

Jalapeno or Jalapeño: Do diacritics in consonant letters modulate visual similarity effects during word recognition?

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Short title: Diacritics and visual similarity

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## Abstract

Prior research has shown that word identification times to *DENTIST* are faster when briefly preceded by a visually similar prime (*dentjst*;  $i \leftrightarrow j$ ) than when preceded by a visually dissimilar prime (*dentgst*). However, these effects of visual similarity do not occur in the Arabic alphabet when the critical letter differs in the diacritical signs: for the target صحفية, the visually similar one-letter replaced prime صحفية (compare خ and ح) is no more effective than the visually dissimilar one-letter replaced prime صكفية. Here we examined whether this dissociative pattern is due to the special role of diacritics during word processing. We conducted a masked priming lexical decision experiment in Spanish using target words containing one of two consonants that only differed in the presence/absence of a diacritical sign: *n* and *ñ*. The prime-target conditions were identity, visually similar, and visually dissimilar. Results showed an advantage of the visually similar over the visually dissimilar condition for muñeca-type words (*muneca*-*MUÑECA* < *museca*-*MUÑECA*), but not for moneda-type words (*moñeda*-*MONEDA* = *moseda*-*MONEDA*). Thus, diacritical signs are salient elements that play a special role during the first moments of processing, thus constraining the interplay between the “feature” and “letter” levels in models of visual word recognition.

Key words: masked priming; lexical decision; visual similarity; diacritical signs

Skilled readers can easily identify printed words in a variety of formats (e.g., *animal*, animal, *animal*, see Rayner, Pollatsek, Ashby, & Clifton, 2012, for review). To explain the resilience of the cognitive system to the changes in the visual appearance of words, most models of written word recognition assume that the visual features of each of the word's component letters (e.g., curvatures, lines, terminals, junctions, etc.) are gradually mapped onto an array of abstract letter detectors (e.g., the detector for "G" would respond similarly to g, g, G, and G; see Dehaene, Cohen, Sigman, & Vinckier, 2005; Grainger, Rey, & Dufau, 2008, for neurally-inspired models; see also Grainger, Dufau, & Ziegler, 2016, for a recent review). These abstract letter detectors would be the impelling force behind lexical access (see Bowers, Vigliocco, & Haan, 1998; Jacobs, Ferrand, & Grainger, 1995, for early empirical evidence with the masked priming technique [Forster & Davis, 1984]).

A much less studied topic is whether the activation of these abstract letter detectors is modulated by visual similarity in the initial moments of word processing. As acknowledged by Davis (2010), the implemented version of most computational models of visual word recognition use a rudimentary scheme between the "feature" and "letter" levels (Rumelhart & Siple's, 1974, font), the reasons being that: 1) the main focus of these models was the "word" level; 2) one needs to know what are the key phenomena to simulate in the "feature" and "letter" levels (see Rosa, Perea, & Enneson, 2016, for discussion). A plausible assumption is that, as occurs with the encoding of letter order (see Massol, Duñabeitia, Carreiras, & Grainger, 2013), there is some perceptual uncertainty at encoding abstract letter identities in the initial moments of word processing

(Bayesian Reader model: Norris & Kinoshita, 2012). Indeed, previous research has shown that abstract letter detectors are resilient to variations in the printed form of the stimuli: degraded stimuli (e.g., *unique*) or stimuli created with letter-like digits (e.g., *M4T3RIAL*) are very effective as masked primes (see Hannagan, Ktori, Chanceaux, & Grainger, 2012; Molinaro, Duñabeitia, Marín-Gutiérrez, & Carreiras, 2010; Perea, Duñabeitia, & Carreiras, 2008).

