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Is morpho-orthographic decomposition purely orthographic?

Evidence from masked priming in the same-different task

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Abstract

Two experiments used the cross-case same-different task to test whether the orthographically driven morphological decomposition effects that have been found in the lexical decision task are obligatory. Experiment 1 replicated the manipulation used by Duñabeitia, Perea, and Carreiras (2007), testing transposed-letter priming effects spanning the boundary between the affix and the stem. In contrast to their finding observed with the lexical decision task, transposed-letter priming effect did not vanish with polymorphemic or pseudomorphemic words. Experiment 2 used the manipulation used by Rastle, Davis, and New (2004), comparing the effects of polymorphemic affixed words (e.g., walker), pseudo-affixed words (e.g., corner), and non-affixed monomorphemic words (e.g., brothel) in target word recognition. Unlike the results observed in the original lexical decision study, equal priming effects were observed with all three types of words. These results suggest that the presence of an orthographically defined subunit (affix) is not sufficient to drive morphological decomposition processes. (150)

Introduction

Although written words might conceivably be recognized by being processed as unstructured sequences of letters, readers are sensitive to the internal structure of words. For example, sub-word units such as syllables and morphemes play an important role in visual word recognition (Carreiras & Grainger, 2004; Carreiras & Perea, 2002; Duñabeitia, Laka, Perea, & Carreiras, 2009; Duñabeitia, Perea, & Carreiras, 2008). The role of morphological structure in reading has received considerable attention in recent years (see Frost, Grainger & Carreiras, 2008; Frost, Grainger & Rastle, 2005, for reviews), and one issue that is currently of considerable theoretical interest is whether sensitivity to morphological structure arises early or late on in the recognition process. One possibility is that morphological processing is a very late process being triggered only after lexical access (e.g., Giraudo & Grainger, 2001, 2003; Grainger, Cole, & Seguí, 1991; see Rastle & Davis, 2008, for review). The other possibility is that there is a very fast and early process of "morpho-orthographic" segmentation that begins before lexical-access has been completed (e.g., Gold & Rastle, 2007; Rastle & Davis, 2003; Rastle, Davis, & New, 2004; see also Taft, 1981; Taft & Forster, 1975, 1976). These views may be referred to as the post-lexical account and the pre-lexical account, respectively.

Recent studies have offered compelling evidence in favor of the pre-lexical account of morphological decomposition. The critical experiments used the Forster and Davis (1984) masked priming task. In this task participants first see a forward mask (usually '#' signs) which is immediately followed by a briefly presented prime. The prime is then substituted by another letter-string which must be classified as a word or a nonword. Longtin, Segui and Hallé (2003) and Rastle, Davis and New (2004) demonstrated that when primes were orthographically and morpho-semantically related to the targets by means of derivation (e.g., *walker-WALK*), participants recognized the targets much faster than when these were preceded by unrelated primes. In contrast, when monomorphemic words were used as primes and targets, and when the relationship between the two strings was purely orthographic (e.g., *brothel-BROTH*), no such priming effects were observed as compared to a control unrelated priming condition. However, the critical data from these experiments concerns "pseudo-affixed" primes, such as in *corner–CORN*. Pseudo-affixed primes contain the orthographic form of an affix but cannot be decomposed as stem+affix. For example, *corner*, cannot be decomposed as *corn+er*. *Corner* is not derived from *CORN*. Nevertheless, the pseudo-affixed primes also produced priming (see Rastle & Davis, 2008, for a compelling summary; see also Feldman, O'Connor, & Moscoso del Prado Martín, 2009). Rastle et al. suggested that the initial stages of word recognition involve a morpho-orthographic segmentation process which identifies potential morphemic constituents, irrespective of semantic transparency . They argued that "*morphological decomposition is defined on a purely orthographic basis, where words are segmented simply because they have a morphological structure*" (Rastle et al., 2004, p.1095).

The idea of an early morpho-orthographic parsing process has been also supported by other studies that have employed a different methodological approach. Duñabeitia, Perea and Carreiras (2007; see also Christianson, Johnson, & Rayner, 2005) investigated whether morphological decomposition processes could interact with purely orthographic effects. To this end, Duñabeitia et al. explored whether the masked transposed-letter similarity effect was modulated by morphological decomposition. Participants typically respond significantly faster to target words (e.g., *JUDGE*) when these are preceded by primes in which two adjacent letters from the target have been transposed (e.g., *jugde*), as compared to when targets are preceded by strings in which these two letters have been replaced by two other different letters (e.g., a replaced-letter prime like *junpe*). This transposed-letter priming effect (TL priming effect, hereafter) has been demonstrated to be orthographic in nature (Perea & Carreiras, 2006a, 2006b; Perea, Duñabeitia & Carreiras, 2008; Perea & Lupker, 2003; Schoonbaert & Grainger, 2004). Following the morpho-orthographic account of morphological decomposition put forward by Rastle et al., (2004), Duñabeitia et al. examined whether the orthographic TL priming effect might be modulated by the presence of a morphological boundary.

