion	*bambino*	child	*vertice*	top_N
NV	*NEVICARE*	to snow	*neve*	snow_N	*dose*	dose_N	*montagna*	mountain	*sostegno*	help_N
NV	*PARTIRE*	to leave	*partenza*	departure	*campione*	sample_N	*viaggio*	travel_N	*stampa*	press_N

			Morphological condition				*Semantic condition*			
GC	*Target words*		*Related primes*		*Control primes*		*Related primes*		*Control primes*	
NV	*PATTINARE*	to skate	*pattinaggio*	skating	*mozzarella*	mozzarella	*ghiaccio*	ice	*schiera*	$host_N$
NV	*PIANGERE*	to cry	*pianto*	crying	*scalpo*	scalp	*lacrima*	tear	*tributo*	$tribute_N$
NV	*PIOVERE*	to rain	*pioggia*	$rain_N$	*dramma*	drama	*ombrello*	umbrella	*carisma*	charisma
NV	*POTARE*	to prune	*potatura*	pruning	*fusibile*	fuse	*albero*	tree	*ettaro*	hectare
NV	*PREGARE*	to pray	*preghiera*	prayer	*quattrino*	penny	*chiesa*	church	*cambio*	$change_N$
NV	*RACCOGLIERE*	to harvest	*raccolta*	$harvest_N$	*ingresso*	entrance	*frutta*	fruit	*maglia*	shirt
NV	*RADERE*	to shave	*rasatura*	shaving	*papavero*	poppy	*barba*	beard	*freno*	brake
NV	*RIDERE*	to laugh	*risata*	$laugh_N$	*laguna*	lagoon	*allegria*	cheerfulness	*cammello*	camel
NV	*RUGGIRE*	to roar	*ruggito*	$roar_N$	*crinale*	ridge	*leone*	lion	*catena*	chain
NV	*SALTARE*	to jump	*salto*	$jump_N$	*furto*	robbery	*ostacolo*	hurdle	*indirizzo*	$address_N$
NV	*SALUTARE*	to greet	*saluto*	greeting	*dogana*	toll	*incontro*	meeting	*modello*	$model_N$
NV	*SALVARE*	to save	*salvataggio*	$rescue_N$	*accessorio*	accessory	*miracolo*	miracle	*verifica*	$check_N$
NV	*SBADIGLIARE*	to yawn	*sbadiglio*	$yawn_N$	*crespella*	crepe	*sonno*	$sleep_N$	*forno*	oven
NV	*SCOPPIARE*	to burst	*scoppio*	$burst_N$	*broglio*	poll-rigging	*ordigno*	$bomb_N$	*casello*	toll gate

			Morphological condition				*Semantic condition*			
GC	*Target words*		*Related primes*		*Control primes*		*Related primes*		*Control primes*	
NV	*SCRIVERE*	to write	*scrittura*	writing	*concerto*	concert	*matita*	pencil	*cupola*	cupola
NV	*SOFFIARE*	to blow	*soffio*	blow_N	*milza*	spleen	*aria*	air	*data*	date_N
NV	*SPARARE*	to shoot	*sparo*	shot	*fieno*	hay	*pistola*	gun	*colonia*	colony
NV	*STARNUTIRE*	to sneeze	*starnuto*	sneeze	*trespolo*	stand_N	*fazzoletto*	tissue	*tartaruga*	turtle
NV	*ULULARE*	to howl	*ululato*	howl_N	*obitorio*	obituary	*lupo*	wolf	*dote*	gift
NV	*VOLARE*	to fly	*volo*	flight	*data*	date_N	*uccello*	bird	*barile*	barrel
VN	*ABBRACCIO*	embrace_N	*abbracciare*	to embrace	*sconvolgere*	to tear	*stringere*	to tighten	*spostare*	to move
VN	*APPLAUSO*	applause	*applaudire*	to applaud	*adoperare*	to use	*ammirare*	to admire	*abbinare*	to couple
VN	*ARRESTO*	arrest_N	*arrestare*	to arrest	*collocare*	to put	*rubare*	to steal	*dormire*	to sleep
VN	*BACIO*	kiss_N	*baciare*	to kiss	*giovare*	to help	*amare*	to love	*curare*	to take care
VN	*BALLO*	dance_N	*ballare*	to dance	*mediare*	to mediate	*cantare*	to sing	*versare*	to pour
VN	*BOMBARDAMENTO*	bombardment	*bombardare*	to bomb	*sfrigolare*	to frizzle	*distruggere*	to destroy	*proteggere*	to protect
VN	*CADUTA*	fall_N	*cadere*	to fall	*basare*	to fund	*scivolare*	to slip	*implicare*	to imply
VN	*CALCOLO*	calculation	*calcolare*	to calculate	*ascoltare*	to listen	*sommare*	to sum	*premere*	to press

