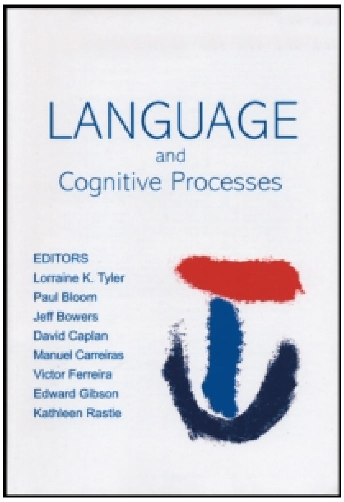

Language and Cognitive Processes
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713683153

Does darkness lead to happiness? Masked suffix priming effects

Jon Andoni Duñabeitia [a]; Manuel Perea [b]; Manuel Carreiras [a]
[a] Instituto de Tecnologías Biomédicas, Universidad de La Laguna, Tenerife, Spain [b] Universitat de València, València, Spain

First Published:November2008

To cite this Article Andoni Duñabeitia, Jon, Perea, Manuel and Carreiras, Manuel(2008)'Does darkness lead to happiness? Masked suffix priming effects',Language and Cognitive Processes,23:7,1002 — 1020

To link to this Article: DOI: 10.1080/01690960802164242

URL: http://dx.doi.org/10.1080/01690960802164242

LANGUAGE AND COGNITIVE PROCESSES
2008, 23 (7/8), 1002–1020

Psychology Press
Taylor & Francis Group

Does *darkness* lead to *happiness*? Masked suffix priming effects

Jon Andoni Duñabeitia
Instituto de Tecnologías Biomédicas, Universidad de La Laguna, Tenerife, Spain

Manuel Perea
Universitat de València, València, Spain

Manuel Carreiras
Instituto de Tecnologías Biomédicas, Universidad de La Laguna, Tenerife, Spain

Masked affix priming effects have usually been obtained for words sharing the initial affix (e.g., *reaction-REFORM*). However, prior evidence on masked suffix priming effects (e.g., *baker-WALKER*) is inconclusive. In the present series of masked priming lexical decision experiments, a target word was briefly preceded by a morphologically or orthographically related prime, or by an unrelated prime. In Experiment 1, the prime words in the suffix priming condition were formed by their suffixes (e.g., *er-WALKER*). In Experiment 2, the primes included the suffix inserted in a nonsense symbol string (e.g.,*%%%%er-WALKER*). In Experiment 3, the primes were formed by a real word that shared the suffix with the target (e.g., *baker-WALKER*). The results showed that, when compared with an orthographic priming condition, masked suffix priming can be obtained independently of the degree of segmentation of the prime. Furthermore, the present experiments reveal a clear dissociation between orthographic priming and morphological priming.

Keywords: Derivational morphology; Morphological priming; Orthographic priming; Suffixes.

Correspondence should be addressed to Jon Andoni Duñabeitia, Departamento de Psicología Cognitiva, Universidad de La Laguna, 38205-Tenerife (Spain). E-mail: jaduna@ull.es

This research has been partially supported by Grants SEJ2004-07680-C02-02/PSIC, SEJ2006-09238/PSIC and SEJ2005-05205/EDU from the Spanish Government, and BFI05.310 from the Basque Government. The authors thank Jonathan Grainger and an anonymous reviewer for their comments on an earlier draft. Thanks are also due to Margaret Gillon-Dowens for her priceless patience.

http://www.psypress.com/lcp DOI: 10.1080/01690960802164242

How morphologically complex words are accessed in visual word recognition is a cornerstone for many theoretical frameworks on lexical access (see Davis, 2004; Diependaele, Sandra, & Grainger, 2005, for review). A number of recent experiments has revealed that not only are words with a real morphological structure decomposed very early while accessing the lexicon (e.g., the word *walker* would be decomposed as *walk* + *er*), but also monomorphemic words with an apparent morphological structure (e.g., the word *corner* would be decomposed as *corn* + *er*, despite the fact that *–er* is a pseudosuffix; see Duñabeitia, Perea, & Carreiras, 2007; Lavric, Clapp, & Rastle, 2007; Longtin, Segui, & Halle, 2003; Rastle, Davis, & New, 2004; but see Morris, Frank, Grainger, & Holcomb, 2007).

To determine the extent to which two strings that share a morphological overlap exert mutual influence, researchers have typically used a priming paradigm. Most studies have manipulated the morpho-orthographic overlap between two words sharing the same (bound or free standing) root morpheme (e.g., *walker-WALK*; see Devlin, Jamison, Matthews, & Gonnerman, 2004). In this light, there is empirical evidence demonstrating greater priming effects for morphologically related word pairs (e.g., *walker-WALK*) than for orthographically related word pairs (e.g., *brothel-BROTH*; Longtin, Segui, & Hallé, 2003; Marslen-Wilson et al., 1994; Rastle, Davis, Tyler, & Marslen-Wilson, 2000; Rastle, Davis, & New, 2004). Robust morphological priming effects have also been reported when both prime and target words share the initial root morpheme and are derived with different suffixes (e.g., *balayeur-BALAYAGE*, in French, where *balayeur* is *sweeper* and *balayage* is the action of *sweeping*, both sharing the root *balai*, which means *broom*; see Giraudo & Grainger, 2001). Final free-standing and bound morphemes also facilitate the recognition of a related word – in comparison to unrelated or orthographically related prime words (e.g., *deform-CONFORM* and *revive-SURVIVE*, where *-form* is a free-standing morpheme and *-vive* is a bound morpheme that cannot stand by itself; see Pastizzo & Feldman, 2004; see also Duñabeitia, Laka, Perea, & Carreiras, in press, for a parallel finding with compound words).