They reasoned that if the TL effect was attenuated for transpositions which crossed morpheme boundaries (e.g., *walekr* from *walker* and *dilsike* from *dislike*), this would represent strong evidence for pre-lexical morphological decomposition occurring very early in recognition while letter position or order information was still being resolved. In a series of experiments, Duñabeitia et al. showed that this was indeed the case, and that while a significant TL priming effect was observed for monomorphemic words (e.g., *brotehl-BROTHEL* vs. *brotabl-BROTHEL*) there was no priming for letter transpositions that spanned the morphemic boundary of prefixed and suffixed words (e.g., *walekr-WALKER* vs. *walabr-WALKER*). Thus, Duñabeitia et al. concluded that their results supported the existence of an early morpho-orthographic decomposition process.

The morpho-orthographic decomposition process is, by definition, orthographic, and the TL priming effect operates at an orthographic level. But are these processes separable? Is morpho-orthographic segmentation an obligatory part of all orthographic processing, or is it invoked only in the service of lexical access? For example, Rastle et al. (2004) suggested that morpho-orthographic segmentation might be a consequence of the statistical distribution of bigram and trigram frequencies and that "*a connectionist network that learns the orthographic properties of morphologically complex words may* *divide complex words into their constituent morphemes*" (p. 1094; see also Seidenberg, 1987). This would seem to imply that morpho-orthographic segmentation would be a necessary and intrinsic property of orthographic processing.

One way to address this question is to examine the interaction between morphological structure and orthographic processing in a task which we know is sensitive to orthography, but is not influenced by lexical processing. Kinoshita and Norris (2009) showed that masked priming in the cross-case same-different matching task shows a TL priming effect, but is not influenced by lexical factors (see also Norris & Kinoshita, 2008; Perea & Acha 2009). The cross-case same-different matching task is a variant on the Forster and Davis (1984) paradigm, but where a reference stimulus is presented before the target for about 1000ms. The participant's task is to decide whether the target is the same as or different from the reference.

Kinoshita and Norris obtained equivalent TL priming effects for word and nonword targets, which is not typically the case in regular masked priming lexical decision studies dealing with letter transpositions (e.g., Perea, Duñabeitia, & Carreiras, 2008; Perea & Lupker, 2003; Schoonbaert & Grainger, 2004), where the TL effect for nonword targets is generally absent, or at least much weaker than for word targets (see Perea & Carreiras, 2008). Given the evidence that masked priming in this task was not influenced by low-level perceptual similarity or by phonology, Kinoshita and Norris concluded that the cross-case masked priming same-different task is based on pre-lexical abstract orthographic representations. Specifically, Kinoshita and Norris (2009, Experiment 2, see also Kinoshita & Kaplan, 2008, and Norris & Kinoshita, 2008) showed that the featural similarity of the prime and target letters (e.g., *kiss* and *KISS* are composed of featurally similar letters, *edge* and *EDGE* contain only featurally dissimilar letters) had no impact on the size of priming. Kinoshita and Norris (2009, Experiment 3) also showed that pseudohomophone primes and non-pseudohomophone primes generated by a single letter substitutions (e.g., *skore-SCORE* vs. *smore-SCORE*) produced the same amount of priming, and less than the identity primes (e.g., *score-SCORE*). They stated that this task taps onto "*the same representations that support word recognition*" but that it is not "*influenced by the lexical retrieval processes*" (2009, p. 13), supported by simulations of masked priming effects in the same-different task and the lexical decision task based on Norris' (2006) Bayesian Reader model of visual word recognition. Therefore, the cross-case masked priming same-different task seems to be a suitable task if one aims to explore whether morphological decomposition takes place at early pre-lexical stages of orthographic processing. In other words, the cross-case masked priming same-different task allows us to shed light on whether orthographically defined morphological structure is represented in a pre-lexical orthographic code.

In Experiment 1 we used the cross-boundary letter transposition manipulation used by Duñabeitia, Perea and Carreiras (2007) in the cross-case masked priming same-different task. Duñabeitia et al. showed that the TL priming effect vanished for prefixed and suffixed words when the critical letters bracketed an affix boundary (i.e., in the case of prefixed words, the final letter of the prefix and the initial letter of the stem; in the case of suffixed words, the final letter of the stem and the initial letter of the suffix). In the present Experiment 1 the same materials as Duñabeitia et al.'s Experiment 2 were used. Spanish participants were presented with prefixed, suffixed and control words as references and targets, that could be briefly preceded by masked primes that included a letter transposition (e.g., reference: *walker*, prime: *walekr*, target: *WALKER*) or a letter replacement (e.g., reference: *walker*, prime: *walabr*, target: *WALKER*). Based on the preceding evidence, significant TL priming effects were expected to be found in the case of non-affixed words (e.g., *brotehl-BROTHEL*, see Duñabeitia et al., 2007). The critical issue in this experiment was whether the cross-boundary TL priming effect would appear also for affixed and pseudo-affixed words. According to a "very early" view of pre-lexical morpho-orthographic decomposition, if morphemes are detected and this drives the morphological decomposition process, the same modulation of cross-boundary TL priming by morphological complexity observed by Duñabeitia et al. in their lexical decision task is expected (i.e., cross-boundary TL priming effects should be observed for monomorphemic words but not for affixed words). In contrast, according to the view that the presence of orthographically defined sub-word units like affixes is not sufficient to drive the morphological decomposition process, TL priming effects of equal magnitude are expected for the three types of words, irrespective of whether the letter transposition spans the boundary between an affix and a stem. In Experiment 2 a similar approach was followed, but this time using the "priming of the stem" manipulation used by Rastle et al. (2004) and by Longtin et al. (2003). We tested participants in a cross-case same-different task that used stems as references and targets, which were preceded by related masked primes that could either be derived forms of the given stems (e.g., reference: *walk*, prime: *walker*, target: *WALK*), pseudo-derived forms of the given stems (e.g., reference: *corn*, prime: *corner*, target: *CORN*), or formally related but morphologically and semantically unrelated forms of the given stems (e.g., reference: *broth*, prime: *brothel*, target: *BROTH*). As with Experiment 1, two different patterns of outcomes could be expected. According to a very early view of morphological decomposition process driven solely by the presence of orthographically defined sub-word units, the pattern observed with previous studies using the lexical decision task should be replicated (i.e., modulation in the size of priming by morphological structure, with larger priming effects expected with polymorphemic and pseudo-polymorphemic primes than by monomorphemic prime). In contrast, if the detection of an orthographically defined sub-word unit like an affix is not sufficient to drive morphological decomposition, the three types of words should produce equivalent amount of priming of the stem.

