Early morphological decomposition of suffixed words:

Masked priming evidence with transposed-letter nonword primes.

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Abstract

Many studies have previously reported that the recognition of a stem target (e.g. *teach*) is facilitated by the prior masked presentation of a prime consisting of a derived form of it (e.g. *teacher*). We conducted two lexical decision experiments to investigate masked morphological priming in Spanish. Experiment 1 showed that equal magnitudes of masked stem-target priming are obtained for both morphologically complex word primes (e.g. *doloroso-DOLOR* [*painful-PAIN*]) and morphologically complex nonword primes that included letter transpositions within the stem (e.g. *dlooroso-DOLOR*). Experiment 2 used morphologically complex nonword primes comprising lexically illegal combinations of stems and suffixes (e.g. *total + ito* [*a little total*]). Priming was obtained for morphologically related nonword primes (e.g. *totalito-TOTAL*), but not for nonword primes that included letter transpositions within the pseudo-stem (e.g. *ttoalito-TOTAL*). Our data suggest that morpho-orthographic parsing mechanisms benefit from semantic constraints at early stages in the reading system, which we discuss in the context of current morphological processing accounts.

Key words: visual word recognition, masked priming, transposed-letters, letter position coding.

Early morphological decomposition of suffixed words: Masked priming evidence with transposed-letter nonword primes.

Many decades of research have been directed towards understanding how and when readers gain access to morphological information in visual word recognition (Bybee, 1995; Colé, Beauvillain, & Segui, 1989; Taft & Forster, 1975). Full-listing theories propose that morphologically complex words are stored and retrieved as whole entities in the lexicon (e.g. Butterworth, 1983; Manelis & Tharp, 1977). Recently however, research has begun to more extensively explore the concept of morphological decomposition. Post-lexical decomposition accounts propose that morphologically complex words are always initially mapped onto whole-word representations and only decomposed after access to the lexicon has been achieved (e.g. Giraudo & Grainger, 2000; Giraudo & Grainger, 2001). Pre-lexical accounts of morphological decomposition suggest that morphologically structured words are automatically decomposed into their morpho-orthographic subunits which then in turn activate the lexical representation of the whole word (e.g. Duñabeitia, Perea, & Carreiras, 2007; (Grainger, Colé, & Segui, 1991; Longtin & Meunier, 2005; Longtin, Segui, & Hallé, 2003); Rastle, Davis, Marslen-Wilson, & Tyler, 2000; Rastle, Davis, & New, 2004; Taft, 2003, 2004). Other researchers favour a dual-pathway account, proposing a combination of pre- and post-lexical decomposition strategies, such that a morphologically complex input letter string can be either processed pre-lexically (via the decompositional pathway) or post-lexically (via the whole-word route; e.g., Diependaele, Sandra, & Grainger, 2009; see also Baayen, Dijkstra, & Schreuder, 1997, for a related account).

More recently, it has been debated as to when exactly semantic influences in automatic morphological processing can be found. In this respect, theories of morphological decomposition split into two different camps. One hypothesis proposes that early morphological decomposition is purely based on the analysis of orthographic form (e.g. McCormick, Rastle & Davis, 2008, 2009; Rastle & Davis, 2008). This hypothesis argues that morphological decomposition is initially semantically 'blind', as it operates purely on the basis of *morpho-orthographic* encoding, and that *morpho-semantic* information then gradually comes in as time increases. The second hypothesis considers that semantic influences on morphological parsing can already be observed at initial stages of word recognition (e.g. Diependaele et al., 2009; Feldman, O'Connor, Moscoso del Prado Martin, 2009). Results favouring this view have been obtained in experiments reporting processing asymmetries between truly polymorphemic words (such as the derived word *teacher*), and pseudo-complex monomorphemic words that have an internal structure that resembles that of polymorphemic words (such as *corner*, which could be incorrectly decomposed in *corn+er*; see Feldman et al., 2009, for review). It is thus considered that morpho-orthographic and morpho-semantic processing co-occur at initial morphological processing stages.

The masked priming paradigm has been typically used to explore automatic stages of the processing of derivationally-affixed words (Longtin et al., 2003; Rastle, Davis, Marslen-Wilson, & Tyler, 2000). In a prototypical masked priming experiment, a forward mask is presented, followed by a briefly presented stimulus (the prime), which in turn is immediately replaced by another stimulus (the target). Participants are not aware of the existence of the masked prime, but its influence can still be measured on target recognition. The processing of the briefly presented prime (typically shown for 40-70 ms) is posited to show early, automatic processes (Forster & Davis, 1984; Forster, Davis, Schoknecht, & Carter, 1987). In this line, many masked priming studies have shown that the recognition of a target (e.g. *corn*) is facilitated by the prior presentation of a morpho-orthographically related prime (e.g. *corner*), suggesting that there is a mechanism that decomposes morphologically complex letter strings at early pre-lexical stages in visual word recognition (e.g. Longtin & Meunier, 2005).

Our present studies aimed at further investigating early morphological decomposition and affix stripping mechanisms in visual word recognition in masked priming to explore whether priming still occurs for morphologically complex primes including a letter transposition within their stems (Experiment 1) and exploring the influences of semantics on early morphological transposed-letter priming effects by altering the lexical status of the primes (Experiment 2). As explained below, this manipulation represents a critical test for accounts based on early and automatic morphological decomposition, due to the orthographic nature of the transposed-letter similarity effect (TL effect, hereafter, see also Christianson, Johnson, & Rayner, 2005; Duñabeitia, Perea, & Carreiras, 2007; Rueckl & Rimzhim, in press).

Evidence from masked transposed-letter priming studies shows that a nonword prime with two transposed letters at internal positions such as *wlak* facilitates the recognition of the target *walk* relative to an orthographic control like *whuk* (e.g. Andrews, 1996; Forster et al., 1987; Perea & Lupker, 2003; Peressotti & Grainger, 1999; Schoonbaert & Grainger, 2004). This masked TL-similarity effect can be accounted for by models of orthographic encoding that assume imprecise initial coding of letter positions at early stages of word processing (Gómez, Ratcliff, & Perea, 2008; Grainger & van Heuven, 2003; Whitney, 2001). As a consequence of the imprecise position encoding of the letters within a string, when a TL-nonword like *wlak* is presented the orthographic representation of the word *walk* is activated, and consequently the lexical representation of the word *walk* is the one receiving the highest activation, since this is the closest pattern matching the misspelled input (see

Duñabeitia, Perea, & Carreiras, 2009). Hence, the TL-effect is assumed to reflect positionally imprecise whole-word processing (Gómez et al., 2008).

In a recent lexical decision study in English, Rueckl and Rimzhim (2010) investigated the effects of TL-manipulations in morphological masked priming to test the time course of morphological processing in visual word recognition. Critically, as compared to previous studies (e.g. Christianson et al., 2005; Duñabeitia et al., 2007) which have always used morphologically complex targets, Rueckl and Rimzhim (2010, Experiment 1-3) were the first to investigate the effects of TL-manipulated morphologically complex word primes on stem-target recognition. Primes were created by either transposing the two last letters of the stem (*teahcer-TEACH*) or by transposing the last letter of the stem and the first of the suffix (*teacehr-TEACH*). An additional condition was introduced in which targets were preceded by a morphologically related prime (*teacher-TEACH*). TL-primes and morphologically related primes were compared to a substituted-letter control, in which the two transposed letters (*teahcer*) were substituted with two new letter identities (*teakser*).