Critically, there is empirical evidence of visual similarity effects in Latin-based orthographies: a target word like *DENTIST* is responded to faster when briefly preceded by a visually similar substituted-letter prime (*dentjst*; note that *i* and *j* are rated as visually very similar [5.12 of 7] in the Simpson, Mousikou, Montoya, & Defior, 2012, norms) than when preceded by a visually dissimilar substituted-letter prime (*dentgst*) (Kinoshita, Robidoux, Mills, & Norris, 2013; Marcet & Perea, 2017, 2018a; see also Marcet & Perea, 2018b, for evidence with the boundary technique during sentence reading). To examine in detail the time course of the effects of visual similarity during word recognition, Gutiérrez-Sigut, Marcet, and Perea (2019) conducted two masked priming lexical decision experiments using the stimuli from Marcet and Perea (2017) while recording Event-Related Potentials (ERPs). They found that the identity condition (e.g., *dentist-DENTIST*) and the visually similar condition (*dentjst-DENTIST*) produced similar ERP waves in a component related to the orthographic overlap between prime and target (N250; see Grainger & Holcomb, 2009, for a review of the ERP literature in word recognition), whereas the visually dissimilar condition (e.g., *dentgst-DENTIST*) produced larger amplitudes. Later in processing, when measuring a component related to lexico-semantic activation (N400), the amplitudes were larger in the visually similar and visually dissimilar conditions

than in the identity condition. Taken together, these findings suggest that there is some uncertainty at encoding letter identity during word processing that is finally resolved.

In contrast, the effects of visual similarity do not seem to occur in Arabic. Perea, Abu Mallouh, Mohammed, Khalifa, and Carreiras (2016, 2018) found that word identification times for a target word like صحيفة (SHfyp with the Buckwalter transliteration [*journalist* in English]) are remarkably similar when preceded by a visually similar replaced-consonant prime that only differed in the diacritical sign of the critical letter (e.g., صحفية Sxfyp; compare خ and ح) and when preceded a visually dissimilar replaced-consonant prime (e.g., صكفية Skfyp)—this was accompanied by a substantial advantage of the identity condition over the visually similar condition. Perea and colleagues suggested that the lack of visual similarity effects in Arabic was due to the fundamental importance of these signs in Arabic: most consonant letters only differ by the number and/or position of these signs (e.g., ح - ج , خ - ح - ج , غ - ع ; ظ - ط ; ض - ص , among others). (footnote 1)

The dissociation of visual similarity effects in the Latin and Arabic scripts may be taken to suggest that there may be qualitative differences in letter/word processing in these scripts. Indeed, Wiley, Wilson, and Rapp (2016) found that diacritical signs are the most important feature when processing isolated letters in Arabic. Another explanation is that there is something special with the processing of letters with diacritics regardless of script. Although diacritical signs are absent in modern English, they are the norm rather than the exception in the vast majority of European languages (e.g., ñ, č, š, ž, ř, ć, ğ, ź, ć, š, ž, ç, k, l, ŋ, r, s, t, among others). Furthermore, diacritics are also employed in other scripts (e.g., Thai, Hebrew, Greek, Sanskrit, Japanese kana, among others). However, given that most

current models word recognition focus on letter/word processing in English (see Share, 2008, for discussion), they are agnostic as to the similarities/differences in processing between letters with/without diacritical signs.

There is some recent evidence that supports the idea that diacritics have a special role in letter/word processing in the Latin script. In a recent masked priming lexical decision experiment in French, Chetail and Boursain (2019) found a substantial 50-ms advantage of the identity condition (e.g., *taper-TAPER*) over a visually similar replaced-vowel priming condition in which the vowel had a diacritical sign (*tâper-TAPER*). Furthermore, the latencies of the visually similar priming condition (*tâper-TAPER*) were similar as the latencies of a visually different replaced-vowel priming condition (*tuper-TAPER*). Chetail and Boursain also found a similar pattern when using a masked priming alphabetic decision task with isolated letters (i.e.,  $a-A < \hat{a}-A = z-A$ ). Likewise, in masked priming lexical decision, Domínguez and Cuetos (2018) reported this same pattern with Spanish words (*rasgo-RASGO < rasgó-RASGO = persa-RASGO*). Taken together, these experiments suggest not only that participants can rapidly encode diacritical signs from vowels in the Latin script, but that they treat these vowels with diacritical signs as completely separate letters from the original vowels (i.e., the letter *â* does not seem to activate the unit corresponding to the letter *a*).