Experiment 1

Method

Participants. Thirty undergraduate students from the University of La Laguna took part in the present experiment. They all had normal or corrected-to-normal vision. All of them were monolingual Spanish speakers and received 3 € in exchange for their participation.

Materials. The same 88 affixed words (44 prefixed, 44 suffixed) and 88 control words used in the original Duñabeitia et al. study (2007, Experiment 2) were used in the present experiment. Each of these words was used twice as targets, once requiring a "same" response and once requiring a "different" response. In the "same" response group, the reference and the target were identical (e.g., prefixed: *biznieto-BIZNIETO*; suffixed: *mesonero-MESONERO*; control: *escombro-ESCOMBRO*). Masked primes were created either transposing the two letters at the morphemic boundary (e.g., prefixed: *binzieto*; suffixed: *mesoenro*; control: *escobmro*), or replacing these two letters with other formally similar letters (e.g., prefixed: *bicsieto*; suffixed: *mesoasro*; control: *escohcro*). In the "different" response group, masked primes and targets were the same as in the "same" response group, while references were rotated within each subset of items, so that these were different to the targets. Two list versions were constructed for the purpose of counterbalancing assignment of sets to the two prime types, so that within a list, each target word appeared only once, and across both lists, each target appeared in both prime conditions. Assignment of list versions was counterbalanced across participants so that half (fifteen participants) were assigned to one list, and the other half, to the second list.

Procedure. The experiment was run individually in a quiet and well-lit experimental room located in the dependencies of the Neurocog laboratory at the University of La Laguna. The stimuli presentation and data collection of the response times were run by using DMDX (Forster & Forster, 2003) in a PC associated with a CRT monitor. They were told that in each trial they were going to be presented with a pair of letter strings, one after another. They were instructed to decide whether the two letter strings were identical (pressing the “L” button in the keyboard) or different (pressing the “S” button in the keyboard). They were requested to decide as fast and accurately as possible. References and primes were always presented in lowercase while targets were presented in uppercase. All stimuli were presented in white, in Courier New 12-pt font. The background was kept black. Forward masks were made of # symbols, and their length was adjusted for each trial so that this was identical to the length of the intervening strings. Each of the trials started with the brief presentation of a fixation point in the center of the screen (“·”), displayed for 250 ms. Immediately after this, the reference was presented for 1000 ms, together with the forward mask that was presented for the same time in the line underneath the reference. After the 1000 ms, the two elements disappeared from the screen and the location of the forward mask was then taken by the prime, which was presented for 50 ms. The target was then presented in this same location for 2500 ms or until a response was given (see Figure 1 for a schematic representation of a trial). Participants were not informed of the presence of the masked prime, and none of them reported awareness of these stimuli when asked after the experiment. Different random order was generated for each participant. Each participant received a total of 12 practice trials prior to the 352 experimental trials.

-Insert Figure 1 around here-

Results and Discussion

The latency analysis excluded all data from incorrect responses, as well as the percentage of responses beyond the 250–1500 ms cutoff values. The mean response latencies and percentages of error are presented in Table 1. Following previous studies using the same task, analyses were carried out separately for “same” and for “different” responses. For each type of response, participant ANOVAs based on the participant response latencies and percentages of error were conducted based on a 2 (Type of affix: suffix, prefix) x 2 (Type of word: affixed, control) x 2 (Type of prime: transposed, replaced) x 2 (List: list 1, list 2) design. Considering that the assignment of items to the different prime conditions was counterbalanced across the groups of participants, and that all participants were presented with all experimental conditions, we only report F ratios over participants. This is the appropriate analysis for testing the significance of the effects in a counterbalanced design, such as that used in the present study (see Clark, 1973; Raaijmakers, 2003; Raaijmakers, Schrijnemakers, & Gremmen, 1999)[1]. List was incorporated in the ANOVAs to extract the variance of the error associated with the lists (Pollatsek & Well, 1995).

[1] In any case, it should be noted that the significance levels corresponding to the F ratios over items in the present experiments essentially mimicked the reported significance levels of the F ratios over participants.

-Insert Table 1 around here-

"Same" responses. In the response latency analyses, the main effect of Type of affix was significant, F(1,28)=22.99, p<.001, showing that words in the Suffix group were responded significantly faster than words in the Prefix group (a 20 ms difference). The effect of Type of prime was also significant, F (1,28)=17.74, p<.001, showing that target words preceded by transposed-letter primes were recognized significantly faster than replaced-letter primes (a difference of 17 ms). None of the other effects or interactions were significant (all Fs<1 and ps>.44). None of the analyses of the error rates were significant (all ps>.11).