			Morphological condition				*Semantic condition*			
GC	*Target words*		*Related primes*		*Control primes*		*Related primes*		*Control primes*	
VN	*CAMMINATA*	walk_N	*camminare*	to walk	*inventare*	to invent	*correre*	to run	*citare*	to quote
VN	*CANTO*	song	*cantare*	to sing	*fermare*	to stop	*suonare*	to play	*rompere*	to break
VN	*CONVERSAZIONE*	conversation	*conversare*	to converse	*disprezzare*	to despise	*parlare*	to talk	*seguire*	to follow
VN	*CORSA*	run_N	*correre*	to run	*lottare*	to fight	*camminare*	to walk	*convocare*	to call
VN	*COSTRUZIONE*	construction	*costruire*	to build	*accettare*	to accept	*distruggere*	to destroy	*proteggere*	to protect
VN	*CROLLO*	collapse_N	*crollare*	to collapse	*spargere*	to spread	*cadere*	to fall	*curare*	to take care
VN	*ESPLOSIONE*	explosion	*esplodere*	to explode	*dipingere*	to paint	*distruggere*	to destroy	*proteggere*	to protect
VN	*EVASIONE*	escape_N	*evadere*	to escape	*affinare*	to refine	*scappare*	to run away	*spedire*	to send
VN	*GIURAMENTO*	oath_N	*giurare*	to swear	*fingere*	to pretend	*promettere*	to promise	*sorprendere*	to surprise
VN	*INTERROGAZIONE*	interrogation	*interrogare*	to examine	*moltiplicare*	to multiply	*studiare*	to study	*giungere*	to come to
VN	*LANCIO*	throw_N	*lanciare*	to throw	*gestire*	to manage	*prendere*	to take	*trattare*	to treat
VN	*LETTURA*	reading	*leggere*	to read	*vendere*	to sell	*scrivere*	to write	*spiegare*	to explain
VN	*MASSAGGIO*	massage_N	*massaggiare*	to massage	*strangolare*	to strangle	*rilassare*	to relax	*rammentare*	to recall
VN	*MORSO*	bite_N	*mordere*	to bite	*narrare*	to narrate	*mangiare*	to eat	*marciare*	to march

			Morphological condition				*Semantic condition*			
GC	*Target words*		*Related primes*		*Control primes*		*Related primes*		*Control primes*	
VN	*NASCITA*	birth	*nascere*	to be born	*perdere*	to lose	*morire*	to die	*subire*	to undergo
VN	*NEVE*	$snow_N$	*nevicare*	to snow	*immolare*	to sacrifice	*piovere*	to rain	*destare*	to wake up
VN	*PARTENZA*	departure	*partire*	to leave	*rendere*	to give back	*arrivare*	to arrive	*rimanere*	to stay
VN	*PATTINAGGIO*	skating	*pattinare*	to skate	*mendicare*	to beg	*scivolare*	to slip	*implicare*	to imply
VN	*PIANTO*	crying	*piangere*	to cry	*mangiare*	to eat	*ridere*	to laugh	*varare*	to inaugurate
VN	*PIOGGIA*	$rain_N$	*piovere*	to rain	*destare*	to wake up	*nevicare*	to snow	*immolare*	to sacrifice
VN	*POTATURA*	pruning	*potare*	to prune	*chinare*	to bow	*tagliare*	to cut	*suonare*	to play
VN	*PREGHIERA*	prayer	*pregare*	to pray	*stupire*	to amaze	*adorare*	to adore	*obbedire*	to obey
VN	*RACCOLTA*	$harvest_N$	*raccogliere*	to harvest	*affrontare*	to face	*buttare*	to trash	*dormire*	to sleep
VN	*RASATURA*	shaving	*radere*	to shave	*munire*	to equip	*tagliare*	to cut	*cacciare*	to hunt
VN	*RISATA*	$laugh_N$	*ridere*	to laugh	*varare*	to vote	*piangere*	to cry	*marciare*	to march
VN	*RUGGITO*	$roar_N$	*ruggire*	to roar	*fremere*	to look forward to	*sbranare*	to devour	*strigliare*	to scold
VN	*SALTO*	$jump_N$	*saltare*	to jump	*versare*	to pour	*superare*	to overcome	*ricevere*	to receive
VN	*SALUTO*	greeting	*salutare*	to greet	*recitare*	to play	*partire*	to leave	*cercare*	to search