These experiments revealed that the recognition of the target (*teach*) was facilitated by the prior masked presentation of morphologically related TL-primes, independently of whether it comprised a TL-manipulation within the stem or across the morpheme boundary (*teahcer-TEACH vs. teacehr-TEACH*). These results conflict with previous findings (Christianson et al., 2005; Duñabeitia et al., 2007) suggesting that the position of the transposition had no impact on the obtained size of priming. In fact, there was no difference between the size of the priming effects in the morphologically related and the TL-across condition when compared to the substituted letter condition (Rueckl & Rimzhim, 2010, Experiment 2 & 3; *teacher-TEACH* vs. *teacifr-TEACH* and *teacehr-TEACH* vs. *teacifr -TEACH*). Interestingly however, the difference between the morphologically related and the TL-within condition (*teacher-TEACH* vs. *teakser-*

TEACH and *teahcer-TEACH* vs. *teakser-TEACH*) *was* significant in Experiment 1, but *not* in Experiment 3.

The evidence reported by Rueckl and Rimzhim (2010) show that inconsistencies remain in morphological transposed-letter priming studies. While Christianson et al. (2005) and Duñabeitia et al. (2007) reported evidence for the disappearance of transposed-letter priming for across-boundary transpositions, Rueckl and Rimzhim demonstrate that this is not always the case. However, two points should be noted regarding the generalization of their findings. First, position-specific orthographic prime-target overlap was always greatest in the morphologically related condition (*teacher-TEACH*, 5 letter overlap), less in the across-morpheme boundary condition (*teacehr-TEACH*, 4 letter overlap) and lowest in the within-morpheme boundary condition (*teahcer-TEACH*, 3 letter overlap). It cannot therefore be ruled out that the largest priming effects found in the morphologically related condition relative to the TL-within condition were due to greater orthographic prime-target overlap as measured in terms of position-specific overlap. A second concern arises with the external position of letter transpositions (*teahc*). It is known that TL-nonwords with transpositions at external positions resemble their corresponding real word to a lesser degree than TL-nonwords with transpositions at internal positions (Johnson, Perea, & Rayner, 2007; Perea & Lupker, 2007; Rayner, White, Johnson, & Liversedge, 2006). It is possible that the involvement of external letters reduced the amount of priming observed in the TL-within condition. It is therefore important to establish whether this difference would also be obtained when (i) the amount of orthographic prime-target overlap is balanced across conditions and (ii) only internal letters of the stem are transposed.

We conducted two masked primed lexical decision experiments to further explore the role of transposed-letter manipulations in morphological processing, in Spanish. In particular, we were interested in directly comparing the magnitudes of the priming effects obtained for suffixed primes and TL-primes relative to an unrelated control, in order to gain a better understanding of the impact of letter transpositions in morphological processing. Our goal was to control for orthographic prime-target overlap by introducing an unrelated priming condition while transposing at internal positions of the stem morpheme only. We conducted two masked primed lexical decision experiments. Experiment 1 assessed the role of letter position coding in morphologically complex word processing in Spanish. Experiment 2 was designed to extend the findings from Experiment 1, in particular to investigate the influences of semantic factors in early morphological processing.

Experiment 1

TL-nonword primes were constructed from Spanish suffixed words (e.g. *dlooroso* from *doloroso* [*painful*]). Targets were made of the monomorphemic stems of these suffixed words (*DOLOR* [*pain*]). To guarantee that the transposed-letter similarity effect would not be reduced by the transposition of external letters (Johnson et al., 2007; Perea & Lupker, 2007; Rayner et al., 2006), transpositions were only performed with internal letters of the stem. Priming in the TL-conditions (*dlooroso-DOLOR*) was compared to a substituted-letter control (*dteoroso-DOLOR*). Furthermore, we used a morphologically related priming condition (*doloroso-DOLOR* [*painful-PAIN*]) and a fully unrelated word priming condition (*tumoroso-DOLOR* [*tumorous-PAIN*]).

If it is the case that morphological effects operate purely over *early* orthographic encoding mechanisms with high positional uncertainty (e.g. Longtin & Meunier, 2005; Rastle et al., 2004; Taft, 2003), no differences between the size of the priming effects for morphologically related primes and morphologically complex TL-primes (*doloroso-DOLOR* vs. *dlooroso-DOLOR*) should be observed, as measured against the unrelated word priming condition. That is, while some basic positional context is needed in order to recognize a morpheme, positional information is still underspecified at the time that morphological information is encoded. If however, morphologically complex words are decomposed at *later* stages in lexical processing with less positional uncertainty (e.g. Giraudo & Grainger, 2003; Marslen-Wilson, Tyler, Waksler & Older, 1994, see also Diependaele et al., 2009), *dlooroso* should prime *dolor* to a lesser degree than *doloroso*. That is, the magnitude of priming in the TL-condition should be reduced.

Method

Participants

Thirty-six undergraduate students from the University of the Basque Country participated in this study. All participants were native Spanish speakers and had normal or corrected-to-normal vision.

Materials

A set of 76 Spanish words was selected as targets (e.g., *dolor* [*pain*]; see Table 1 for characteristics). Each target could be preceded by four possible primes: a morphologically related prime (*doloroso* [*painful*], a transposed-letter prime (*dlooroso*), a replaced-letter control prime (*dteoroso*), or an unrelated prime (*tumoroso* [*tumorous*]). Related and unrelated prime words were matched on length, orthographic N, word frequency, bigram frequency, stem length, stem orthographic N, and stem frequency (see Table 1). In order to control for the potential impact of the suffix, the unrelated word selected for each related word prime always included the same suffix (*doloroso* and *tumoroso*). Transposed-letter nonword primes were created by transposing two internal letters of the stems (*dlooroso*). None of the transpositions included two vowels (see Lupker, Perea, & Davis, 2008), and none of the letter transpositions led to the creation of a real word (Duñabeitia, Molinaro, Laka, Estévez, & Carreiras, 2009; Duñabeitia, Perea, & Carreiras, 2009). The replaced-letter (RL) control condition was created by substituting the two transposed-letters with two new letter identities with a similar formal resemblance (*dteoroso*). Transposed and replaced-letter primes were matched on length, orthographic N, and bigram frequency (see Table 1). A complete list of stimuli is provided in Appendix 1.

For the purpose of the lexical decision task, we included a set of 76 nonword targets which were all orthographically legal and pronounceable by replacing the first and the last letter of a real word (e.g., the nonword *ozus* from the word *azul*). Each nonword target was preceded by four different primes, following the same conditions used for word trials (Morphologically related: *ozusado*; Transposed-letters: *ouzsado*; Replaced-letters: *oicsado*; Unrelated: *loctosado*).

Four lists were created, so that each target only appeared once in each list, but each time in a different priming condition. Nine participants were randomly assigned to each of the lists.