"Different" responses. In the latency data analysis the main effect of Type of affix was significant by participants F(1,28)=5.74, p<.03, showing that words in the Suffix group were responded to significantly faster than words in the Prefix group (a 11 ms difference). The main effect of Type of word was also significant, F(1,28)=15.32, p<.01, showing that control words were responded to faster than affixed words (a 15 ms difference). The interaction between these two factors was significant, F(1,28)=6.55, p<.02. Further analyses confirmed that within the group of affixed words, words in the suffix set were responded to significantly faster than words in the prefix set, F(1,28)=16.21, p<.001 (a 23 ms difference). The rest of the effects or interactions were not significant. The analyses on the error rates showed a main effect of Type of word, F(1,28)=4.28, p<.05, indicating that affixed words were responded to less accurately than control words (a 0.91% difference)[2]. Also, words preceded by transposed-letter

[2] As seen, suffixed words were responded to faster than prefixed words in the "same" and "different" response analysis. A similar effect was found in Duñabeitia et al. (2007). *A priori*, we have no theoretical reason for this effect. We believe that this effect might be due to uncontrolled factors that could have potentially enhanced processing of suffixed words over prefixed words, but we have no clear explanation for this result. In any case, considering that the critical manipulations were carried out within-items, we believe

primes were responded to more accurately than words preceded by replaced-letter primes, even though this result only approached significance, $F(1,28)=3.39$, $p=.08$ (a 0.91% difference).

The results from Experiment 1 were clear-cut: For "same" responses, a significant masked TL priming effect was observed for targets preceded by transposed-letter primes as compared to targets preceded by primes that included letter replacements (an overall 17 ms TL effect). Importantly, this TL priming effect was observed for all types of words (i.e., prefixed, suffixed, non-prefixed and non-suffixed words), and no significant differences were found in the magnitude of the TL effect across word types (effects of 19, 14, 20 and 17 ms, respectively). These data confirm that in the cross-case masked priming same-different task the magnitude of the TL priming effect is not modulated as a consequence of manipulating the affix boundary of polymorphemic words. While in the masked priming lexical decision study by Duñabeitia, Perea and Carreiras (2007) the TL effect vanished for manipulations on the affix boundary of polymorphemic words, this was not the case when the same materials were tested in a cross-case masked priming lexical decision task. Masked priming effects in the same-different task are assumed to be based on pre-lexical orthographic representations (see Kinoshita & Norris, 2009). The fact that no hint of morphological decomposition effects is found, and polymorphemic and monomorphemic words behave similarly suggests that orthographically driven morphological decomposition process of polymorphemic words does not take place during the earliest stages of orthographic encoding.

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that slight processing differences between the different target sets are not critical for the ultimate aim of the present study (especially if these effects are mainly evident in the "different" response analysis).

In Experiment 2 we investigated whether polymorphemic, pseudo-polymorphemic and monomorphemic prime words (e.g., *walker, corner, brothel*) influence target word processing (e.g., *walk, corn, broth*) in the same manner in the cross-case masked priming same-different task, using a design similar to the one used by Rastle, Davis and New (2004). Based on the results of Experiment 1 indicating that TL priming effects in the same-different task were not modulated by morphological structure, it was expected that in Experiment 2 target words should be primed equally, irrespective of whether the prime was polymorphemic, pseudo-polymorphemic, or monomorphemic.

Experiment 2

Method

Participants. A group of 34 native Spanish speakers from the University of La Laguna took part in the present data collection. None of them had taken part in Experiment 1 and they all had normal or corrected-to-normal vision. They received 3 € or course credit in exchange for their participation.

Materials. A total of 126 Spanish words taken from the LEXESP database (Sebastián-Gallés, Martí, Carreiras, & Cuetos, 2000) were selected as references and targets in this experiment. Each of these words was used twice as targets, once requiring a “same” response and once requiring a “different” response. One third of these words constituted the Non-suffixed set (e.g., *alma* [soul]). Target words in the Non-suffixed set were preceded by masked related prime words that were monomorphemic words that included the same letter string of the reference/target at the beginning of the word (e.g., *almacén* [warehouse]; note that *–cén* in *almacén* does not correspond to a real Spanish suffix). Another third of the 126 words constituted the Pseudo-suffixed set (e.g., *arma* [weapon]). Target words in the Pseudo-suffixed set were briefly preceded by masked related prime words that included the same letter string of the reference/target at the beginning of the word, followed by an existing Spanish suffix that did not act as a suffix in that word (e.g., *armario* [wardrobe]; note that *–rio* is a real Spanish suffix, but that in *armario* it does not act as a suffix and therefore *armario* cannot be decomposed in *arma*+*rio*). The other third of the 126 words constituted the Suffixed set (e.g., *hora* [hour]). Target words in the Suffixed set were briefly preceded by masked related polymorphemic prime words that included the same letter string of the reference/target at the beginning of the word as a real stem, followed by an existing Spanish suffix (e.g., *horario* [schedule]; note that *horario* can be decomposed in *hora*+*rio*). The target words in the three groups were matched in frequency, length and number of orthographic neighbors. The same matching procedure was followed for the masked related prime words across the sets. A different set of 126 prime words was selected as masked unrelated primes for the 126 references/targets. As shown in Table 2, these words were also matched as closely as possible to the masked related primes in word frequency, length and number of orthographic neighbors (see Appendix for the complete list of materials used in Experiment 2)[3]. As in Experiment 1, in the "same" response group, the reference and the target were identical. In the "different" response group, masked primes and targets were the same as in the "same" response group, while references were rotated within each subset of items, so that these were different to the targets. Two