			Morphological condition				Semantic condition			
GC	*Target words*		*Related primes*		*Control primes*		*Related primes*		*Control primes*	
VN	*SALVATAGGIO*	rescue_N	*salvare*	to save	*godere*	to enjoy	*morire*	to die	*toccare*	to touch
VN	*SBADIGLIO*	yawn_N	*sbadigliare*	to yawn	*strimpellare*	to play	*dormire*	to sleep	*buttare*	to trash
VN	*SCOPPIO*	burst_N	*scoppiare*	to burst	*tracciare*	to trace	*bruciare*	to burn	*pregare*	to pray
VN	*SCRITTURA*	writing	*scrivere*	to write	*chiamare*	to call	*leggere*	to read	*vendere*	to sell
VN	*SOFFIO*	blow_N	*soffiare*	to blow	*guastare*	to spoil	*sbuffare*	to puff	*stridere*	to squeak
VN	*SPARO*	shot	*sparare*	to shoot	*vietare*	to forbid	*colpire*	to hit	*firmare*	to sign
VN	*STARNUTO*	sneeze_N	*starnutire*	to sneeze	*tramortire*	to hit hard	*tossire*	to cough	*vibrare*	to vibrate
VN	*ULULATO*	howl_N	*ululare*	to howl	*erodere*	to erode	*abbaiare*	to bark	*dirimire*	to settle
VN	*VOLO*	flight	*volare*	to fly	*recare*	to yield	*decollare*	to take off	*oscillare*	to oscillate

Note. GC, grammatical class; NV, nouns priming verbs; VN, verbs priming nouns.

Appendix B. Prime and target words used in Experiment 2.

GC	*Target words*		*Morphological primes*		*Control primes*	
NV	*ABBRACCIARE*	to embrace	*abbraccio*	$embrace_N$	*abbazia*	abbey
NV	*APPLAUDIRE*	to applaud	*applauso*	applause	*appetito*	appetite
NV	*ARRESTARE*	to arrest	*arresto*	$arrest_N$	*arredo*	furniture
NV	*BACIARE*	to kiss	*bacio*	$kiss_N$	*bagno*	bathroom
NV	*BALLARE*	to dance	*ballo*	$dance_N$	*balzo*	$jump_N$
NV	*BOMBARDARE*	to bomb	*bombardamento*	bombardment	*bordo*	$edge_N$
NV	*CADERE*	to fall	*caduta*	$fall_N$	*carota*	carrot
NV	*CALCOLARE*	to calculate	*calcolo*	calculation	*calma*	calm
NV	*CAMMINARE*	to walk	*camminata*	$walk_N$	*cammello*	camel
NV	*CANTARE*	to sing	*canto*	song	*campo*	field
NV	*CONVERSARE*	to converse	*conversazione*	conversation	*concerto*	concert

GC	*Target words*		*Morphological primes*		*Control primes*	
NV	*CORRERE*	to run	*corsa*	run_N	*corda*	rope
NV	*COSTRUIRE*	to build	*costruzione*	construction	*costume*	swimsuit
NV	*CROLLARE*	to collapse	*crollo*	collpase	*cronaca*	column
NV	*ESPLODERE*	to explode	*esplosione*	explosion	*esperienza*	experience
NV	*EVADERE*	to escape	*evasione*	escape_N	*etichetta*	label_N
NV	*GIURARE*	to swear	*giuramento*	oath_N	*giugno*	June
NV	*INTERROGARE*	to examine	*interrogazione*	interrogation	*indirizzo*	address_N
NV	*LANCIARE*	to throw	*lancio*	throw_N	*lanterna*	lantern
NV	*LEGGERE*	to read	*lettura*	reading	*lenzuolo*	sheet
NV	*MASSAGGIARE*	to massage	*massaggio*	massage_N	*massiccio*	massif
NV	*MORDERE*	to bite	*morso*	bite_N	*morbo*	disease
NV	*NASCERE*	to be born	*nascita*	birth	*natura*	nature
NV	*NEVICARE*	to snow	*neve*	snow_N	*nido*	nest_N

GC	*Target words*		*Morphological primes*		*Control primes*	
NV	*PARTIRE*	to leave	*partenza*	departure	*parlamento*	parliament
NV	*PATTINARE*	to skate	*pattinaggio*	skating	*pattuglia*	patrol$_{N}$
NV	*PIANGERE*	to cry	*pianto*	crying	*pianta*	plant$_{N}$
NV	*PIOVERE*	to rain	*pioggia*	rain$_{N}$	*piombo*	lead$_{N}$
NV	*POTARE*	to prune	*potatura*	pruning	*popolo*	people
NV	*PREGARE*	to pray	*preghiera*	prayer	*presidio*	garrison
NV	*RACCOGLIERE*	to harvest	*raccolta*	harvest	*raccordo*	joint
NV	*RADERE*	to shave	*rasatura*	shaving	*rapina*	robbery
NV	*RIDERE*	to laugh	*risata*	laugh$_{N}$	*riparo*	shelter$_{N}$
NV	*RUGGIRE*	to roar	*ruggito*	roar$_{N}$	*rossetto*	lipstick
NV	*SALTARE*	to jump	*salto*	jump$_{N}$	*saldo*	balance$_{N}$
NV	*SALUTARE*	to greet	*saluto*	greeting	*sabato*	Saturday
NV	*SALVARE*	to save	*salvataggio*	rescue$_{N}$	*salmone*	salmon