- Insert Table 1 around here -

Procedure

Stimuli were presented in the centre of a CRT computer screen using the DMDX display system (Forster & Forster, 2003) in randomised order. Each participant was tested individually in a quiet room located at the Basque Center on Cognition, Brain and Language. Each trial consisted of the presentation of a forward mask of # symbols for 500 ms, followed by the presentation of the prime in lowercase for 53 ms, and immediately followed by the presentation of the uppercase target stimulus. The target remained on the screen until the subject responded or for a maximum of 2500 ms. Participants were asked to decide as quickly and accurately as possible whether the visually presented targets were real Spanish words or not (i.e., a lexical decision task). Two keys of the keyboards were appropriately labelled. The whole experimental session lasted for about 10 minutes.

Results and Discussion

Reaction times longer than 1500 ms or shorter than 300 ms were discarded (18 outliers were identified, 0.7 % of the data). Mean reading latencies and error rates averaged over subjects are presented in Table 2.

- Insert Table 2 around here -

RTs were transformed logarithmically and the main analyses were performed using linear mixed effect model modelling (e.g. Baayen, 2008; Baayen, Davidson, & Bates, 2008). To reduce the variance in the models, we included the predictor Trial Number as a measure of how far the participant has progressed into the experiment. This measure allows us to control for longitudinal task effects such as fatigue or habituation. Furthermore, since every participant was presented with items in a different random order, the order of trial presentation may have had different effects on individual subjects. Therefore, to adjust the by-subject random slopes for Trial Number, we included a correlation parameter specified in the random-effect structure of each subject (Baayen, 2008, pp. 251-252). A generalised linear mixed-effects model as implemented in the lme4 package (from http://cran.r-project.org/web/packages/) in the statistical software R (version 2.10.1, RDevelopmentCoreTeam, 2008) was used with two fixed effects factors (Trial Number and Prime Type: Related, Transposed-letter, Replaced-letter, Unrelated) and two random-effects factors (random intercepts for Subjects and Items). Factors were selected in a step-wise model selection procedure and only included when a formal comparison between models showed a significant improvement of the model's fit when the factor was added to the model. Significance was accessed with p-value sampling *pvals.fnc*, as implemented in the language R package (Baayen, 2008).

The model revealed that words preceded by morphologically related primes were responded to significantly faster than words preceded by unrelated primes (26 ms), $t = 4.3$, $p < .001$. Similarly, words in the transposed-letter priming condition were classified significantly faster than words preceded by unrelated primes (25 ms), $t = 4.0$, $p < .001$. The replaced-letter condition did not differ significantly from the unrelated condition (9 ms), $t = 1.5$, $p = .125$. No significant differences were obtained between the morphologically related and the transposed-letter priming condition, $t = 0.4$, $p = .704$. Critically, there was a significant difference between the replaced-letter priming condition and the morphologically related priming condition (17 ms), $t = 2.8$, $p = .005$. Similarly, the transposed-letter primes significantly facilitated target recognition as compared to replaced-letter primes (16 ms), $t = 2.4$, $p = .015$. None of the effects in the error rate analyses and in the nonword data were significant.

The results obtained in the present masked priming experiment can be summarized as follows: First, we replicated the well-known masked morphological priming effect using Spanish materials (*doloroso-DOLOR* vs. *tumoroso-DOLOR*). Second, a significant priming effect was also obtained for morphologically related primes that included a letter transposition within the stems (*dl<u>o</u>oroso-DOLOR* vs. *tumoroso-DOLOR*). Third, the priming effect was no larger in the morphologically related condition (*doloroso-DOLOR*) than in the transposed-letter condition (*dl<u>o</u>oroso-DOLOR*). Fourth, we replicated the transposed-letter priming effect, showing that targets preceded by transposed-letter primes were recognized significantly faster than targets preceded by primes including a letter replacement (*dlooroso-DOLOR* vs. *dteoroso-DOLOR*). And fifth, we showed that no signs of priming effects are found when two of the internal letters of the morphologically related primes are replaced by other letters, as compared to completely unrelated primes (*dteoroso-DOLOR* vs. *tumoroso-DOLOR*).

The key finding in this study was the lack of difference in the magnitude of the priming effects observed for the non-transposed morphologically related primes and the morphologically related primes that included a letter transposition within the stem (namely, for *doloroso-DOLOR* and *dlooroso-DOLOR*; 26 ms and 25 ms respectively, as compared to the unrelated primes, and 17 ms and 16 ms respectively as compared to the replaced-letter primes). The masked transposed-letter priming effect (Andrews, 1996; Forster et al., 1987; Perea, Duñabeitia, & Carreiras, 2008; Perea & Lupker, 2003; Peressotti & Grainger, 1999; Schoonbaert & Grainger, 2004) has been generally taken as clear-cut evidence in favor of models that assume imprecise initial coding of letter position (Grainger & van Heuven, 2003; Whitney, 2001). The present results confirm that masked morphological subset priming effects (*doloroso-DOLOR*) do also occur for nonword primes in which internal letters of the stem have been distorted by means of letter transpositions (*dlooroso-DOLOR*). Despite the increased complexity of the nonword string *dlooroso* (suffixed and TL-manipulated) as compared to the word *doloroso* (only suffixed, no TL-manipulation), no difference was found between the priming effects.

The present priming effects, are in line with Rueckl and Rimzhim's Experiment 3 in English, which found equal amounts of morphological priming and within-boundary transposed-letter priming (*teacher-TEACH* vs. *teahcer-TEACH*). However, the present findings differ from Rueckl and Rimzhim's Experiment 1 which showed significantly less within-boundary transposed-letter priming than morphological priming. Our results may have differed for the following two reasons. First, Rueckl and Rimzhim measured morphological priming and transposed-letter priming against a substituted-letter control. Therefore, since the position-specific orthographic prime-target overlap in the morphologically related condition was greater than in the transposed-letter and substituted-letter condition, the obtained effects may reflect an orthographic boost of priming for highly orthographically related prime-target pairs. Second, the decreased size of priming in the TL-within condition in Rueckl and Rimzhim's Experiment 1 may be attributed to the inclusion of external letter positions in within-boundary transpositions. Transposed-letter priming has been found to be less reliable for letter transpositions at external positions of a letter string (Johnson et al., 2007; Perea & Lupker, 2007; Rayner et al., 2006). However, more systematic investigations of internal versus external stem transpositions are needed to draw explicit conclusions.

In summary, the present results show that stem-target priming is equally obtained from both morphologically complex real words and morphological complex TL-nonwords. The virtually identical effect size in both conditions indicates that *dlooroso* and *doloroso* are practically the same at these early stages in visual word processing. This is inconsistent with the hypothesis that morphological decomposition effects are triggered at late processing stages (e.g. Giraudo & Grainger, 2003). If letter position coding had already had time to develop precise representations of positional information prior to the stem morpheme activation process, then the input string *dlooroso*, with high positional certainty, would prime *dolor* to a lesser extend than *doloroso*. The present data thus support the hypothesis that morphological processing operates with high positional uncertainty over early orthographic stages in visual word recognition (e.g. Longtin & Meunier, 2005; Rastle et al., 2004; Taft, 2003). This has critical implications for letter position encoding schemes indicating that the encoding of letter position and morphological information both occur at the same time, at early automatic word processing stages.