[3] The same complete set of items had been previously used in a Spanish two-choice lexical decision masked priming experiment, showing the classical "corner" effect (Diependaele, Duñabeitia, Morris, & Keuleers, in preparation).

list versions were constructed for the purpose of counterbalancing assignment of sets to the two prime types, so that within a list, each target word appeared only once, and across both lists, each target appeared in both prime conditions. Assignment of list versions was counterbalanced across participants so that half (seventeen participants) were assigned to one list, and the other half, to the second list.

-Insert Table 2 around here-

Procedure. The same procedure as in Experiment 1 was followed.

Results and Discussion

The latency analysis excluded all data from incorrect responses, as well as the percentage of responses beyond the 250–1500 ms cutoff values. The mean response latencies and percentages of error are presented in Table 3. Analyses were also carried out separately for “same” and for “different” responses. For each type of response, participant ANOVAs based on the participant response latencies and percentages of error were conducted based on a 3 (Type of word: Suffixed, Pseudo-suffixed, Non-suffixed) x 2 (Type of prime: related, unrelated) x 2 (List: list 1, list 2) design.

-Insert Table 3 around here-

“Same” responses. In the response latency analyses, the main effect of Type of prime was significant, $F(1,32)=107.57$, $p<.001$, showing that target words were responded to significantly faster when preceded by related primes as compared to when they were

preceded by unrelated primes (an overall 43 ms difference). None of the other effects or interactions were significant (all $Fs<1$ and $ps>.52$). The analyses on the error rates showed a main effect of Type of word which closely approached significance, $F1(2,64)=2.87$, showing that participants responded to words in the different sets with a different level of accuracy (Suffixed: 5.53% of errors; Pseudo-suffixed: 3.64% of errors; Non-suffixed: 4.62% of errors). The effect of Type of prime was also significant, $F(1,32)=13.26$, $p<.01$, showing that participants responded to target words more accurately when these were preceded by related primes as compared to when these were preceded by unrelated primes (a 2.75% difference in the error rates). The interaction between the two factors did not approach significance ($Fs<1$ and $ps>.91$).

"Different" responses. None of the main effects or interactions in the latency data analyses or in the error rate analyses were significant (all $ps>.13$).

Results from Experiment 2 were clear-cut: In contrast to what has been previously found in masked priming lexical decision experiments (e.g., Longtin et al., 2003; Rastle et al., 2004), priming effects of virtually the same magnitude are found for words preceded by masked polymorphemic, pseudo-polymorphemic and monomorphemic related primes as compared to unrelated primes in the cross-case masked priming same-different task (effects of 45, 46 and 39 ms, respectively). A similar pattern is also observed in the error data. Hence, these data support the idea that morpho-orthographic decomposition of polymorphemic (and pseudo-polymorphemic) words takes place when more than merely orthographic representation is required, or that at least, is not driven obligatorily upon the presence of an orthographically defined sub-word unit.

General Discussion

The results in the present cross-case masked priming same-different study could be summarized as follows: First, as shown in Experiment 1, the masked transposed-letter similarity effect has been replicated for monomorphemic words (e.g., *brotehl-BROTHEL*). Second, the masked TL effect has been also obtained for prefixed and suffixed words when manipulations involved the letters that constituted the affix boundaries of those words (e.g., *walekr-WALKER*). Third, no differences were observed in the magnitude of the TL effect for monomorphemic and polymorphemic words. Fourth, as shown in Experiment 2, when primes and targets had a truly or apparent morphological relationship (e.g., *walker-WALK* and *corner-CORN*), significant priming effects were found. Fifth, when primes and targets had a purely orthographic relationship (e.g., *brothel-BROTH*), a significant priming effect was also found. And sixth, the magnitude of these priming effects did not significantly differ from each other. In the following sections, we will now relate these findings to the original studies testing the same issues in the regular masked priming lexical decision task, and propose a definition of a morpho-orthographic decomposition stage of processing that operates after an initial orthographic screening of the visual input has been completed.

Duñabeitia, Perea and Carreiras (2007) showed that when letter transpositions were carried out with the letters that constituted the affix boundary of an affixed word, the TL effect vanished, and no differences were observed for targets preceded by transposed-letter primes as compared to targets preceded by replaced-letter primes in a masked priming lexical decision task (e.g., *walekr-WALKER* = *walabr-WALKER*). Experiment 1 showed a contrasting pattern of findings (e.g., *walekr-WALKER* ≠ *walabr-WALKER*). With exactly the same materials being tested in a cross-case masked priming same-different task, the TL effect for polymorphemic words in which the affix boundary was altered and for monomorphemic words was almost identical. Hence, when the cross-case masked priming same-different task is used, we find a restoration of the TL effect for polymorphemic words.