However, there is an interpretative issue when comparing the effects of visual similarity obtained with the Arabic vs. Latin scripts in the above-cited experiments: the experiments in Arabic manipulated visual similarity in consonants, whereas the experiments in Latin-based orthographies manipulated visual similarity in vowels. There is ample consensus in the literature of word recognition and reading that consonants and vowels are processed differently (see



A second goal of the experiment is to examine whether the effects of visual similarity when processing words containing letters with a diacritical sign are bidirectional or not. Previous masked priming experiments using visually similar letters in the Latin alphabet found a similar pattern regardless of the frequency of the letters (Marcet & Perea, 2017, 2018b): the effects were equivalent in size from *i* to *j* (e.g., *pasaiero-PASAJERO* = *pasajero-PASAJERO* [PASSENGER]) and from *j* to *i* (e.g., *dentjst-DENTIST* = *dentist-DENTIST*) despite the fact that the letter *i* is considerably more frequent than the letter *j* in Spanish (6.2 vs. 0.5% per million). However, this bidirectional pattern may not be generalized to diacritical letters. A prime containing the letter *n* would be a good match for the letter *ñ* (i.e., it contains the same basic letter shape), so it may be initially confusable with its counterpart *ñ* thus producing a visual similarity effect (e.g., *jalapeno* would activate the entry corresponding to *JALAPEÑO*). However, the diacritical sign *~* is a highly salient element so that a prime containing this sign on top of the glyph *n* might not be highly effective—keep mind that the diacritical sign *~* would exclude the letter “*n*” as a good match. This question was not examined in the Chetail and Boursain (2019) and Domínguez and Cuetos (2018) experiments: they always used stimuli with diacritical signs as primes (e.g., *tâper-TAPER*, but not *decider-DÉCIDER*).

In sum, we designed a masked priming lexical decision experiment to examine the role of diacritical signs on consonants in the initial moments of word processing in a Latin-based orthography (Spanish). We included three prime-target conditions: 1) a visually similar condition in which we replaced the letter *n/ñ* with its counterpart (SIM condition; e.g., *moñeda-MONEDA*; *muneca-MUÑECA* [moneda and muñeca are the Spanish for coin and doll, respectively]); 2) a visually dissimilar condition in which we replaced the letter *n/ñ* with a visually dissimilar



letter (DIS condition; e.g., *moseda-MONEDA*; *museca-MUÑECA*); and 3) an identity condition (ID condition; e.g., *moneda-MONEDA*; *muñeca-MUÑECA*)—this condition allowed us to estimate the degree of effectiveness of the visually similar priming condition. Primes and targets were presented in different case (from lowercase to uppercase) to avoid physical continuity, thus ensuring a more abstract processing of the stimuli (see Forster, Mohan, & Hector, 2003, for discussion). As in previous research, the two critical comparisons were between the visually similar condition and the visually dissimilar condition (SIM vs. DIS) and between the identity condition and the visually similar condition (ID vs. SIM) (see Marcet & Perea, 2017; Perea et al., 2018, for discussion).

If consonant letters that share the basic shape (e.g., *n* and *ñ*) were initially processed as other visually similar letters in the Latin script (e.g., *i-j*, *u-v*; see Marcet & Perea, 2017, 2018a), target words like *MONEDA* would produce faster word identification times when preceded by a visually similar prime (e.g., *moñeda*) than when preceded by a visually dissimilar prime (e.g., *moseda*). Furthermore, the visually similar condition might be as effective as the identity condition (i.e.,  $SIM < DIS$  and  $ID \leq SIM$ ). This pattern would generalize the visual similarity effects obtained by Marcet and Perea (2017; see also Gutiérrez-Sigut et al., 2019) to letters with diacritical signs (*n/ñ*), thus suggesting a qualitative difference between the processing of consonants with diacritics in Arabic and Latin-based scripts. Alternatively, if diacritical consonants and their counterparts activate completely separate abstract letter representations in the initial moments of processing (i.e., *n* would not activate *ñ* more than a control letter; *ñ* would not activate *n* more than a control letter), one would expect no visual similarity effects (i.e.,  $SIM=DIS$  and  $ID < SIM$ ). This pattern would resemble the findings in the Arabic script (see Perea et

al., 2016, 2018) and it would suggest that, regardless of script, diacritics play a major role in the initial moments of word processing. Finally, there is an intermediate scenario: one might argue that only the letters with diacritical signs play a special role during the initial stages of processing (i.e., *n* would activate *ñ*, whereas *ñ* would not activate *n* more than a control letter; see above). If so, one would expect a different pattern for moneda-type words and muñeca-type words: word identification times would be similar for *moñeda-MONEDA* and *moseda-MONEDA* (i.e., a pattern similar to that reported by Chetail & Boursain, 2019, and Perea et al., 2016, 2018, using primes in which the critical letters contained diacritical signs), but word identification times would be faster for *muneca-MUÑECA* than for *musca-MUÑECA* (i.e., a visual similarity effect; Gutiérrez et al., 2019; Marcet & Perea, 2017, using primes in which the critical letters did not contain diacritical signs).