GC	*Target words*		*Morphological primes*		*Control primes*	
NV	*SBADIGLIARE*	to yawn	*sbadiglio*	$yawn_N$	*sbarra*	bar
NV	*SCOPPIARE*	to burst	*scoppio*	$burst_N$	*scoperta*	discovery
NV	*SCRIVERE*	to write	*scrittura*	writing	*straccio*	rag
NV	*SOFFIARE*	to blow	*soffio*	$blow_N$	*soffitto*	ceiling
NV	*SPARARE*	to shoot	*sparo*	shot	*spada*	sword
NV	*STARNUTIRE*	to sneeze	*starnuto*	$sneeze_N$	*statua*	statue
NV	*ULULARE*	to howl	*ululato*	$howl_N$	*universo*	universe
NV	*VOLARE*	to fly	*volo*	flight	*voce*	voice
VN	*ABBRACCIO*	$embrace_N$	*abbracciare*	to embrace	*abbondare*	to abound
VN	*APPLAUSO*	applause	*applaudire*	to applaud	*appendere*	to hang
VN	*ARRESTO*	$arrest_N$	*arrestare*	to arrest	*arredare*	to furnish
VN	*BACIO*	$kiss_N$	*baciare*	to kiss	*bagnare*	to wet
VN	*BALLO*	$dance_N$	*ballare*	to dance	*balzare*	to jump

GC	*Target words*		*Morphological primes*		*Control primes*	
VN	*BOMBARDAMENTO*	bombardment	*bombardare*	to bomb	*bollire*	to boil
VN	*CADUTA*	fall_N	*cadere*	to fall	*capire*	to understand
VN	*CALCOLO*	calculation	*calcolare*	to calculate	*calmare*	to calm down
VN	*CAMMINATA*	walk_N	*camminare*	to walk	*cambiare*	to change
VN	*CANTO*	song	*cantare*	to sing	*cancellare*	to erase
VN	*CONVERSAZIONE*	conversation	*conversare*	to converse	*convertire*	to convert
VN	*CORSA*	run_N	*correre*	to run	*corrispondere*	to correspond
VN	*COSTRUZIONE*	construction	*costruire*	to build	*costringere*	to force
VN	*CROLLO*	collapse_N	*crollare*	to collapse	*criticare*	to criticize
VN	*ESPLOSIONE*	explosion	*esplodere*	to explode	*esclamare*	to exclaim
VN	*EVASIONE*	escape_N	*evadere*	to escape	*evolvere*	to evolve
VN	*GIURAMENTO*	oath_N	*giurare*	to swear	*giustificare*	to justify
VN	*INTERROGAZIONE*	interrogation	*interrogare*	to examine	*installare*	to install

GC	*Target words*		*Morphological primes*		*Control primes*	
VN	*LANCIO*	throw$_N$	*lanciare*	to throw	*lottare*	to fight
VN	*LETTURA*	reading	*leggere*	to read	*legare*	to bind
VN	*MASSAGGIO*	massage$_N$	*massaggiare*	to massage	*massacrare*	to slaughter
VN	*MORSO*	bite$_N$	*mordere*	to bite	*mormorare*	to murmur
VN	*NASCITA*	birth	*nascere*	to be born	*nascondere*	to hide
VN	*NEVE*	snow$_N$	*nevicare*	to snow	*negare*	to negate
VN	*PARTENZA*	departure	*partire*	to leave	*parlare*	to chat
VN	*PATTINAGGIO*	skating	*pattinare*	to skate	*pendere*	to lean
VN	*PIANTO*	crying	*piangere*	to cry	*piantare*	to plant
VN	*PIOGGIA*	rain$_N$	*piovere*	to rain	*piegare*	to fold
VN	*POTATURA*	pruning	*potare*	to prune	*posare*	to put down
VN	*PREGHIERA*	prayer	*pregare*	to pray	*premere*	to press
VN	*RACCOLTA*	harvest$_N$	*raccogliere*	to harvest	*raccontare*	to tell