However, the evidence reported in Experiment 1 does not allow us to draw conclusions regarding the influences of semantics on morphological parsing. It is possible that morphological decomposition does not exclusively rely on morpho-orthographic encoding mechanisms and that the observed priming effects in Experiment 1 were at least partially driven by the morpho-semantic relationship between the prime and the target. There are thus two possible interpretations of the results. Since we only used primes which were either derived from real words (*dlooroso* or *dteoroso*) or were real words themselves (*doloroso* or *tumoroso*), it is not clear whether priming from *doloroso* or *dlooroso* to *dolor* occurred because of (a) early semantically ‘blind’ morpho-orthographic decomposition of *doloroso* into *dolor* or *dloor* and *oso* (Longtin & Meunier, 2005; Rastle & Davis, 2008) or (b) a combination of early morpho-orthographically and morpho-semantically guided parsing into morphemes (e.g. Diependaele et al., 2009; Feldman et al., 2009). The first hypothesis proposes that automatic affix-stripping occurs for all presented letter strings, based on purely structural information. Since this account predicts that early morphological processing stages operate solely on basis of orthographic analysis, priming to the stem would be expected to occur independently of the semantic prime-target relationship. The second hypothesis considers that morphological decomposition does not exclusively rely on morpho-orthographic encoding mechanisms and that the observed priming effects in Experiment 1 were at least partially driven by the morpho-semantic relationship between the prime and the target. Stem-target priming would therefore largely depend on the semantic transparency of morphemic subunits. Given that the primes in Experiment 1 were always words, these two hypotheses cannot be distinguished, as both hypotheses would predict the same pattern of effects from word primes. In order to understand to what extent the priming effects in Experiment 1 were affected by the semantic relatedness between prime and target, we designed Experiment 2 using suffixed nonword-primes.

Experiment 2

Based on a similar procedure as in Experiment 1, primes were now constructed by using lexically illegal stem-suffix combinations. Primes in all four conditions were created such that the whole prime did not have a lexical representation on its own (i.e., all primes were nonwords). Primes in the related condition were constructed from a Spanish stem morpheme (*total*) and a suffix (*ito*), and were followed by the stem target (*totalito-TOTAL*). In addition, we introduced a transposed-letter condition (*ttoalito-TOTAL*) with letter transpositions within the stem, and a replaced-letter control condition (*tfealito-TOTAL*). Finally, for every related prime we created an unrelated control prime by combining the same suffix (*ito*) with an orthographically unrelated stem of the same length (*sudorito-TOTAL*).

Due to the lack of semantic relationship between the stems and the whole primes (e.g. *total* has a meaning, but *totalito* does not), we significantly reduced the likelihood that any of the effects obtained in Experiment 2 could be driven by the semantic relationship between target and prime. The non-lexical nature of the primes allowed us to explore the influences of semantics on masked morphological priming. If morphological decomposition is purely based on orthographic analysis (e.g. Rastle et al., 2004; Taft, 2003) priming should occur independently of whether or not there is a semantic relationship between the prime and the target. We would thus expect priming to occur in the morphologically related condition (*totalito-TOTAL)* and in the transposed-letter condition (*ttoalito-TOTAL*). However, if morphological decomposition was triggered by a combination of morpho-orthographic and morpho-semantic factors (e.g. Diependaele et al. 2009; Feldman et al., 2009) priming in the morphologically related and in the TL-condition should be reduced or disappear.

Method

Participants

Forty undergraduate students from the University of the Basque Country participated in this study. All participants were native Spanish speakers and had normal or corrected-to-normal vision.

Materials

A set of 84 Spanish words was selected as targets (e.g., *TOTAL*; see Table 3 for characteristics). Each target could be preceded by four possible primes: a morphologically related prime (*totalito*), a transposed-letter prime (*ttoalito*), a replaced-letter control prime (*tfealito*), or an unrelated prime (*sudorito*). Related primes were created by combining stems (e.g. *total*) and suffixes (e.g. *ito*) such that the whole letter string would not make a word (e.g. *totalito* is not a word). All stem-suffix combinations were orthographically legal and pronounceable[1].

Related and unrelated nonword primes used the same suffixes and were matched on length, bigram frequency, orthographic N, stem length, stem orthographic N, and stem frequency (see Table 3). As in Experiment 1, transposed-letter nonword primes were created by transposing two internal letters of the stems (*ttoalito*). None of the transpositions included two vowels (see Lupker et al., 2008), and none of the letter transpositions led to the creation of a real word (Duñabeitia, Molinaro et al., 2009; Duñabeitia, Perea et al., 2009). The replaced-letter control condition was created by substituting the two transposed-letters with two new letter identities with a similar formal resemblance (*tfealito*). Transposed and replaced-letter primes were matched on length, orthographic N, and bigram frequency (see Table 3). A complete list of stimuli is provided in Appendix 2.

For the purpose of the lexical decision task, we included a set of 84 nonword targets which were all orthographically legal and pronounceable by replacing the first and the last letter of a real word (e.g., the nonword *fotan* from the word *total*). Each nonword target was preceded by four different primes, following the same conditions used for word trials (Morphologically related: *fotanito*; Transposed-letters: *ftoanito*; Replaced-letters: *fdeanitio*; Unrelated: *sigacito*).

Four lists were created, so that each target only appeared once in each list, but each time in a different priming condition. Ten participants were randomly assigned to each of the lists.

- Insert Table 3 around here -

Procedure

We followed the same procedure as in Experiment 1.

Results and Discussion

Reaction times longer than 1500 ms or shorter than 300 ms were discarded (28 outliers were identified, 0.9 % of the data). Mean reading latencies and error rates averaged over subjects are presented in Table 4.

- Insert Table 4 around here -

RTs were transformed logarithmically and the main analyses were performed using linear mixed effect model methodology as in Experiment 1. The model used had two fixed effects factors (Trial Number and Prime Type: Related, Transposed-letter, Replaced-letter, Unrelated) and two random-effects factors (random intercepts for Subjects and Items). Significance was assessed with p-value sampling *pvals.fnc*, as implemented in the language R package (Baayen, 2008).

The model revealed that words preceded by morphologically related primes were responded to significantly faster than words preceded by unrelated primes (12 ms), $t = 2.0$, $p = .05$. However, there was no significant difference between the transposed-letter priming condition and the unrelated condition (3 ms), $t = 0.6$, $p = .459$. The replaced-letter condition did not differ significantly from the unrelated condition (0 ms), $t = 0.0$, $p = 1$. No significant differences were obtained between the morphologically related and the transposed-letter priming condition (9 ms), $t = 1.4$, $p = .162$. There was a significant difference between the replaced-letter priming condition and the morphologically related priming condition (12 ms), $t = 2.0$, $p = .04$. There was no difference between the transposed-letter primes as compared to replaced-letter primes (3 ms), $t = 0.6$, $p = .549$. None of the effects in the error rate analyses and in the nonword data were significant[2].

The morphological priming effect obtained in Experiment 2 (*totalito-TOTAL* vs. *sudorito-TOTAL*) adds evidence to a growing body of studies showing that nonwords with an apparent polymorphemic structure are initially taken by the visual word recognition system as truly polymorphemic words. For instance, Meunier and Longtin (2007) showed that morphologically complex interpretable pseudowords effectively prime existing target words (*rapidifier-RAPIDE* [*quickify-QUICK*]) in masked priming. In a similar line, McCormick, Rastle and Davis (2009) have recently offered evidence showing that this is also the case in English. Our results confirm that morphologically complex Spanish nonword primes like *totalito* are also morphologically decomposed on the mere appearance of morphological complexity.