The focus of the present study is on how *affixes* (suffixes, in particular) are processed in the course of lexical access. Previous research has shown that morphological priming effects can be obtained when the shared portion of the words is an affix instead of a root morpheme. For instance, in a recent experiment carried out in Spanish, Domínguez, Alija, Cuetos, and de Vega (2006) presented participants with unmasked prime words that shared the prefix with the target words (e.g., *reaction-REFORM*). With a 200-ms presentation time of the prime (plus a 100 ms blank screen after it), Domínguez et al. found that responses to target words were facilitated by the presentation of a morphologically related word relative to a control condition (a 28-ms priming effect). In the masked priming paradigm, there is also empirical evidence of morphological priming when prime and target share the same prefix (see Chateau, Knudsen, & Jared, 2002; Giraudo & Grainger, 2003; Marslen-Wilson, Ford, Older, & Zhou, 1996). For instance, Chateau et al. (2002) found masked morphological priming effects with words sharing the initial prefixes (e.g., *dislike-DISPROVE*), and no reliable orthographic priming effects with words merely sharing the initial letters (e.g., *element-ELEVATOR*).

Only a few studies have explored this issue when the overlap between prime and target occurs in the final part of the letter string. Giraudo and Grainger (2003) sought for priming effects between pairs of French words that either shared the final suffix (e.g., *fumet-MURET*, meaning 'aroma-low wall', where *–et* is a real French suffix in both words, as compared with *crabe-MURET*, meaning 'crab-low wall') or a non-morphological ending (e.g., *béret-MURET*, meaning 'beret-low wall', where *–et* in *béret* is not a suffix, as compared to *crabe-MURET*). Giraudo and Grainger failed to find any reliable priming effects. (It should be noted, however, that these authors did find morphological priming effects for prefixes.) In Experiment 1, Giraudo and Grainger employed three different prime exposure times in a masked priming paradigm (42, 57, and 115 ms), and failed to obtain any significant morphological or orthographic priming when the shared chunks between prime and target were the ending parts of the words (e.g., a 3-ms effect for morphologically related pairs, and a 1-ms effect for orthographically related pairs in the 57-ms prime exposure condition). In Experiment 4, with a 57-ms stimulus-onset asynchrony, Giraudo and Grainger increased the proportion of shared letters between primes and targets (e.g., *rouage-PLIAGE*, meaning 'cog-folding', and *stage-PLIAGE*, meaning 'vocational training-folding', where the *–age* in *stage* does not correspond to a morpheme) and they found a priming effect only slightly greater for the morphological relationships than for purely orthographic relationships (26 and 22 ms, respectively) relative to an unrelated control condition (e.g., *casino-PLIAGE,* 'casino-folding'). Conversely, Marslen-Wilson et al. (1996), employing a similar manipulation in a cross-modal priming experiment in English, found a significant priming effect for morphologically related pairs (e.g., *darkness-TOUGHNESS*), and no hints of orthographic priming when the overlap did not involve real suffixes (e.g., *darkness-HARNESS*; see also Reid and Marslen-Wilson, 2000, for a replication in Polish). However, the prime words in the Marslen-Wilson et al. experiments were presented auditorily and the target words appeared at the offset of the primes, which largely differs from the visual-visual masked priming paradigm used by Giraudo and Grainger.

One potential limitation of the Giraudo and Grainger findings on masked suffix priming is that the orthographic overlap condition was composed by a monomorphemic prime with a pseudo-affix and a polymorphemic target (e.g., *béret-MURET*, where *–et* in *béret* is not a suffix, but it is in *muret*). As indicated earlier, there is robust empirical evidence suggesting that this type of stimulus (like *corner* in English) may be decomposed early in word processing (e.g., see Duñabeitia, Perea, Acha, & Carreiras, 2008; Gold & Rastle, 2007; Lavric et al., 2007; Longtin, Seguí, & Hallé, 2003; McCormick, Rastle, & Davis, 2008; Rastle & Davis, 2003; Rastle et al., 2004). Therefore, it is not surprising that the morphological and the pseudo-morphological conditions behave similarly in the French study (i.e., between *fumet-MURET* where both *–et* are suffixes and *béret-MURET*), in particular, in Experiment 4 of Giraudo and Grainger (2003), in which they found a significant priming effect. Thus, taking into account the *corner* effect, the presence of a similar priming effect for the morphological and the pseudo-morphological conditions in the Giraudo and Grainger study could be explained in terms of the same blind-to-semantics morphological decomposition process: Participants may have decomposed *fumet* and *béret* in a similar way at initial stages of processing. Note also that the findings of Marslen-Wilson and colleagues with the cross-modal paradigm seem to suggest that suffix priming effects can be obtained early in processing.