GC	*Target words*		*Morphological primes*		*Control primes*	
VN	*RASATURA*	shaving	*radere*	to shave	*ragionare*	to reason
VN	*RISATA*	$laugh_N$	*ridere*	to laugh	*rifiutare*	to refuse
VN	*RUGGITO*	$roar_N$	*ruggire*	to roar	*russare*	to snore
VN	*SALTO*	$jump_N$	*saltare*	to jump	*saldare*	to solder
VN	*SALUTO*	greeting	*salutare*	to greet	*sapere*	to know
VN	*SALVATAGGIO*	$rescue_N$	*salvare*	to save	*sancire*	to ratify
VN	*SBADIGLIO*	$yawn_N$	*sbadigliare*	to yawn	*sbagliare*	to make a mistake
VN	*SCOPPIO*	$burst_N$	*scoppiare*	to burst	*scoprire*	to discover
VN	*SCRITTURA*	writing	*scrivere*	to write	*scuotere*	to shake
VN	*SOFFIO*	$blow_N$	*soffiare*	to blow	*soffrire*	to suffer
VN	*SPARO*	shot	*sparare*	to shoot	*sparire*	to disappear
VN	*STARNUTO*	$sneeze_N$	*starnutire*	to sneeze	*stancare*	to make tired
VN	*ULULATO*	$howl_N$	*ululare*	to howl	*unire*	to unify

GC	*Target words*		*Morphological primes*		*Control primes*	
VN	*VOLO*	flight	*volare*	to fly	*votare*	to vote

Notes. GC, grammatical class; NV, nouns priming verbs; VN, verbs priming nouns.

Appendix C. Prime and target words used in Experiment 3.

Condition	*Target*		*Related prime*		*Control prime*	
Transparent	*potatura*	pruning	*potare*	to prune	*posare*	to place
Transparent	*donatore*	benefactor	*donare*	to donate	*dosare*	to dose
Transparent	*ruggito*	roar$_N$	*ruggire*	to roar	*rubare*	to steal
Transparent	*ululato*	howl$_N$	*ululare*	to howl	*ubbidire*	to obey
Transparent	*starnuto*	sneeze$_N$	*starnutire*	to sneeze	*stimolare*	to stimulate
Transparent	*camminata*	walk$_N$	*camminare*	to walk	*camuffare*	to disguise
Transparent	*giuramento*	oath$_N$	*giurare*	to take an oath	*giungere*	to come
Transparent	*avviamento*	launch$_N$	*avviare*	to launch	*avvitare*	to screw
Transparent	*duello*	duel$_N$	*duellare*	to fight a duel	*dubitare*	to doubt
Transparent	*proiettore*	projector	*proiettare*	to cast	*precisare*	to specify
Transparent	*mangime*	animal feed	*mangiare*	to eat	*mantenere*	to maintain
Transparent	*fioritura*	bloom$_N$	*fiorire*	to bloom	*fioccare*	to snow
Transparent	*resistenza*	resistance	*resistere*	to resist	*recitare*	to play
Transparent	*solletico*	tickle$_N$	*solleticare*	to tickle	*sollevare*	to lift
Transparent	*pulsazione*	beat$_N$	*pulsare*	to pulsate	*puzzare*	to stink
Transparent	*augurio*	wish$_N$	*augurare*	to wish	*auspicare*	to wish
Transparent	*incitazione*	support$_N$	*incitare*	to support	*incidere*	to cut

Condition	*Target*		*Related prime*		*Control prime*	
Transparent	*colonia*	colony	*colonizzare*	to conquer	*collocare*	to position
Transparent	*intonazione*	intonation	*intonare*	to put in tune	*intervenire*	to intervene
Transparent	*delegazione*	delegation	*delegare*	to delegate	*delirare*	to rave
Transparent	*inibizione*	inhibition	*inibire*	to inhibit	*inoltrare*	to forward
Transparent	*pulizia*	cleanliness	*pulire*	to clean	*pubblicare*	to publish
Transparent	*narratore*	narrator	*narrare*	to narrate	*nascere*	to be born
Transparent	*bacio*	$kiss_N$	*baciare*	to kiss	*bagnare*	to wet
Transparent	*sparo*	shot	*sparare*	to shoot	*sparire*	to disappear
Transparent	*lancio*	$throw_N$	*lanciare*	to throw	*lottare*	to fight
Transparent	*soffio*	$blow_N$	*soffiare*	to blow	*soffrire*	to suffer
Transparent	*abbraccio*	$embrace_N$	*abbracciare*	to embrace	*abbondare*	to abandon
Transparent	*massaggio*	$massage_N$	*massaggiare*	to massage	*massacrare*	to massacre
Transparent	*pattinaggio*	skating	*pattinare*	to skate	*pendere*	to lean
Transparent	*duello*	$duel_N$	*duellare*	to fight a duel	*dubitare*	to doubt
Transparent	*proiettore*	projector	*proiettare*	to cast	*precisare*	to specify
Transparent	*pulsazione*	$beat_N$	*pulsare*	to pulsare	*puzzare*	to stink
Transparent	*inibizione*	inhibition	*inibire*	to inhibit	*inoltrare*	to forward
Transparent	*pulizia*	cleanliness	*pulire*	to clean	*pubblicare*	to publish
Transparent	*sparo*	shot	*sparare*	to shoot	*sparire*	to disappear