These findings are incompatible with full-listing accounts (e.g. Butterworth, 1983; Manelis & Tharp, 1977) that entirely reject the concept of morphological decomposition. Experiment 2 also provides evidence against post-lexical morphological processing theories (e.g. Giraudo & Grainger, 2003; Marslen-Wilson et al., 1994), as they assume that morphological decomposition is based on the prior activation of lexical representations and would therefore occur only for lexically represented letter strings. That is, they would predict the absence of priming effects for suffixed nonword primes such as *totalito-TOTAL*, and therefore cannot account for the observed pattern.

Interestingly however, no priming was obtained for nonword primes in which internal letters of the stem had been distorted by means of letter transpositions (*tt<u>o</u>alito-TOTAL*). That is, in contrast to the morphologically related condition, there was no evidence for a transposed-letter priming effect. However, it should be noted that the results for the comparison between the morphologically related and transposed-letter condition were not entirely clear-cut, showing a statistically non-significant 9 ms difference. If it was truly the case that only morphologically related words produced priming, the morphologically related condition and the transposed-letter priming condition should have differed significantly. The strength of conclusions that can be drawn thus needs to be qualified in light of the absence of significance for this critical comparison. Most critically, however, the lack of masked transposed-letter priming effect proposes a challenge to purely morpho-orthographic processing accounts (e.g. Taft, 2003), which we discuss in more detail below.

General Discussion

The present experiments provide evidence for the morphological decomposition of affixed words and nonwords and affixed transposed-letter nonwords, and have important implications for models of morphologically complex written word recognition as well as theories of letter position coding. Experiment 1 investigated suffixed word primes and showed that morphologically complex primes without (*doloroso*) and with transpositions (*dlooroso*) equally facilitate participants' lexical decision response to the stem target (*DOLOR*). Experiment 2 extended this pattern of results to the domain of nonword primes showing that stem-target priming was only obtained in the morphologically related condition (*totalito*) but not in the transposed-letter condition (*ttoalito*).

The findings of Experiment 1 and 2 demonstrate that priming occurs with morphologically complex primes independently of whether stem and suffix do combine to a real word (*dolor* + *oso*) or not (*total* + *ito*). Since these results cannot be attributed to the semantic similarity of prime and target, one explanation of the results is to argue that the data are a reflection of orthographic relatedness. This explanation however seems highly unlikely given that numerous masked morphological priming studies have reported the absence of or inhibitory priming for orthographically related prime-target pairs with no shared morphology (*brothel-BROTH*; see Rastle & Davis, 2008, for a review of 14 related masked priming studies). In the present set of experiments, however, robust priming effects were obtained for morphologically related primes over an equivalent baseline. Hence, the former argument seems hard to make. We thus conclude that the present results are a reflection of the morphological relationship between prime and target supporting the view that morphological analysis occurs at a very early pre-lexical stage in word recognition (e.g. Taft & Forster, 1975; Rastle et al., 2004).

Our findings are incompatible with purely post-lexical accounts of the processing of written polymorphemic words (Giraudo & Grainger, 2001, 2003; Marslen-Wilson, Tyler, Waksler, & Older, 1994; Plaut & Gonnerman, 2000). These accounts assume that decomposition is a semantically driven process that takes place once the whole word has been recognized in the lexicon (e.g. *full-listing* accounts; see Colé et al., 1989). If this were the case, no priming effects would have been observed for nonword primes such as *totalito-TOTAL*, since the nonsense string would not be listed in the lexicon, and therefore no morphological decomposition could occur for this type of primes, preventing morphological priming. Thus, although these accounts could predict priming effects for morphologically related prime words (*doloroso-DOLOR*) and for TL-manipulated real word primes (*dlooroso-DOLOR*) as used in Experiment 1, they would predict an absence of priming effects for suffixed nonword primes such as *totalito-TOTAL*, and therefore cannot account for the observed pattern. Hence, the present data converge with earlier masked morphological priming results (e.g. Meunier & Longtin, 2007; McCormick, Rastle, & Davis, 2009) showing that morphologically complex Spanish nonword primes like *totalito* are morphologically decomposed on the mere appearance of morphological complexity.

Taken together, Experiments 1 and 2 reveal important insights into how exactly readers access the internal structure of morphologically complex words. The priming effects found for suffixed real word primes (*doloroso-DOLOR,* Experiment 1) and for suffixed nonword primes (*totalito-TOTAL*, Experiment 2) confirm the hypothesis of an early automatic decomposition of strings with an apparent morphological structure (see Rastle et al., 2004), based on affix stripping mechanisms (e.g. Taft, 1979; Taft & Forster, 1975). On the basis of the presence of an affixed string, the visual word recognition system strips off the affix, starting a lexical search of the remaining letter chunk, independently of whether the whole string is a real word or not.

The findings in the TL-conditions however are not as clear-cut. While a significant TL-priming effect was found in Experiment 1 (*dlooroso-DOLOR*), there was no evidence for TL-priming in Experiment 2 (*ttoalito-TOTAL*). The observed difference cannot be explained by early letter position encoding accounts, because similarly to Experiment 1, the TL-stems in Experiment 2 (*ttoal*) only differed with respect to two letter positions to the target word (*total*). This difference also cannot be due to a morphological decomposition mechanism operating at the level of orthography, because both types of items equally comprise morpho-orthographic surface structures which the system would identify as formally identical. The differences must therefore be due to a mechanism originating from a different higher-level locus in the word recognition system.

Previous evidence suggests that the semantic interpretability of morphologically complex nonwords is taken into account at early processing stages (Diependaele et al., 2009; Feldman et al., 2009). In the present study, the semantic interpretability of the TL-nonwords differed across the two experiments. Given that the TL-nonwords used in Experiment 1 were created by transposing two letters in an existing letter string comprising a lexically legal combination of stems and suffixes (*doloroso*), readers could easily attach a meaning to the presented TL-nonword primes. The TL-nonwords in Experiment 2 however, were created by combining stems and suffixes such that the whole string was not a word (*totalito*), reducing the semantic interpretability of the letter string and inhibiting the reader's ability to attach a meaning to the presented nonword primes.

One explanation for the different results obtained in Experiment 1 and Experiment 2 may therefore be that the semantic interpretability of printed words affects early morphological processing stages. Thus, the priming of TL-nonwords like *dlooroso* obtained in Experiment 1 would not purely rely on the activation of the stem *dloor* (and *dolor* respectively) but also be partially driven by the semantic interpretability of the whole prime *doloroso*. The activation of *doloroso* through *dlooroso* would provide a boost to the activation of the morphemic sub-constituent *dolor* which would then in turn facilitate the TL-priming lexical decision response. In Experiment 2 however, the TL-prime *ttoalito* would not activate a whole prime, as the lexical representation for *totalito* does not exist. As compared to *dlooroso*, the processing of *ttoalito* would be lacking the same 'semantic boost' from the whole word level, and therefore purely rely on a morpho-orthographic processing mechanism, insufficient to produce TL-priming. Thus, the increased size of priming obtained for suffixed TL-nonwords in which the non-transposed whole string is a real word must origin from a different type of representational constraint within the word recognition system taking the semantic interpretability of the morphemic constituents into account.