In the present paper, we examine the extent to which morphological (via suffixes) and orthographic priming effects can be dissociated in Spanish by using a masked priming paradigm. To refine the study by Giraudo and Grainger (2003), we used two basic conditions. In one condition, we included morphologically complex words (root + suffix, as in *walker*), while in the other condition we included monomorphemic words with no pseudo-affixes (e.g., as in the word *brothel*) – thus avoiding any confounds with pseudo-morphological priming (e.g., *corner*). This way, if there is a fast morpho-orthographic decomposition at early stages of word processing, we expect to find a clear dissociation between suffix priming and orthographic priming: The priming effect with suffixes should be greater than the priming effect with series of letters that do not form a suffix.

The dissociation between orthography and morphology would be consistent with recent work by Duñabeitia et al. (2007) on transposed-letter priming effects. Duñabeitia et al. showed that readers are highly sensitive to orthographic manipulations over the morphological boundary of a polymorphemic word. When the two letters of the affix boundary[1] of a suffixed word were transposed (e.g., *walekr* instead of *walker*), there was no significant transposed-letter priming effect relative to an orthographic control (e.g., *walekr-WALKER* vs. *walutr-WALKER*). However, a similar manipulation with monomorphemic words (e.g., *brotehl-BROTHEL*)

[1] The *affix boundary* refers to the last letter of a root morpheme and the initial of a suffix for suffixed words, and the final letter of the prefix and the initial of the root morpheme for prefixed words (i.e., *walker* or *review*).

resulted in a robust transposed-letter priming effect (see also Christianson, Johnson, & Rayner, 2005; Duñabeitia et al., 2008). This dissociation between transposed-letter priming effects across and within affix boundaries was interpreted in terms of morphological decomposition of affixed words taking place at early stages of word processing, co-occurring with letter position assignment. We (Duñabeitia et al., 2007) tentatively interpreted these results in terms of an early affix detection mechanism (ADM for short) that operates at the initial stages of visual word recognition, similar to the *Affix Stripping Hypothesis* of Taft and Forster (1975, 1976). This ADM is in part responsible for fast suffix detection in a suffixed word, isolating the affix and starting an orthographic letter identity and position encoding of the root morpheme. The basis of the ADM (an early affix recognition and isolation mechanism) would make a clear prediction. Since affixes are early isolated in visual word recognition and treated as separated units, then greater priming effects could be expected for word pairs sharing a suffix (e.g., *-ness* in *darkness-HAPPINESS*) than for words sharing only non-morphological endings (e.g., *-llow* in *shallow-FOLLOW*). This hypothesis is directly tested in the present experiments.

In sum, in the present series of masked priming lexical decision experiments, we examined the extent to which masked suffix priming can be obtained, and whether such an effect can be dissociated from a purely orthographic effect. In Experiment 1, a set of Spanish polymorphemic suffixed targets (e.g., *IGUALDAD*, meaning *equality*) was briefly preceded by: (1) the constituent suffix (e.g., *dad-IGUALDAD*) or (2) an unrelated suffix (*aje-IGUALDAD*). As a control, we included a set of monomorphemic targets (e.g., *CERTAMEN*, meaning *contest*). These words were preceded by their ending letters or by an unrelated ending that did not constitute a suffix (e.g., *men-CERTAMEN* vs. *cio-CERTAMEN*). In Experiment 2, and to assess the role of specific letter position in the priming effect, the same polymorphemic and monomorphemic target words were preceded by a nonsense string sharing the same suffix or ending letters (e.g., *%%%%%dad-IGUALDAD* and *%%%%%men-CERTAMEN*), or by strings finishing in a different suffix or ending (e.g., *%%%%%aje-IGUALDAD* and *%%%%%cio-CERTAMEN*). Finally, in Experiment 3, a similar manipulation was implemented. However, we employed existing polymorphemic and monomorphemic prime words instead of using subset strings: Target words (e.g., *IGUALDAD*, *CERTAMEN*) were preceded by a prime word sharing their suffixes or endings (e.g., *brevedad-IGUALDAD* and *volumen-CERTAMEN*, the Spanish for *brevity* and *volume*), or by a word that did not share either the suffix or the last letters (e.g., *plumaje-IGUALDAD* and *topacio-CERTAMEN*, the Spanish for *plumage* and *topaz*). Thus, in Experiment 1 the affix was given already segmented (e.g., *dad*), while in Experiment 2 the affix was semi-segmented, by including it in a nonsense symbol string (e.g., *%%%%%dad*). Finally, in Experiment 3, the affix was part of a polymorphemic word (e.g., *brevedad*).

Accounts that support an early prelexical morphological decomposition (e.g., Duñabeitia et al., 2007; Rastle & Davis, 2003; Rastle et al., 2004) would predict an interaction between morphological and orthographic priming, with greater suffix priming than form-based priming. In contrast, if morphological decomposition takes place at a postlexical stage, no differences would be expected between suffix and form-based priming effect (e.g., Giraudo & Grainger, 2001).

EXPERIMENT 1

In Experiment 1, we examined whether there is a masked suffix priming effect (*dad-IGUALDAD* faster than *aje-IGUALDAD*), and whether this effect goes beyond a purely form-based priming (e.g., *men-CERTAMEN* vs. *cio-CERTAMEN*; note that *CERTAMEN* is a monomorphemic word). By providing the reader with the minimal meaningful unit of a language (i.e., an affix) already segmented, we expected participants to recognise faster the words preceded by their suffixes than those preceded by nonsense strings of letters. If morphemes have an autonomous representation in the lexicon (Aronoff, 1994; Di Sciullo & Williams, 1987), a greater advantage effect (relative to the unrelated condition) would be expected for suffix priming than for orthographic priming.