Condition	*Target*		*Related prime*		*Control prime*	
Transparent	*lancio*	$throw_N$	*lanciare*	to throw	*lottare*	to fight
Transparent	*soffio*	$blow_N$	*soffiare*	to blow	*soffrire*	to suffer
Opaque	*fornaio*	baker	*fornire*	to provide	*fallire*	to fail
Opaque	*stilista*	stylist	*stilare*	to draft	*stipulare*	to stipulate
Opaque	*pastorizia*	sheep farming	*pastorizzare*	to pasteurize	*partorire*	to hatch
Opaque	*trattino*	$dash_N$	*trattare*	to negotiate	*trattenere*	to keep
Opaque	*costiera*	coast	*costare*	to cost	*contenere*	to contain
Opaque	*marinaio*	sailor	*marinare*	to marinate	*marcire*	to go rotten
Opaque	*brandina*	camp bed	*brandire*	to brandish	*brindare*	to make a toast
Opaque	*scaglietta*	little flake	*scagliare*	to throw	*scaldare*	to heat
Opaque	*campetto*	little court	*campare*	to live	*cancellare*	to erase
Opaque	*cassone*	(marriage) chest	*cassare*	to repeal	*caricare*	to upload
Opaque	*minatore*	miner	*minare*	to undermine	*mietere*	to harvest
Opaque	*portiera*	car door	*portare*	to bring	*popolare*	to inhabit
Opaque	*partitura*	(music) score	*partire*	to leave	*parare*	to block
Opaque	*saletta*	little hall	*salare*	to salt	*saziare*	to fill
Opaque	*seminarista*	seminarian	*seminare*	to sow	*sembrare*	to seem
Opaque	*ritrattista*	portrait painter	*ritrattare*	to retract	*riunire*	to gather
Opaque	*cancelletto*	little gate	*cancellare*	to erase	*cambiare*	to change

Condition	*Target*		*Related prime*		*Control prime*	
Opaque	*cavetto*	little cable	*cavare*	to remove	*causare*	to cause
Opaque	*contessa*	countess	*contare*	to count	*contrarre*	to contract
Opaque	*colpevole*	culprit	*colpire*	to hit	*colorare*	to paint
Opaque	*saliera*	salt shaker	*salire*	to come up	*saltare*	to jump
Opaque	*spratoria*	shooting	*sparire*	to disappear	*spargere*	to disseminate
Opaque	*gradazione*	gradation	*gradire*	to like	*grattare*	to scratch
Opaque	*levatrice*	midwife	*levare*	to remove	*lessare*	to stew
Opaque	*bollatura*	$stamp_N$	*bollire*	to boil	*bocciare*	to reject
Opaque	*fondatore*	founder	*fondere*	to melt	*forzare*	to compel
Opaque	*violetta*	african violet	*violare*	to infringe	*visitare*	to visit
Opaque	*mentina*	mint	*mentire*	to lie	*meritare*	to merit
Opaque	*libretto*	little book	*librare*	to hover	*licenziare*	to fire
Opaque	*tubetto*	little tube	*tubare*	to coo	*tutelare*	to protect
Opaque	*gestaccio*	gesture	*gestire*	to manage	*gettare*	to throw
Opaque	*cremeria*	creamery	*cremare*	to burn	*criticare*	to criticize
Opaque	*testiera*	headboard	*testare*	to test	*tentare*	to try
Opaque	*tornitore*	lathe turner	*tornare*	to come back	*tossire*	to cough
Opaque	*venatura*	vain	*venire*	to come	*versare*	to pour
Opaque	*laccetto*	little lace	*laccare*	to lacquer	*lavorare*	to work

Condition	*Target*		*Related prime*		*Control prime*	
Opaque	*tendaggio*	curtains	*tendere*	to stretch	*temere*	to be afraid of
Opaque	*baleniera*	whaler	*balenare*	to flash	*badare*	to look after

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Footnotes

1. In the vast majority of the experiments on the visual identification of complex words, the stimuli were such that roots and stems coincided. This is also the case in the experiments illustrated in this paper, with the only exception of *bombardare-bombardamento*. The two terms might therefore be used interchangeably when describing these findings. Although the term stem is more commonly adopted than the term root in the psycholinguistic literature on Indo-European languages, we will use the latter in the present manuscript, as we will also refer to data obtained in Hebrew, where the term "stem" would be inappropriate.

2. Giraudo and Grainger (2001) dubbed their model as *supra-lexical*, rather than *post-lexical*. Here we use the more general term *post-lexical* so as to include under this label *any* morphological level of analysis that comes into play after the orthographic input lexicon (e.g., the *lemma level* in Crepaldi, Rastle, Coltheart, & Nickels, 2010), and any model that includes such a level of processing.

3. Of course, morphologically related nouns and verbs would also be orthographically and semantically similar, and thus some priming effect might be expected at these levels.