## Method

### **Participants**

Forty-two undergraduate students of a public university in Spain participated voluntarily in the experiment. With this sample size, the number of observations in each priming condition was 1848, which is above the recommendations of Brysbaert and Stevens (2018). All participants were native of Spanish with no problems of vision or reading. They signed a consent informed form before the experiment.

### **Materials**

We selected 132 Spanish words from the subtitle database of the EsPal database (Duchon, Perea, Sebastián-Gallés, Martí, & Carreiras, 2013). Half of them contained

the letter *ñ* in an internal position (*muñeca*-type words) and the other half contained the letter *n* in an internal position (*moneda*-type words)—the letter *n/ñ* was always between two vowels. These two types of words were matched in Zipf frequency, number of letters, and orthographic neighborhood (OLD20) (all *ps* > .35). For the *muñeca*-type words, the average Zipf frequency [ $\log_{10}(\text{frequency per million})+3$  in EsPal] was 3.9 (range: 2.5–5.6), the average number of letters was 6.9 (range: 5-10), and the average OLD20 was 2.0 operations (range: 1.0–3.5), whereas for the *moneda*-type words, the average Zipf frequency was 3.9 (range: 2.3–5.8), the average number of letters was 6.9 (range: 5-10), and the average OLD20 was 2.0 operations (range: 1.2–3.3). Each target word was preceded by a prime that could be: 1) identical to the target word (identity [ID] condition: *muñeca-MUÑECA*; *moneda-MONEDA*); 2) the same that the target word except that the letter “*n*” was replaced with “*ñ*” or vice versa, creating a pseudoword (visually similar [SIM] condition: *muneca-MUÑECA*; *moñeda-MONEDA*); 3) the same except that the letters “*n*” or “*ñ*” were replaced with a visually different letter creating a pseudoword (visually dissimilar [DIS] condition: *museca-MUÑECA*; *moseda-MONEDA*). For the purposes of the lexical decision task, we created 132 orthographically legal pseudowords with Wuggy (Keuleers & Brysbaert, 2010), half of them with the letter *n* in an internal position and the other half with the letter *ñ* in an internal position. The prime-target manipulation for the pseudoword targets was the same as that for the word targets (i.e., identity condition, *cepiña-CEPIÑA*; visually similar condition, *cepina-CEPIÑA*; visually dissimilar condition, *cepisa-CEPIÑA*). We created three lists to counterbalance the stimuli (e.g., *muñeca-MUÑECA* in list 1, *muneca-MUÑECA* in list 2, and *museca-MUÑECA* in list 3). All prime-target pairs are presented in the Appendix.

## **Procedure**

The experiment was conducted individually or in groups of three or four in a silent room. We employed computers equipped with DMDX (Forster & Forster, 2003) to present the stimuli and register the response time and accuracy of each response. The participants were told that, on each trial, there would be a string of letters on the computer screen. They were asked to respond, as quickly and accurately as possible, whether the string of letters formed a Spanish word or not—for words they had to press a “sí” (yes) button with their right hand and for nonwords they had to press a “no” button with their left hand. In each trial, a pattern mask (i.e., a sequence of #'s) was presented for 500 ms, which was replaced by a lowercase prime during 50 ms (3 refresh cycles in the 60-Hz CRT screen). This was immediately replaced by the target stimulus in uppercase, which remained on the screen until the participant responded or up to 2000 ms—the program automatically encoded an error response (i.e., -2000) if no answer was given before this deadline. All the stimuli were presented in 12-pt Courier New. The order of the stimuli was fully randomized for each participant and there were three short breaks during the experiment. The experimental phase was preceded by a practice phase composed of 16 trials of similar characteristics as the experimental trials (8 words and 8 pseudowords). As usual with the masked priming technique, there was no mention of the prime stimuli in the Instructions and, when asked in the debriefing after the experiment, none of the participants commented on the presence of briefly presented items. The experimental session took around 12-15 minutes.

## **Results**

Incorrect responses and very fast responses (less than 250 ms; 4 observations in the word trials [0.07%]) were omitted from the latency analyses. Table 1 displays the mean response times and accuracy in each experimental condition.