In line with this interpretation, recent morphological decomposition accounts have proposed that meaning-relatedness contributes to masked morphological priming (e.g. Diependaele, Sandra, & Grainger, 2009; Feldman, O'Connor, & Moscoso del Prado Martin, 2009) suggesting that morphological decomposition does not exclusively rely on morpho-orthographic mechanisms (Duñabeitia, Kinoshita, Carreiras, & Norris, in press). Such accounts are primarily based on evidence showing increased priming effects for truly suffixed prime-target pairs (*cleaner-CLEAN*) as compared to pseudo-suffixed prime-target pairs (*corner-CORN*; the so-called *semantic transparency effect*; Diependaele et al., 2005). Effects of semantic-transparency indicate that there is a morpho-orthographic decomposition process which operates in a way such that every word bearing a true morphological structure (*cleaner*) or a morphological pseudo-structure (*corner*) is decomposed. However, the greater priming effects obtained for truly suffixed items suggest that there is a mechanism which takes into account the semantic or syntactic relationships between the lexical representations of prime and target. Although this difference has not always been significant in masked priming studies (see Rastle & Davis, 2008 for a review of 16 related masked priming studies), a numerical difference has almost always been observed. Particularly, it has been shown that semantic transparency effects in masked priming are more likely to be revealed with increased prime-target relatedness proportions (e.g. Feldman et al., 2009) and with procedures in which primes are partially or fully visible (e.g. Meunier & Longtin, 2007).

Further evidence for the co-occurrence of morpho-orthographic and morpho-semantic mechanisms in morphological decomposition comes from a set of masked priming studies by Diependaele et al. (2009) using cross-modal lexical decision, in English. In order to test the depth of the processing of the prime, the complexity of the prime was manipulated by comparing stem-primes (followed by derived targets) to derived-primes (followed by stem targets). The findings revealed that truly affixed (*rename-NAME*) and pseudo-affixed (*relate-LATE*) primes equally produced priming to their stem targets. However, when the prime-target order was reversed, significant priming was only obtained in the truly affixed condition (*name-RENAME*), whereas priming in the pseudo prefixed target condition completely disappeared (*late-RELATE*). It was concluded that, due to shorter length and higher frequency of stem-primes, they were processed more rapidly than their morphologically complex counterparts allowing the processing of the prime at a deeper semantic activation level. Thus, while Diependaele et al.'s results provide evidence for a decomposition mechanism operating at the level of orthography and decomposing any letter string bearing a morphological surface structure, there is clear support for a second decomposition procedure which takes into account the semantic relatedness between stem and whole word.

In light of these findings, the interpretation of the lack of TL-priming observed in Experiment 2 (*ttoalito-TOTAL*) seems straightforward. While the semantically transparent TL-nonwords in Experiment 1 (*dlooroso*) are experiencing feedback activation from the morpho-semantic parsing system, the semantically opaque TL-nonwords in Experiment 2 (*ttoalito*) do not benefit from higher-level semantic activations. In spite of the initially fuzzy encoding of the graphemes, the morpho-semantic system sends back reinforcing information helping to better establish and to reorder the position of the letters. The system will therefore process *dlooroso* based on the semantic coherence between the prime and the target, leading to nearly equal magnitudes of priming of *doloroso-DOLOR* and *dlooroso-DOLOR*. In the case of affixed TL-nonword primes like *ttoalito*, the feedback is so weak that it has limited influence on reordering processes. The lack of priming observed for TL-nonword primes with ungrammatical stem-suffix combinations (*ttoalito*) may therefore be attributed to the influences of higher-level processing mechanisms rather than entirely being due to decoding mechanisms operating at the level of orthography.

According to this account, it is also not surprising that the magnitude of morphological priming obtained in Experiment 1 (26 ms; *doloroso-DOLOR*) was numerically greater than that observed in Experiment 2 (12 ms; *totalito-TOTAL*). A word-prime like *doloroso* would be decomposed into its morphemic subunits, which would in turn activate their semantic features, so that then the combined meaning of the morphemic sub-constituents would strongly activate the existing representation of the whole word. Thus, a combination of a pre-lexical morpho-orthographic and a post-lexical morpho-semantic processing mechanism would lead to an increased activation of the stem morpheme *dolor*, producing priming. Similarly, a pre-lexical morphological parsing mechanism would decompose a nonword-prime like *totalito* into its morphemic sub-constituents, which would also activate their corresponding semantic features, producing priming. As opposed to *doloroso* however, the subunits *total* and *ito* do not combine to form a meaningful unit in the lexical system. That is, *totalito* would be purely decomposed on basis of an orthographic form analysis, which explains the relatively smaller size of priming observed in Experiment 2. Obviously, this involves drawing conclusions across experiments. A combined design would offer a more direct test of morphological parsing mechanisms underlying the processing of true morphological structures relative to morphologically complex nonword structures and provide a desirable extension of the present research.

An interesting way of teasing out further whether differences between the observed effects of priming were due to feedback from whole-word form activations or rather triggered by the semantic compatibility of stem and affix, would be to look at pseudo-structural transposed-letter nonwords (*nmuber-NUMB*). Pseudo-derivations make an interesting case, given that although the whole-string exists, the stem (*numb*) and the whole-word (*number*) are semantically incompatible. If the TL-priming differences in Experiment 1 and 2 were entirely morpho-semantic in nature, priming of *nmuber-NUMB* should be reduced. If however TL-priming was at least partially driven by the activation of pre-existing lexical form representations, *nmuber-NUMB* and *number-NUMB* should produce similar magnitudes of priming. Future research is needed to explore these alternatives.

In summary, our data suggest that morpho-orthographic parsing mechanisms benefit from semantic influences at early stages in the reading system producing increased amounts of priming (*doloroso* or *dlooroso*) as compared to semantically non-interpretable (*totalito* or *ttoalito*) letter strings. The present semantic transparency effect obtained with non-transposed letter primes (*doloroso-DOLOR* vs. *totalito-TOTAL*) is consistent with models proposing an early semantically ‘blind’ morpho-orthographic segmentation stage (e.g. Rastle, Davis, & New, 2004; Taft, 2003; Taft & Nguyen-Hoan, 2010). These models suggest that semantic transparency effects arise at a later stage in the reading system, due to links between lexical form representations (Taft &

Nguyen-Hoan, 2010) or morpho-semantic activations of transparent derivations (Rastle & Davis, 2008). They predict, for example, that if the morpho-orthographic parsing system initially generates morphemic subunits that are semantically transparent (*doloroso*), then these processes will later benefit from higher-level semantic activations and thus produce additional priming in comparison to semantically opaque morpho-orthographically segmented letter-strings (*totalito*). However, it is more challenging to account for the pattern of TL-effects observed in the present set of studies in the context of these models. On the one hand one would expect significant transposed-letter priming to arise from both semantically transparent (*dlooroso*) and semantically opaque (*ttoalito*) TL-manipulated letter strings, which is inconsistent with the lack of masked transposed-letter priming in Experiment 2. However, it is also possible that initial morpho-orthographic processing is influenced by extremely rapid feedback from higher-level semantic processing stages, such that semantic constraints are able to influence letter reordering processing, which is not necessarily inconsistent with the idea that morphological processing stages are initially semantically blind.