Method

Participants. Thirty students from the University of La Laguna received course credit for their participation. They were all native Spanish speakers and had normal or corrected-to-normal vision.

Materials. A set of 44 suffixed words was selected from the Spanish database (Davis & Perea, 2005). The mean frequency of these words was 9.75 per million (range: 0.18–92.86), and the mean length was 7.7 letters (range: 6–10). All these words included suffixes that had an overall number of 3.2 letters (range: 3–5). These words (e.g., *igualdad*, translated as *equality*) were presented preceded by their suffixes (e.g., *dad-IGUALDAD*) or by unrelated suffixes (e.g., *aje-IGUALDAD*). Another set of 44 non-affixed words was also selected from the database. The mean frequency was 10.13 (range: 0.18–47.86) and the mean length was 7.3 (range: 5–10). These monomorphemic words also served as targets (e.g., *certamen*, translated as *contest*), and could be preceded either by their ending letters (e.g., *men-CERTAMEN*), or by other unrelated ending letters (e.g., *cio-CERTAMEN*). The mean length of the letters presented as primes was 3.2 (range: 3–5), as in the suffix priming stimuli. It is important to note that the ending chunks in both mono and polymorphemic conditions have similar type and token letter frequencies throughout the experiments (all *p*s > .60). Eighty-eight nonwords were also created for the purposes of lexical decision, changing letters from the initial part of the words (e.g., *salaldad* from *igualdad*, and *contamen* from *certamen*). The length of the strings was preserved so that they converged with the length of the words. Also, the endings of the words were safeguarded, so that half of them had real suffixes as endings, and the other half did not. The same primes as in the word conditions were used as primes for the nonwords (*salaldad* could be preceded by *dad* or by *aje*; *contamen* could be preceded by *men* or by *cio*). Two lists of materials were constructed, and each target string was only presented once in each list, but in a different condition each time.

Procedure. Participants were tested individually in a well-lit room, with a PC computer associated to a CRT monitor using DMDX (Forster & Forster, 2003). Each trial consisted of the centred presentation of a row of hash marks (######) for 500 ms, immediately followed by the brief presentation of the centred lowercase primes for 50 ms, which were in turn replaced by the uppercase target strings. The target strings remained on the screen for a maximum of 2500 ms, or until a response was given. Participants were instructed to respond by pressing the 'Yes' button when the displayed string was a real Spanish word, and by pressing the 'No' button when the string was a nonword. They were told to do so as fast and as accurately as possible, and were trained with a 12-trial practice.

Results and discussion

Incorrect responses and latencies beyond the 250–1500 ms cutoffs (2.9% of the word data) were eliminated from the response time analyses. Mean reaction times and percentages of error are presented in Table 1. Analyses of variance (ANOVAs) were performed for participants (F_1) and items (F_2), based on a 2 (Type of target: suffixed, non-suffixed) × 2 (Type of prime: related, unrelated) × 2 (List: list1, list2) design. List was included as a dummy variable to extract the variance due to the counterbalancing lists (Pollatsek & Well, 1995).

Word data. On average, polymorphemic targets were responded to faster than monomorphemic targets, $F_1(1, 28) = 29.87$, $MSe = 2695$, $p < .001$; $F_2(1, 84) = 4.81$, $MSe = 12070$, $p < .04$. The main effect of prime-target relatedness was not significant, $F_1(1, 28) = 2.42$, $MSe = 2715$, $p > .13$; $F_2(1, 84) = 0.44$, $MSe = 9204$, $p > .50$. More important, the interaction between the two factors was significant, $F_1(1, 28) = 10.73$, $MSe = 1592$,

TABLE 1
Mean lexical decision times (in ms) and percentage of errors (in parentheses) for word and nonword targets in Experiment 1. Examples of primes and targets in square brackets

	Type of prime		
	Related	*Unrelated*	*Priming*
Words			
Monomorphemic [CERTAMEN]	916 (5.2) [men]	907 (5.5) [cio]	−9 (0.3)
Polymorphemic [IGUALDAD]	840 (4.4) [dad]	879 (3.9) [aje]	39 (−0.6)
Nonwords			
Monomorphemic [CONTAMEN]	969 (3.9) [men]	977 (5.2) [cio]	8 (1.3)
Polymorphemic [SALALDAD]	1020 (6.1) [dad]	1013 (5.3) [aje]	−7 (−0.8)

$p < .01$; $F_2(1, 84) = 4.37$, $MSe = 9204$, $p < .05$: we found a robust priming effect for suffixed words (a 39 ms effect), $F_1(1, 28) = 10.58$, $MSe = 2121$, $p < .01$; $F_2(1, 42) = 8.74$, $MSe = 3987$, $p < .01$, whereas there were no sign of a parallel effect for monomorphemic words (a nonsignificant −9 ms effect), $F_1(1, 28) = 0.56$, $MSe = 2186$, $p > .45$; $F_2(1, 42) = 0.42$, $MSe = 14421$, $p > .40$.There were no significant effects on the error rates, with all Fs < 1.2, and all ps $> .25$.