4. Italian has a very consistent orthography-to-phonology mapping, and so orthographic overlap between primes and targets always yields an identical degree of phonological overlap.

5. Following Baayen (2008), outliers were defined as those datapoints whose standardised residuals were higher than 2.5 in absolute value.

Tables

Table 1. Lexical-semantic variables for related and unrelated primes in the experimental conditions of Experiment 1.

(a) Morphological conditions

	VN		NV	
	Related	Unrelated	Related	Unrelated
Spoken word frequency	2.55 ± .54	2.55 ± .54	2.29 ± .46	2.26 ± .46
Written word frequency	1.57 ± .55	1.41 ± .61	1.73 ± .50	1.55 ± .60
Number of letters	8.06 ± 1.54	8.09 ± 1.62	7.64 ± 2.39	7.35 ± 1.95
Number of syllables	3.47 ± .59	3.47 ± .59	3.07 ± .99	3.02 ± .89

(b) Semantic conditions

	VN		NV	
	Related	Unrelated	Related	Unrelated
Spoken word frequency	2.71 ± .55	2.67 ± .56	2.49 ± .62	2.49 ± .63
Written word frequency	1.82 ± .56	1.64 ± .44	2.16 ± .55	1.93 ± .60
Number of letters	7.78 ± 1.31	7.80 ± 1.24	6.17 ± 1.48	6.11 ± 1.35
Number of syllables	3.33 ± .47	3.33 ± .47	2.64 ± .65	2.64 ± .65

Notes. NV, nouns priming verbs; VN, verbs priming nouns. Frequency values are reported as the logarithm of the total number of occurrences in the corpus.

Table 2. An example of prime-target pairs for each condition in Experiment 1.

	Morphological condition				Semantic condition			
	Related pair		Unrelated pair		Related pair		Unrelated pair	
	Prime	Target	Prime	Target	Prime	Target	Prime	Target
NV	*camminata* walk$_N$	*camminare* to walk	*mozzarella* mozzarella	*camminare* to walk	*passo* step$_N$	*camminare* to walk	*borsa* bag	*camminare* to walk
VN	*camminare* to walk	*camminata* walk$_N$	*inventare* to invent	*camminata* walk$_N$	*correre* to run	*camminata* walk$_N$	*citare* to quote	*camminata* walk$_N$

Notes. NV, nouns priming verbs; VN, verbs priming nouns.

Table 3. Mean reaction times (in ms) obtained by the participants in Experiment 1.

	VN				NV			
	SOA = 300 ms		SOA = 100 ms		SOA = 300 ms		SOA = 100 ms	
	Morph	Sem	Morph	Sem	Morph	Sem	Morph	Sem
Unrelated	533	499	551	503	543	498	564	509
Related	500	492	520	502	498	493	534	500
Facilitation	-33	-7	-31	-1	-45	-5	-30	-9

Notes. NV, nouns priming verbs; VN, verbs priming nouns; Morph, primes and targets are morphologically related; Sem, primes and targets are semantically – but not morphologically – related.

Table 4. Assessment of cross-class morphological and semantic priming in the 300 ms SOA–nouns priming verbs, 300 ms SOA–verbs priming nouns, 100 ms SOA–nouns priming verbs, and 100 ms SOA–verbs priming nouns conditions.

	Morphological priming		Semantic priming	
	Wald chi-square [df=1]	p	Wald chi-square [df=1]	p
300 ms SOA, NV	155.64	< .001	3.73	.053
300 ms SOA, VN	111.83	< .001	10.80	= .001
100 ms SOA, NV	77.24	< .001	1.49	.22
100 ms SOA, VN	70.98	< .001	.18	.70

Notes. NV, nouns priming verbs; VN, verbs priming nouns

Table 5. Lexical-semantic variables for related and unrelated primes in Experiment 2.

	VN		NV	
	Related	Unrelated	Related	Unrelated
Spoken word frequency	2.55 ± .54	2.48 ± .59	2.29 ± .46	2.16 ± .60
Written word frequency	1.57 ± .55	1.46 ± .59	1.73 ± .50	1.73 ± .50
Number of letters	8.06 ± 1.54	8.09 ± 1.70	7.64 ± 2.39	6.78 ± 1.58
Number of syllables	3.47 ± .59	3.44 ± .59	3.07 ± .99	2.80 ± .76

Notes. VN, verbs priming nouns; NV, nouns priming verbs. Frequency values are reported as the logarithm of the total number of occurrences in the corpus.