Finally, the present work provides evidence for accounts postulating the simultaneous processing of morpho-orthographic and morpho-semantic information via two different pathways (e.g. Diependaele et al., 2009; Baayen et al., 1997; Feldman et al., 2009; Meunier & Longtin, 2007). The *hybrid model*, for instance, proposed by Diependaele et al. (2009), considers that any word possessing a true morphological structure (*doloroso* or *dlooroso*) is simultaneously decomposed via a (i) morpho-orthographic parsing route and a (ii) morpho-semantic pathway (after the activation of the whole word in the lexicon). Morphologically complex nonwords however (*totalito* or *ttoalito*) are parsed via the morpho-orthographic pathway only, given that the subunits *total* and *ito* do not form a meaningful unit in the lexical system. The hybrid model thus provides an explanation for the increased pattern of activation observed for lexically represented words as compared to non-existing letter strings.

In conclusion, the present masked priming letter transposition experiments demonstrate that morphologically structured words and nonwords are decomposed at early morpho-orthographic processing stages with high positional uncertainty. These Spanish data converge with evidence from other languages with morphologically complex structures suggesting that morphological decomposition is a universal language-independent mechanism. The current studies further provide evidence for influences from higher-level processing stages to the morphological recognition system, suggesting that morpho-orthographic parsing mechanisms benefit from semantic constraints at early stages in the reading system. The exact mechanisms underlying morpho-orthographic and morpho-semantic mechanisms still remain to be explored.

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Footnotes

[1] The selected stem-suffix combinations were either syntactically legal (e.g. *fusilote*; the suffix *ote* is typically attached to a noun, and *fusil* is a noun) or syntactically illegal (e.g. *exitodad*; the suffix *dad* is typically attached to an adjective, but *exito* is a noun).

[2] A post-hoc factorial analysis revealed that the magnitude of priming in the related priming condition did not differ according to Syntactic Legality, $t = 1.0$, $p = .317$.

Table 1

Mean word frequency, bigram frequency, length and orthographic N for the stimuli in Experiment 1, taken from Davis & Perea (2005).

	Word frequency	Bigram frequency	Length	N
Targets	56.02	2.34	5.21	3.93
Related primes	9.58	2.32	7.70	0.88
TL-primes	--	1.83	7.71	0.17
RL-primes	--	1.78	7.71	0.14
Unrelated primes	6.78	2.37	7.63	0.92

Table 2

Mean lexical decision times (in ms) and percentage of errors for real word targets in Experiment 1. Standard deviations are shown in parentheses.

Type of prime	Reaction times	Error rates
Related	647	5.0%
	(70)	(4.4%)
Transposed-letter	648	5.1%
	(61)	(4.6%)
Replaced-letter	664	5.3%
	(66)	(4.7%)
Unrelated	673	6.2%
	(73)	(5.8%)
TL-priming effect	25	0.2%
Morphological priming effect	26	1.2%

Table 3

Mean word frequency, bigram frequency, length and orthographic N for the stimuli in Experiment 2, taken from Davis & Perea (2005).

	Word frequency	Bigram frequency	Length	N
Targets	96.97	2.56	4.68	4.27
Related primes	--	2.0	8.0	0
TL-primes	--	1.67	7.68	0.04
RL-primes	--	1.68	7.68	0.04
Unrelated primes	--	2.0	8.0	0

Table 4

Mean lexical decision times (in ms) and percentage of errors for real word targets in Experiment 2. Standard deviations are shown in parentheses.

Type of prime	Reaction times	Error rates
Related	673	3.2%
	(65)	(4.5%)
Transposed-letter	682	3.0%
	(78)	(3.7%)
Replaced-letter	685	2.6%
	(71)	(3.7%)
Unrelated	685	3.5%
	(69)	(3.4%)
TL-priming effect	3	-0.4%
Morphological priming effect	12	0.3%

Appendix 1

Stimuli Experiment 1.

Target	*related*	*TL*	*RL*	*unrelated*
COCHE	cochera	ccohera	crehera	guantera
FICHA	fichaje	fcihaje	fruhaje	ramaje
HACHA	hachazo	hcahazo	hrehazo	tortazo
GENTIL	gentileza	gnetileza	gmatileza	vileza
VARÓN	varonil	vraonil	vceonil	pastoril
OVAL	ovalada	oavlada	oeglada	redada
CABEZA	cabezazo	cbaezazo	cfuezazo	cañonazo
SUR	sureño	srueño	scieño	lugareño
AZAR	azaroso	aazroso	aesroso	sudoroso
HOGAR	hogareño	hgoareño	hjeareño	norteño
MELOCOTÓN	melocotonero	mleocotonero	mfaocotonero	relojero
MANCHA	manchada	mnachada	mrechada	riada
CERCA	cercano	crecano	ccacano	parroquiano
PODER	poderío	pdoerío	pfaerío	señorío
GUSTO	gustoso	gsutoso	gritoso	oloroso
NOVIA	noviazgo	nvoiazgo	nweiazgo	maestrazgo
PELO	pelona	pleona	pfaona	gritona
PAUSA	pausado	pasuado	pariado	reinado
ESPERANZA	esperanzador	epseranzador	egreranzador	pescador
PLUMA	plumaje	pulmaje	pitmaje	vendaje
GIGANTE	gigantesco	ggiantesco	gpuantesco	pintoresco
FÁBRICA	fabricante	fbaricante	fdericante	visitante

CONTAGIO	contagioso	cnotagioso	crutagioso	miedoso
POLICÍA	policíaco	ploicíaco	pfaicíaco	elegíaco
ARENA	arenal	aernal	aasnal	peral
PAJA	pajar	pjaar	pyear	telar
CRUEL	crueldad	cureldad	ciseldad	maldad
ÁNGEL	angelote	agneloten	aymeloten	machote
CALLE	callejón	clalejón	ctelejón	jarrón
ESPERA	esperable	epserable	egzerable	estimable
PESA	pesado	pseado	praado	vallado
HORA	horario	hroario	hzuario	rutinario
SEÑA	señal	sñeal	smoal	orinal
LEÑA	leñador	lñeador	lvoador	torturador
CARTEL	cartelera	cratelera	ccetelera	jabonera
ESTAFA	estafador	etsafador	efrafador	programador
DOLOR	doloroso	dlooroso	dteoroso	tumoroso
AZUL	azulado	auzlado	aislado	doctorado
BALÓN	balonazo	blaonazo	bfeonazo	fogonazo
LLAVE	llavero	lalvero	lekvero	traicionero
CAZA	cazador	czaador	cseador	marcador
CAMPEÓN	campeonato	cmapeonato	cnepeonato	patronato
POBRE	pobreza	pboreza	pdereza	grandeza
ÁGIL	agilidad	aiglidad	auplidad	igualdad
ALCOHOL	alcohólico	aclohólico	ardohólico	metálico
CAJÓN	cajonera	cjaonera	cyeonera	ratonera
LIMÓN	limonero	lmionero	lnuonero	refranero
BOCA	bocado	bcoado	bruado	trajeado