Nonword data. Nonwords with an apparent morphological ending were responded to slower than the nonwords with no morphological ending, $F_1(1, 28) = 18.37$, $MSe = 3106$, $p < .001$; $F_2(1, 84) = 4.26$, $MSe = 1595$, $p < .05$. The other effects on response latencies and error rates were not significant, all Fs < 1.6, and ps $> .22$.

The results from this experiment are clear-cut: suffixed words are responded to faster when preceded by their suffix than by an unrelated suffix, whereas a parallel manipulation with the final letters of monomorphemic words did not produce a significant effect. Finally, nonwords with an apparent morphological structure were responded to more slowly than nonwords with no morphological structure, which is in line with previous findings (Taft & Forster, 1975).

EXPERIMENT 2

The results from Experiment 1 have shown that suffixed words are benefited from a preview of their suffixes in isolation. The aim of Experiment 2 was to examine whether this finding can also be observed when the suffixes (or letter clusters) are attached at the end of a nonsense symbol string (i.e., preserving the letter location in the string rather than as an isolated letter string; i.e., *%%%%%dad-IGUALDAD* instead of *dad-IGUALDAD*). Note that this same procedure has been used previously by other researchers in studies that tackled sub-word unit processing (e.g., Carreiras & Perea, 2002; Ferrand, Segui, & Grainger, 1996; Schiller, 1998, among others). The idea behind this manipulation is to explore whether the extraction of the affixes can be done even when these affixes are embedded in a (nonsense) string. Bear in mind that prelexical accounts of morphological decomposition would predict a morphological/orthographic dissociation, as in Experiment 1. In contrast, a supralexical view of morphological decomposition would not predict any differences between morphological and the orthographic priming.

Method

Participants. Twenty eight students from the University of La Laguna took part in this experiment in exchange for course credit. All of them were native speakers of Spanish. None of them had taken part Experiment 1.

Materials. The materials were the same set of polymorphemic targets from Experiment 1. These suffixed words acted as targets (e.g., *IGUALDAD*), and could be preceded by strings starting with% marks that shared the suffix (e.g., *%%%%%dad-IGUALDAD*), or strings starting with% symbols but with an unrelated ending at the end that corresponded to another suffix (e.g., *%%%%%aje-IGUALDAD*). We also included the set of monomorphemic words from Experiment 1. These words also served as target stimuli (e.g., *CERTAMEN*), and could be preceded by strings starting with% marks and finishing with the ending letters from the target (e.g., *%%%%%men-CERTAMEN*), or by symbol strings finishing with an unrelated chunk of letters (e.g., *%%%%%cio-CERTAMEN*). We also included the set of 88 nonwords from Experiment 1. Mimicking the priming conditions for the word pairs, these nonwords could be also preceded by symbol strings that shared the same ending (e.g., *%%%%%dad-SALALDAD* and *%%%%%men-CONTAMEN*), or that did not share the ending letters (e.g., *%%%%%aje-SALALDAD* and *%%%%%cio-CONTAMEN*). Two lists of materials were constructed following a counterbalanced design. Different participants were randomly assigned to each list.

Procedure. This was the same as in Experiment 1.

Results and discussion

Incorrect responses and reaction times beyond the 250–1500 ms cutoffs (1.7% of the word data) were eliminated from the latency analyses. Mean reaction times and percentages of error are presented in Table 2. An ANOVA

TABLE 2
Mean lexical decision times (in ms) and percentage of errors (in parentheses) for word and nonword targets in Experiment 2. Examples of primes and targets in square brackets

	Type of prime		
	Related	*Unrelated*	*Priming*
Words			
Monomorphemic [CERTAMEN]	729 (3.7) [%%%%% men]	721 (4.5) [%%%%% cio]	−8 (0.8)
Polymorphemic [IGUALDAD]	712 (3.4) [%%%%% dad]	738 (4.1) [%%%%% aje]	26 (0.7)
Nonwords			
Monomorphemic [CONTAMEN]	858 (3.4) [%%%%% men]	868 (3.9) [%%%%% cio]	10 (0.5)
Polymorphemic [SALALDAD]	889 (7.3) [%%%%% dad]	899 (6.2) [%%%%% aje]	10 (−0.9)

was performed based on a 2 (Type of target: suffixed, non-suffixed) × 2 (Type of prime: related, unrelated) × 2 (List: list1, list2) design.

Word data. Reaction times for morphologically complex words and for monomorphemic words did not differ significantly, both Fs < 1. The relatedness effect was not significant, both Fs < 2.45 and both ps > .13. More important, the two factors interacted significantly, $F_1(1, 26) = 7.55$, $MSe = 1057$, $p < .02$; $F_2(1, 84) = 5.13$, $MSe = 2773$, $p < .03$: Polymorphemic words were recognised faster when they were preceded by a related prime than when they were preceded by an unrelated prime (a 26 ms effect), $F_1(1, 26) = 11.97$, $MSe = 798$, $p < .01$; $F_2(1, 42) = 5.70$, $MSe = 3237$, $p < .03$. In contrast, we failed to find any signs of a priming effect for monomorphemic words (a nonsignificant − 8 ms effect), $F_1(1, 26) = .65$, $MSe = 1249$, $p > .42$; $F_2(1, 42) = 0.47$, $MSe = 2309$, $p > .45$.