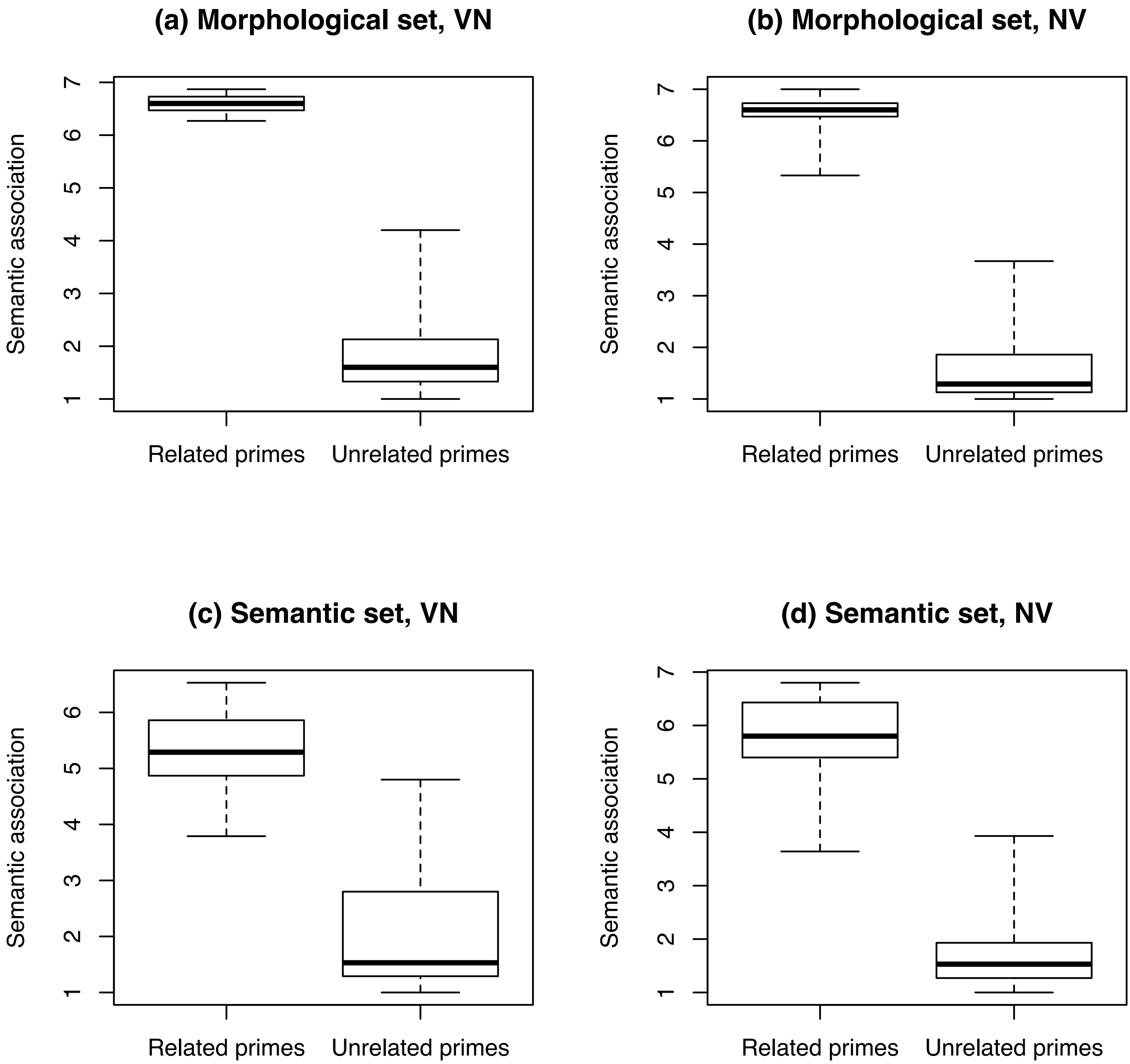
Table 6. Mean reaction times (in ms) obtained by the participants in Experiment 2.

	VN		NV	
	SOA = 300 ms	SOA = 100 ms	SOA = 300 ms	SOA = 100 ms
Unrelated	539	492	539	494
Related	508	465	507	477
Facilitation	-31	-27	-32	-17

Notes. NV, nouns priming verbs; VN, verbs priming nouns.

Figure Captions

Figure 1. Boxplots of the semantic association values between primes and targets in the Morphological-NV, Morphological-VN, Semantic-NV, and Semantic-VN conditions of Experiment 1. The bold lines represent the medians of the distribution, the upper and lower bounds represent the upper and lower quartiles, and the whiskers extend to the extreme values in the distribution.


(a) Morphological set, VN
Semantic association
1
2
3
4
5
6
7
Related primes
Unrelated primes
(b) Morphological set, NV
Semantic association
1
2
3
4
5
6
7
Related primes
Unrelated primes
(c) Semantic set, VN
Semantic association
1
2
3
4
5
6
Related primes
Unrelated primes
(d) Semantic set, NV
Semantic association
1
2
3
4
5
6
7
Related primes
Unrelated primes