Rastle, Davis and New (2004; see also Lavric, Clapp, & Rastle, 2007; Longtin et al., 2003; Morris et al., 2007; see also Diependaele, Sandra, & Grainger, 2009, and Feldman, O'Connor, & Moscoso del Prado Martín, 2009, to some extent) have shown that primes that are orthographically and morpho-semantically related to the targets (e.g., *walker-WALK*) facilitate target recognition in the masked priming lexical decision task as compared to an unrelated control priming condition, while this is not typically the case for prime-target pairs that only have an orthographically based relationship (e.g., *brothel-BROTH*). Moreover, most studies using this same task have also shown that prime-target pairs with an apparent morphological relationship (e.g., *corner-CORN*) exert a mutual facilitative influence as compared to a control priming condition[4]. However, in Experiment 2 we showed that this is not the case when similar materials are used in the cross-case masked priming same-different task. Priming effects were virtually identical for morphologically (opaquely and transparently) related as well as for only orthographically related word pairs.

[4] It should be noted that there is a current debate on the issue of semantic transparency and how it affects masked morphological priming in the lexical decision task (see Feldman et al., 2009). Some recent data show that the magnitude of the priming effects observed for opaquely related pairs like *corner-CORN* is lower than the magnitude of the priming effects observed for transparently related pairs like *walker-WALK*. However, although relevant, this issue is not the focus of the present study. Rather, the critical point for our purposes is whether the presence of an orthographically defined morphological unit triggers a morphological decomposition process (i.e., whether the amount of priming would differ between pseudo-affixed words like in *corner-CORN* and merely orthographically related pairs such as in *brothel-BROTH*.

The present experiments demonstrate that the morpho-orthographic segmentation process observed with masked priming in the lexical decision task is not effective in the masked priming same-different task. In the same-different task, TL priming effects occur regardless of the presence of morphological boundaries. Morpho-orthographic segmentation therefore appears not to be an obligatory component of all orthographic processing but would appear only to be invoked in the service of lexical access – as when required in the lexical decision task. This result seems to rule out any simple version of the connectionist learning account advanced by Rastle et al. (2004). As stated in the Introduction, several authors have highlighted the fact that affixes are highly salient units in orthographic processing, given their unique bigram and trigram frequency contours (Rastle et al., 2000; 2004; see also Seidenberg, 1987). Considering the high bigram/trigram frequencies of the affixes and considering that these frequencies are much lower across morpheme boundaries, morphological segmentation may well be driven by statistics. In accordance, the processing and decomposition of (pseudo-)morphologically complex items is expected to be boosted by these frequency-based computations of the structure of the strings. However, as we will explain below, when the task does not require lexical access (i.e., the masked priming same-different task), the visual word recognition system seems to be blind to such statistical regularities.

The fact that within-morpheme n-gram frequencies are generally higher than across-morpheme n-gram frequencies has led to the conclusion that these particular statistics are computed at early stages of orthographic processing, leading to fast and automatic processes of morphological decomposition (i.e., the morpho-orthographic view). However, in the masked priming same-different task such statistical regularities seem to be overlooked by the visual word recognition system, and do not have any effect on orthographic processing. A possible explanation for this fact is that the same-different task does not tap into abstract orthographic processing, but rather, into low-level visual recognition of objects and their features. According to this pre-linguistic account of the task, no differences are expected to emerge between transpositions within and between morphemes, simply because the visual system is processing them similarly. Nonetheless, several recent studies have shown that this is not the case (e.g., Kinoshita & Norris, 2009), and that priming effects in the masked priming same-different task emerge from the integration of perceptual evidence accumulated by the prime and the target at an abstract level (e.g., Norris & Kinoshita, 2008). In this line, a recent study by García-Orza, Perea and Muñoz (in press) has shown that this paradigm is indeed sensitive to the nature of the characters used to form the strings. García-Orza et al. showed that while character transpositions lead to facilitative priming effects as compared to character replacements for pseudowords, consonant strings, numbers and symbols (e.g., ERPI, SJTN, 2576 and +>”&, respectively), the robust effect of transposition vanishes for strings made of pseudoletters (i.e., false fonts). These results show that the pronounceability of the input string has no impact on the observed transposition effects, since similar effects were obtained for pseudowords and consonant strings (see also Perea & Carreiras, 2006a, 2008; Perea & Pérez, 2009). But more importantly, these results have a clear implication with regard to the present study: Considering that the transposition effect disappeared for non-linguistic characters, it is not feasible to assume that the masked priming same-different task taps into a pre-linguistic stage of visual processing (see Kinoshita & Norris, 2009, for a similar conclusion). Rather, the results from García-Orza et al. suggest that the familiarity of the objects plays a critical role in this task, and that, at least in part, some basic statistical regularities are computed in this task.

As deduced from the present study, the masked priming same-different task is blind to the statistical regularities that make affixes salient units, and despite the greater n-gram frequency of the morphemic constituents as compared to the morphological boundaries (Rastle et al., 2004), this information is not computed in a purely orthographic task, thus reducing the expectancies to obtain significantly different effects for morphologically complex as compared to morphologically simple strings. Certainly, this does not fully disregard the impact of those statistical distributional properties of polymorphemic words. Rather, the present results indicate that those regularities are computed only when the task implies accessing the mental lexicon (i.e., in the lexical decision task; Duñabeitia et al., 2007; Rastle et al., 2004). In contrast, under circumstances in which the lexical representation of a string does not offer valuable information with respect to the task demands, that information can be neglected and consequently, polymorphemic words are comparable to monomorphemic words.