ABAD	abadesa	aabdesa	aeddesa	condesa
FERVOR	fervorosa	frevorosa	fzavorosa	dolorosa
ATRÁS	atrasado	artasado	asbasado	cruzado
BALCÓN	balconada	blaconada	bfeconada	puñalada
HABLA	hablador	hbalador	hdelador	tomador
ENGAÑO	engañoso	egnañoso	eymañoso	poroso
CALMA	calmante	clamante	ctemante	feriante
FANGO	fangoso	fnagoso	fmegoso	ruidoso
MISA	misal	msial	mzual	ventanal
BURLA	burlador	brulador	bsilador	luchador
CULPA	culpable	clupable	cfipable	loable
NOBLE	nobleza	nboleza	nfeleza	tristeza
IDEA	ideal	iedal	iabal	tribunal
PUDOR	pudoroso	pduoroso	pbioroso	amoroso
BILLETE	billetera	blilletera	bfuletera	papelera
BREVE	brevedad	bervedad	basvedad	levedad
DESEO	deseoso	dseeoso	dzaeoso	morboso
AMIGA	amigable	aimgable	aungable	rentable
BARNIZ	barnizado	branizado	bsenizado	ordenado
EDITOR	editorial	eidtorial	eubtorial	normal
JORNAL	jornalero	jronalero	jsunalero	mesonero
COPA	copazo	cpoazo	cgeazo	pantallazo
FIN	final	fnial	fmual	nacional
PALMA	palmada	plamada	ptemada	guarrada
ESPÍRITU	espiritual	epsiritual	egriritual	floral
LLANA	llanada	lalnada	lefnada	patada

FRUTA	frutal	furtal	fistal	rosal
PAR	pareja	praeja	pceeja	moraleja

Appendix 2

Stimuli Experiment 2.

Target	***related***	***TL***	***RL***	***unrelated***
CAPA	capadad	cpaadad	cgeadad	retodad
RISA	risable	rsiable	rceable	finable
CONDE	condedor	cnodedor	cvadedor	mandodor
RIGOR	rigorato	rgiorato	ryeorato	hotelato
FOTO	fotoble	ftooble	fbaoble	roboble
CLIMA	climadad	cilmadad	cedmadad	juliodad
SEDE	sedetud	sdeetud	shaetud	mapatud
CIVIL	civilato	cviilato	cweilato	ordenato
CIMA	cimador	cmiador	cwuador	cunador
TOTAL	totalito	ttoalito	tfealito	sudorito
VINO	vinodad	vniodad	vreodad	gozodad
NUCA	nucatud	ncuatud	nriatud	murotud
HUMOR	humoresa	hmuoresa	hnioresa	mayoresa
RUBIO	rubiotud	rbuiotud	rfaiotud	marcatud
HOGAR	hogarito	hgoarito	hjearito	furorito
LICOR	licorido	lciorido	lreorido	virilido
SOLAR	solarajo	sloarajo	stuarajo	igualajo
CERO	cerotud	creotud	csaotud	filatud
MITAD	mitadano	mtiadano	mdeadano	gafasano
LUJO	lujoble	ljuoble	lgaoble	masable
CRUZ	crucesa	curcesa	concesa	amoresa
AZAR	azaraza	aazraza	aesraza	oloraza

PELO	pelotud	pleotud	pfiotud	purotud
VALOR	valorico	vlaorico	vteorico	robotido
GORDO	gordoble	grodoble	gsudoble	golpeble
LOCAL	localura	lcoalura	lrialura	canalura
USTED	ustedano	utsedano	ulnedano	finalano
TEST	testona	tsetona	tritona	edadona
FRUTO	frutoble	furtoble	fastoble	chinoble
TUMBA	tumbable	tmubable	twobable	aldeable
ÉXITO	exitodad	eixtodad	euwtodad	eticadad
ÁRABE	arabedad	aarbedad	aecbedad	partodad
RIVAL	rivalavo	rvialavo	rnealavo	autoravo
SEÑOR	señorazo	sñeorazo	sziorazo	dosisazo
TUMOR	tumorido	tmuorido	twaorido	fugacita
GRIS	grisano	girsano	gensano	granano
BEBÉ	bebedad	bbeedad	bduedad	bajodad
AZUL	azulano	auzlaja	aoslaja	ayerano
FEROZ	ferozura	freozura	fcaozura	calorura
CASA	casadad	csaadad	croadad	votodad
FLOR	floraje	folraje	fedraje	tresaje
CINCO	cincotud	cnicotud	cvecotud	playatud
JUNIO	juniodor	jnuiodor	jvaiodor	normador
MORAL	moralona	mroalona	msealona	abrilona
PODER	poderato	pdoerato	pbaerato	altarato
METAL	metaleña	mtealeña	mbialeña	atraseña
PLOMO	plomodor	polmodor	petmodor	bolsador
TENOR	tenorona	tneorona	tsuorona	balonona

LEJOS	lejosajo	ljeosajo	lgaosajo	comunajo
VIRUS	viruseza	vriuseza	vseuseza	luneseza
IDEAL	idealeña	iedaleña	iutaleña	anteseña
TESIS	tesisaza	tseisaza	troisaza	señalaza
OESTE	oestedad	osetedad	ozatedad	drogadad
JUSTO	justodad	jsutodad	jzitodad	climadad
CARO	carodad	craodad	cniodad	sumadad
AHORA	ahorable	aohrable	aufrable	pobreble
MENOS	menosaja	mneosaja	mraosaja	favoraja
RELOJ	relojano	rleojano	rbuojano	fatalano
MOTOR	motorosa	mtoorosa	mleorosa	cañonosa
PLANO	planodor	palnodor	peknodor	polvodor
BATA	batable	btaable	bdeable	balable
JOVEN	joveneño	jvoeneño	jcaeneño	facileño
ENERO	enerotud	eenrotud	eazrotud	tributud
GOTA	gotatud	gtoatud	gleatud	ascotud
TÚNEL	tunelavo	tnuelavo	tsielavo	lugaravo
MEJOR	mejorero	mjeorero	myaorero	honorero
CULO	culodor	cluodor	cfiodor	rojodor
SALUD	saludeza	slaudeza	sboudeza	coloreza
PLAN	planeño	palneño	putneño	golfeño
SOCIO	sociotud	scoiotud	sreiotud	barratud
PLAZA	plazatud	palzatud	pedzatud	geniotud
DEDO	dedodor	ddeodor	dkaodor	artedor
TUBO	tuboble	tbuoble	tleoble	actoble
MUSEO	museoble	msueoble	mcieoble	nadieble

NIVEL	nivelona	nvielona	nsaelona	cruelona
TEXTO	textodor	txetodor	tzitodor	rollodor
HIJO	hijoble	hjioble	hyeoble	vagoble
MENOR	menorita	mneorita	msaorita	semenita
RUMOR	rumorico	rmuorico	rneorico	laborico
MANO	manodad	mnaodad	mveodad	coladad
VAPOR	vaporeño	vpaoreño	vgeoreño	teniseño
MUJER	mujeraje	mjueraje	myoeraje	capazaje
FUSIL	fusilote	fsuilote	freilote	adiosote
VITAL	vitalaje	vtialaje	vbealaje	legalaje