The analyses on the error rates did not reveal any significant effects.

Nonword data. Nonwords with an apparent morphological structure were responded to more slowly than nonwords with no (pseudo)morphemes, $F_1(1, 26) = 13.45$, $MSe = 2042$, $p < .01$; $F_2(1, 84) = 3.44$, $MSe = 7385$, $p = .07$. The same effect occurred in the analysis over the error rates, revealing that nonwords that included a (pseudo)morpheme were responded to less accurately, $F_1(1, 26) = 11.93$, $MSe = 22$, $p < .01$; $F_2(1, 84) = 9.14$, $MSe = 46$, $p < .01$. The other effects did not approach significance.

Experiment 2 replicated and extended the findings from Experiment 1: Prime-target word pairs sharing a morphological ending showed a recognition advantage (e.g., *%%%%%dad* facilitated the processing of *IGUALDAD*) whereas prime-target pairs that shared a non-morphological ending did not effectively prime each other more than an unrelated prime did (i.e., *%%%%%men* did not facilitate the processing of *CERTAMEN*). As in Experiment 1, nonwords that had an apparent morphological structure were responded to more slowly and less accurately than nonwords with no morphemic endings.

Thus, the present results have again shown a dissociation between morphological and orthographic priming. We found a robust priming effect for polymorphemic words when the prime stimulus was composed by symbols and the suffix from the target word, while no such effect was observed for purely orthographic relationships.

EXPERIMENT 3

As stated in the Introduction, the ADM account (Duñabeitia et al., 2007, submitted) predicts that each time an affix (or pseudo-affix) is encountered, a lexical search starts for it. This is in line with the assumption of a lexical representation of the affixes (see Aronoff, 1994; Di Sciullo & Williams, 1987; Roelofs & Baayen, 2002; Zwitserlood, Bölte, & Dohmes, 2000, 2002). If affix recognition arises early in the visual-word recognition process, then one would expect a similar morpho-orthographic dissociation when both prime and target strings are two different real words composed by different root morphemes and the same suffix (e.g., *walker* and *driver*). As indicated in the Introduction, prior research with similar manipulations in English, Polish and French have yielded non-conclusive results (see Giraudo & Grainger, 2003; Marslen-Wilson et al., 1996; Reid & Marslen-Wilson, 2000, 2003). While auditorily presented primes that share a derivational suffix with the visually presented targets do exert a reliable facilitation that differs from a purely form/sound based overlap (e.g., Marslen-Wilson et al., 1996; Reid & Marslen-Wilson, 2000, 2003), visually presented masked primes do not (e.g., Giraudo & Grainger, 2003). In contrast, Giraudo and Grainger employed pseudo-morphological relationships rather than mere orthographic relationships. Hence, when these materials are used in a masked priming paradigm, one would expect a priming effect of similar magnitude for *corner-WALKER* pairs and for *baker-WALKER* pairs. Note that morphological priming can be differentiated from orthographic priming by using pairs that do not include pseudo-morphological relationships for the orthographic priming condition, such as *tunnel-BROTHEL*. Experiment 3 was designed to shed more light on this issue by using real words as primes – maintaining the priming conditions as in Experiments 1 and 2 (i.e., real morphological vs. purely orthographic relationships). Considering the previous studies with a cross-modal priming paradigm, the predictions derived from the prelexical decomposition accounts, as well as the results from Experiments 1–2, we expect greater priming effects for morphologically related pairs than for orthographically related pairs.

Method

Participants. Twenty-eight participants from the University of La Laguna took part in the experiment in exchange for 3€. All of them had normal or corrected-to-normal vision, and were native speakers of Spanish. None of them had participated in the previous experiments

Materials. The target stimuli were the 44 suffixed words and 44 monomorphemic words from Experiments 1 and 2. The suffixed words (e.g., *IGUALDAD*) could be preceded by a prime word that shared the same suffix (e.g., *brevedad*, meaning *brevity*), or by a completely unrelated prime word (e.g., *plumaje*, meaning *plumage*). The monomorphemic target words (e.g., *CERTAMEN*) could be preceded by a different word that shared the same ending letters (e.g., *volumen*, translated as *volume*), or by an unrelated word with no overlap (e.g., *topacio*, translated as *topaz*). Primes in the related and unrelated conditions were matched as closely as possible in frequency, length, and number of orthographic neighbours (see Table 3). Nonword targets were the same as those in Experiments 1 and 2 (e.g., *SALALDAD* and *CONTAMEN*). Nonword primes were created by changing some of the initial letters of the word primes, so that the ending letters were kept invariant, maintaining a (pseudo)morphological or an orthographic relationship (e.g., *branedad* from *brevedad*, *gromaje* from *plumaje*, *filumen* from *volumen*, or *refacio* from *topacio*).