One implication of these data is that morpho-orthographic segmentation operates as an additional source of constraint in resolving letter position/order. But how does the morpho-orthographic segmentation process act to eliminate (or at least greatly attenuate) the TL priming effect in lexical decision? In models like the Overlap model of Gómez, Ratcliff and Perea (2008), or the Bayesian Reader (Norris & Kinoshita, 2007; Norris, Kinoshita, & van Casteren, in press), TL priming effects come about because there is uncertainty in the precise coding of letter position or order. The transposed-letters in the prime still manage to provide partial support for the corresponding letters in the target. The fact that TL priming is blocked by a morpheme boundary implies that the morpho-orthographic segmentation process can provide an additional level of constraint on letter position that acts to make the transposed-letters in the prime more dissimilar to the corresponding letters in the target than they would be otherwise. In effect, when there is a morpheme boundary, transposed-letters behave just like substituted-letters. In contrast, the same-different task does not require lexical access. If the system is not attempting lexical access, there will be nothing to be gained by morphological parsing and no way for morphological structure to block priming.

One possibility is that, during normal lexical access, morpho-orthographic segmentation operates in parallel with whole-word recognition (e.g., Schreuder & Baayen, 1995, 1997). A morphological parse of the input could be constructed in much the same way that TRACE (McClelland & Elman, 1986) and Shortlist (Norris, 1994; Norris & McQueen, 2008) parse continuous speech into a sequence of words. If a prime contains a letter transposition within a morpheme this will have little effect on the parsing of either the prime or target. The sequence of potential morphemes will be unchanged. However, if a letter transposition brackets a morpheme boundary this will lead to a mismatch between the morphological parse of the prime and target which may be sufficient to block priming. For example, with the prime-target pairing of *walekr-WALKER*, the transposed-letters will reduce the likelihood that *walekr* will give rise to the parsing *walk+er*. In part, this is simply because the morphemes are necessarily shorter than the words, and a single misplaced or misidentified letter will have a proportionately greater impact on shorter units.

Conclusion

The same-different task is based on a comparison of the target and reference strings at a purely orthographic level (Norris & Kinoshita, 2008; Kinoshita & Norris, 2009). The present experiments showed that the orthography-driven morphological decomposition effects observed in the lexical decision task (Duñabeitia et al., 2007;

Rastle et al., 2004) are absent in this task. These results suggest that there is a fast pre-lexical morpho-orthographic segmentation mechanism, but this operates solely in the service of lexical access and is not a general property of the orthographic processing system.

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Appendix

List of stimuli used in Experiment 2. The first item in each pair corresponds to the related prime while the second item corresponds to the target.

Non-suffixed condition: robot-robo; amargo-amar; carnet-carne; cítara-cita; galope-galo; granja-gran; lacayo-laca; paloma-palo; diablo-día; alfalfa-alfa; almacén-alma; bálsamo-balsa; barroco-barro; caballo-cabal; ciénaga-cien; colapso-cola; fieltro-fiel; galaxia-gala; garrafa-garra; lagarto-lagar; mapache-mapa; masacre-masa; palabra-pala; párrafo-parra; penalti-pena; retorno-reto; todavía-toda; balance-bala; cocochа-coco; milagro-mil; parodia-paro; antesala-antes; barbarie-barba; barranco-barra; caravana-cara; codorniz-codo; mediocre-medio; recuadro-recua; comanche-coma; algarroba-alga; plataforma-plata; primordial-primo.

Pseudo-suffixed condition: aguante-agua; antena-ante; armario-arma; arteria-arte; batalla-bata; bocadillo-boca; camarote-cama; casino-casi; castaño-casta; cincel-cinc; condena-conde; corona-coro; corteza-corte; costado-costa; dichoso-dicho; entero-ente; extraño-extra; firmamento-firma; ganado-gana; letrado-letra; localidad-local; malaria-mala; montaña-monta; muchacho-mucha; notario-nota; pasaje-pasa; pelota-pelo; peseta-pese; planeta-plan; portería-porte; primaria-prima; romance-roma; rosario-rosa; seriedad-serie; solana-sola; testigo-test; tiranía-tira; torrente-torre; trabajo-traba; tribunal-tribu; vacaciones-vaca; ventaja-venta.

Suffixed condition: final-fin; ideal-idea; telar-tela; maldad-mal; pareja-par; manojo-mano; ociosa-ocio; ramaje-rama; airear-aire; bajada-baja; jarrón-jarro; olorosa-olor; ovalada-oval; amoroso-amor; horario-hora; cercano-cerca; gustoso-gusto; hachazo-hacha; morboso-morbo; nobleza-noble; plagado-plaga; vallado-valla; mayoría-mayor; genética-gen; agilidad-ágil; dualidad-dual; grisáceo-gris; tapadera-tapa; brevedad-breve; cableado-cable; colorido-color; culpable-culpa; hablador-habla; limonero-limón; luchador-lucha; noviazgo-novia; papelera-papel; pescador-pesca; santoral-santo; velatorio-vela; bombardeo-bomba; dramático-drama.

Author notes

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Figure 1. Schematic representation of a trial in the cross-case masked priming same-different task.