TABLE 3
Characteristics of the stimuli in Experiment 3. Ranges are provided in parentheses

	Frequency	*Length*	*N*
Monomorphemic targets	10.13 (0.18–47.86)	7.3 (5–10)	1.3 (0–5)
Related primes	8.29 (0.36–52.5)	7.1 (4–10)	0.8 (0–7)
Unrelated primes	8.33 (1.07–53.57)	7.1 (4–10)	1.9 (0–11)
Polymorphemic targets	9.75 (0.18–92.86)	7.7 (6–10)	1.9 (0–12)
Related primes	9.85 (0.54–78.21)	7.6 (6–12)	1.0 (0–7)
Unrelated primes	9.95 (0.89–77.32)	7.6 (6–12)	1.5 (0–6)

Procedure. This was the same as in Experiments 1 and 2.

Results and discussion

Incorrect responses and response latencies beyond the 250–1500 ms cutoff values were not included in the latency analyses (less than 1.2% of the word data). Mean reaction times and percentages of error are presented in Table 4. The design was the same as in Experiments 1–2.

Word data. Lexical decision times to polymorphemic words were faster than to monomorphemic words, even though this difference was not significant, $F_1(1, 26) = 3.60$, $MSe = 1533$, $p = .07$; $F_2(1, 84) = 0.30$, $MSe = 11120$, $p > .55$. Words preceded by a prime word that shared the ending letters/suffixes were responded faster than those preceded by unrelated primes, although this difference only approached significance, $F_1(1, 26) = 3.12$, $MSe = 2076$, $p = .09$; $F_2(1, 84) = 2.66$, $MSe = 3368$, $p = .11$. More important, the interaction between the two factors was significant, $F_1(1, 26) = 5.99$, $MSe = 1367$, $p < .03$; $F_2(1, 84) = 3.03$, $MSe = 3368$, $p = .08$. This interaction revealed that polymorphemic words were facilitated by the preview of a morphologically related prime word (a 33-ms effect), $F_1(1, 26) = 8.20$, $MSe = 1783$, $p < .01$; $F_2(1, 42) = 7.18$, $MSe = 2666$, $p < .02$, while there were no signs of a parallel effect for the monomorphemic words (a non-significant –2 ms effect), both Fs < 1.

None of the effects on the error rates was significant.

Nonword data. Nonwords with an apparent morphological structure were responded to more slowly than nonwords with no morphological

TABLE 4
Mean lexical decision times (in ms) and percentage of errors (in parentheses) for word and nonword targets in Experiment 3. Examples of primes and targets in square brackets

	Type of prime		
	Related	*Unrelated*	*Priming*
Words			
Monomorphemic [CERTAMEN]	764 (5.2) [volumen]	762 (4.7) [topacio]	−2 (−0.5)
Polymorphemic [IGUALDAD]	761 (4.4) [brevedad]	794 (6.0) [plumaje]	33 (1.6)
Nonwords			
Monomorphemic [CONTAMEN]	895 (8.1) [filumen]	900 (6.3) [refacio]	5 (−1.8)
Polymorphemic [SALALDAD]	935 (8.6) [branedad]	928 (8.4) [gromaje]	−7 (−0.2)

structure, $F_1(1, 26) = 12.02$, $MSe = 2787$, $p < .01$; $F_2(1, 84) = 3.56$, $MSe = 15390$, $p = .06$. The other effects were not significant.Again, the results showed a dissociation between morphological and orthographic priming: polymorphemic words were responded to faster when they were preceded by words with the same suffix (e.g., *brevedad-IGUALDAD*). In contrast, monomorphemic words did not benefit from the preview of an orthographically related prime (e.g., *volumen-CERTAMEN*). Finally, and similarly to the nonword data in Experiments 1–2, nonwords with an apparent polymorphemic structure were responded to slower than the nonwords with no morphological structure.

GENERAL DISCUSSION

In the present masked suffix priming experiments, we found a clear dissociation between morphological and orthographic effects. Importantly, this dissociation occurred independently of the segmentation level of the affix in the prime (segmented in Experiment 1, semi-segmented in Experiment 2, and non-segmented in Experiment 3). In Experiment 1, affixed words that were primed by their suffix in isolation (e.g., *dad-IGUALDAD*) were responded to faster than the words primed by a different suffix (e.g., *aje-IGUALDAD*). In contrast, no signs of priming effects where observed when monomorphemic words were preceded by their ending letters or by different letters (e.g., *men-CERTAMEN* vs. *cio-CERTAMEN*). In Experiment 2, we found exactly the same pattern of data when the words were preceded by their ending letters inserted in a symbol string or by another different set of letters: *%%%%%dad-IGUALDAD* faster than *%%%%%aje-IGUALDAD* and no differences between *%%%%%men-VOLUMEN* and *%%%%%cio-VOLUMEN*. Finally, in Experiment 3, the prime stimuli were real words. Again, polymorphemic words were recognised faster when the prime was a morphologically related string (e.g., *brevedad-IGUALDAD* faster than *plumaje-IGUALDAD*), whereas a parallel effect did not occur for monomorphemic words (*volumen-CERTAMEN* vs. *topacio-CERTAMEN*).

Thus, the present series of experiments has shown that masked suffix priming effects are greater than purely form-based priming effects. To our knowledge, this is the first time that a clear dissociation between masked morphological and orthographic priming effects (via suffix priming) has been obtained, and it offers converging evidence supporting a prelexical morphological decomposition account (e.g., Rastle et al., 2004). That is, the cognitive system not only decomposes polymorphemic words into their constituent morphemes at initial stages of word processing (e.g., *brevedad* → *breve* + *dad*), but also decomposes nonsense strings that include an affix (e.g., *%%%%%dad* → *%%%%%* + *dad*; see Experiment 2). Note that even pseudowords with an apparent polymorphemic structure seem to be decomposed at early stages of word processing (e.g., *quickify* → *quick* + *ify*; see Meunier & Longtin, 2007).

As indicated in the Introduction, prior empirical evidence on affix priming effects was not entirely conclusive. On the one hand, prefix priming (e.g., *reaction-REFORM*) has been consistently found with different prime presentation times and modalities (see Chateau et al., 2002; Giraudo & Grainger, 2003; Marslen-Wilson et al., 1996; Reid & Marslen-Wilson, 2000, 2003). On the other hand, evidence from suffix priming experiments has been mixed. Studies in English and Polish with a cross-modal priming paradigm showed that two words that share the same suffix do activate each other, whereas two words that merely share the ending phonemes do not (Marslen-Wilson et al., 1996; Reid & Marslen-Wilson, 2000, 2003). However, the masked priming experiment from Giraudo and Grainger (2003) showed a different pattern. When the overlap between prime and target was low (42% of shared letters), no priming effects were found either for the morphological or for the orthographic conditions. When the overlap between both words was set to 55%, Giraudo and Grainger obtained a priming effect which was similar in size for the morphological and orthographic conditions (26 and 22 ms, respectively).[2]

Hence, the present results mimic those from Marslen-Wilson and colleagues (Marslen-Wilson et al., 1996; Reid & Marslen-Wilson, 2000, 2003), extending them to a (unimodal) visual-visual masked priming paradigm in Spanish. As indicated in the Introduction, we believe that the lack of morphology/orthography interaction in the French study of Giraudo and Grainger – in particular in their Experiment 4 – could be due to the type of orthographic condition they used: Even though *–et* in *béret* is not a real suffix, there is empirical evidence with the masked priming paradigm that shows that not only *fumet-MURET* (where *–et* in *fumet* is a suffix) is decomposed early in processing, but also *béret-MURET* (note that *–et* in *béret* is not a real suffix, but a pseudo-suffix). This is what has been defined as the *corner* effect (e.g., Duñabeitia et al., 2008; Lavric et al.,

[2] We should note that Forster and Azuma (2000), in an English masked priming experiment (50 ms stimulus-onset asynchrony), found significant masked orthographic priming effects when the shared letters were the ending chunks of the words (e.g., *shallow-FOLLOW*). Considering that their manipulation is similar to the one we have employed in our Experiment 3 (e.g., *volumen-CERTAMEN*), one would have expected some orthographic priming to emerge in our experiment. However, there is a key difference between the two studies regarding the amount of shared letters between prime and target words. An analysis on Forster and Azuma's materials reveals that they used word pairs that shared 66% of the letters. In Experiment 3, the percentage of shared letters is smaller (42%). In a masked priming paradigm, this can be a substantial difference that could have resulted in the orthographic priming effect in their experiment.

2007; Longtin et al., 2003; McCormick et al., 2008; Rastle & Davis, 2003; Rastle et al., 2004). To avoid this potential confound, we employed a purely morphological condition and a purely orthographic condition. We acknowledge, however, this is probably not the whole story. Although Giraudo and Grainger failed to find a significant interaction between suffix priming and orthographic priming, they also found a significant masked prefix priming effect which was greater than the corresponding orthographic priming effect. Clearly, future work should re-examine the potential differences in masked prefix and suffix priming as compared with purely orthographic priming. In this light, we should note here that Duñabeitia et al. (2007; Experiment 2) reported early morphological decomposition for both prefixed and suffixed words in Spanish. These results are consistent with the view that prefixes and suffixes are similarly decomposed early in processing, and present evidence against claims stating that the processing of prefixes and suffixes may differ (Colé, Beauvillain, & Segui, 1989; Meunier & Segui, 1999). Hence, according to the Duñabeitia et al. findings, we would expect no differences between masked prefix and suffix priming effects (despite the fact of the left-to-right processing and other functional distinctions described by Giraudo and Grainger). Ongoing work in our laboratory aims to explore this issue.

Finally, it is noteworthy that nonwords with a (pseudo)morphological ending in the three experiments were responded to more slowly and less accurately than nonwords with no morphological structure. These results coincide with the view that nonwords that contain existing morphemes take longer to reject than simple nonwords (Caramazza, Laudanna, & Romani, 1988; Laudanna, Burani, & Cermele, 1994; Taft & Forster, 1975, 1976; Taft, 1979; Taft, Hambly, & Kinoshita, 1986; see Meunier & Longtin, 2007, for a review).

In summary, the present findings are of special relevance for researchers in morphological processing, since they help distinguish purely form-based relationships from morphological relationships. These data can be readily accounted for by models that assume a sublexical (or prelexical) representation of morphemes in polymorphemic words (see Duñabeitia et al., 2007; Longtin et al., 2003; Meunier & Longtin, 2007; Rastle et al., 2000, 2004). Thus, the most parsimonious account of the present data is that morphological processing emerges early in visual word recognition. Future research should be aimed at exploring whether similar masked suffix priming effects can be obtained with target words with an apparent polymorphemic structure (e.g., *er*-*CORNER* and %%%%*er*-*CORNER*).

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