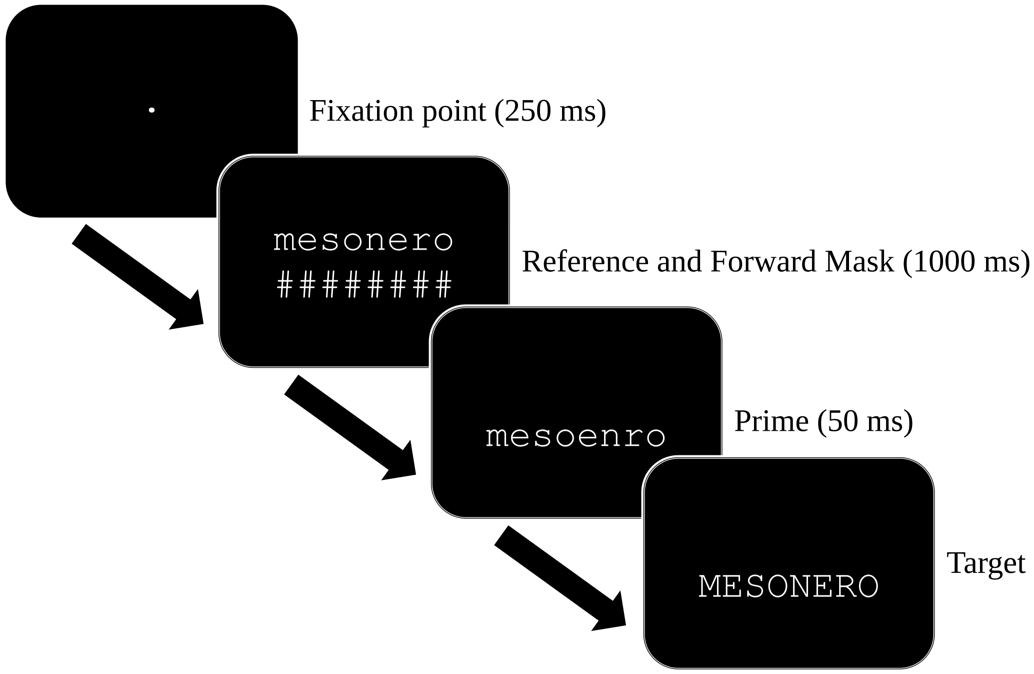

Table 1. Mean reaction times (in ms) and percentages of error for “same” and “different” responses to targets as a function of the type of prime. The TL effect refers to the subtraction of the values in the Transposed-letter condition from the values in the Replaced-letter condition.

	Transposed-letter	Replaced-letter	TL effect
Same Responses			
Suffixed	550 (1.97%)	564 (4.24%)	14 (2.27%)
Non-suffixed	554 (3.64%)	571 (2.88%)	17 (-0.76%)
Prefixed	570 (3.64%)	589 (3.18%)	19 (-0.45%)
Non-prefixed	571 (2.88%)	591 (3.48%)	20 (0.61%)
Different Responses			
Suffixed	615 (1.82%)	605 (2.88%)	-10 (1.06%)
Non-suffixed	601 (1.67%)	613 (2.12%)	12 (0.45%)
Prefixed	643 (2.73%)	623 (4.09%)	-20 (1.36%)
Non-prefixed	607 (1.67%)	602 (2.42%)	-5 (0.75%)

Table 2. Characteristics of the materials used in Experiment 2. Frequency is reported in number of appearances per million words. Length corresponds to the number of letters of the strings. N refers to the number of orthographic neighbors. Standard deviation is provided within parentheses.

	Frequency	Length	N
Non-Suffixed			
Probes-Targets (alma)	83 (155.07)	4.29 (0.6)	11 (6.8)
Masked Related Primes (almacén)	20.2 (59.50)	7.14 (1)	0.4 (0.73)
Masked Unrelated Primes (escasez)	14.2 (31.69)	7.4 (1.16)	0.4 (0.69)
Pseudo-Suffixed			
Probes-Targets (arma)	83.6 (129.82)	4.43 (0.50)	8.4 (6.97)
Masked Related Primes (armario)	27.8 (52.32)	7.2 (1.01)	0.9 (0.96)
Masked Unrelated Primes (cordura)	19.6 (23.35)	7.5 (1.15)	0.9 (1.01)
Suffixed			
Probes-Targets (hora)	84.45 (104.94)	4.43 (0.67)	5.50 (4.55)
Masked Related Primes (horario)	18.35 (47.31)	7.19 (1.06)	1.19 (1.38)
Masked Unrelated Primes (vanidad)	16.57 (38.41)	7.40 (1.34)	1.10 (1.36)

Table 3. Mean reaction times (in ms) and percentages of error for "same" and "different" responses to targets as a function of the type of prime. Difference refers to the subtraction of the values in the Related condition from the values in the Unrelated condition.

	Related	Unrelated	Difference
Same responses			
Non-suffixed	557 (3.36%)	596 (5.88%)	39 (2.52%)
Pseudo-suffixed	557 (2.10%)	603 (5.18%)	46 (3.08%)
Suffixed	551 (4.20%)	596 (6.86%)	45 (2.66%)
Different responses			
Non-suffixed	621 (2.80%)	614 (2.80%)	-7 (0.00%)
Pseudo-suffixed	625 (3.78%)	616 (1.40%)	-9 (-2.38%)
Suffixed	615 (2.52%)	615 (2.24%)	0 (-0.28%)