Please\_Insert\_Table\_1\_around\_here

To conduct the inferential analyses of the latency data, we employed generalized linear mixed models using the package lme4 (Bates, Maechler, Bolker, & Walker, 2015) in R (R Core Team, 2019) and we assumed an underlying Gamma distribution (see Lo & Andrews, 2015; Yang & Lupker, 2019, for discussion of the advantages of this approach). (footnote 2) In the generalized linear mixed models, the fixed factor Prime Type was encoded as to test the two research questions: 1) whether there is an advantage of the visually similar over the visually dissimilar condition (i.e., SIM vs. DIS); and 2) whether there is an advantage of the identity condition over the visually similar condition (i.e., ID vs. SIM) (see Marcet & Perea, 2017, 2018a, 2018b, for a similar approach). Type of target (moneda-type vs. muñeca-type) was included as a factor to examine whether it modulated the size of the priming effects—it was zero-centered (-0.5 vs. 0.5). Subjects and items were incorporated as random effects in the models and we chose the maximal random effect structure model that successfully converged (see Barr, Levy, Scheepers, & Tily, 2013). The final model was  $GLME\_RT = \text{glmer}(RT \sim \text{prime\_type} * \text{target\_type} + (1|\text{subject}) + (1|\text{item}), \text{data} = \text{wordRT}, \text{family} = \text{Gamma}(\text{link} = \text{"identity"}))$ . The analyses of the accuracy data were parallel to those of the latency data except for

the use of the binomial distribution (i.e., “family = binomial”; correct responses were encoded as “1” and incorrect responses were encoded as “0”).

### **Word data**

*Visually similar vs. visually dissimilar conditions.* The overall advantage of the visually similar over the visually dissimilar condition was not significant,  $\beta = 1.231$ ,  $SE = 3.474$ ,  $z = 0.354$ ,  $p = 0.723$ , but, importantly, this difference was modulated by type of target (interaction:  $\beta = 15.147$ ,  $SE = 3.960$ ,  $z = 3.825$ ,  $p < 0.001$ ). This interaction showed that, for muñeca-type words, responses in the visually similar condition were faster than in the visually dissimilar condition ( $\beta = 16.758$ ,  $SE = 4.610$ ,  $z = 3.635$ ,  $p < 0.001$ ); in contrast, for moneda-type words, response times were essentially the same in the visually similar and visually dissimilar conditions behaved similarly,  $\beta = 1.389$ ,  $SE = 4.227$ ,  $z < 1$ ,  $p > 0.70$ .

The analyses of the accuracy data failed to show any significant effects.

*Identity vs. visually similar conditions.* In the latency data, we found an advantage of the identity condition over the visually similar condition,  $\beta = -15.645$ ,  $SE = 3.359$ ,  $z = -4.658$ ,  $p < 0.001$ . This effect interacted with type of word (interaction:  $\beta = 24.801$ ,  $SE = 4.321$ ,  $z = 5.740$ ,  $p < 0.001$ ). This interaction showed that, for muñeca-type words, word identification times were slightly slower in the identity condition than in the visually similar condition,  $\beta = 9.654$ ,  $SE = 4.945$ ,  $z = -1.952$ ,  $p = 0.102$  (footnote 3), whereas for moneda-type words, word identification times in the identity condition were faster than the visually similar condition,  $\beta = -15.197$ ,  $SE = 4.126$ ,  $z = -3.684$ ,  $p < 0.001$ .

The analyses of the accuracy data did not show any significant effects.

**Nonword data.** None of the effects in the latency/accuracy analyses were significant.

## Discussion

We designed a masked priming experiment with the lexical decision task to examine whether visual similarity effects occur in a Latin-based orthography (Spanish) when the critical letter was replaced by a consonant differing in a diacritical sign (e.g.,  $n \rightarrow \tilde{n}$  or  $\tilde{n} \rightarrow n$ , as in *moñeda*-*MONEDA* or *muneca*-*MUÑECA*) and whether these effects were bidirectional (e.g.,  $n \leftrightarrow \tilde{n}$ ) or unidirectional (e.g.,  $n \rightarrow \tilde{n}$ , but not  $\tilde{n} \rightarrow n$ ). Results showed that, for *MONEDA*-type words, the visually similar prime *moñeda* was not more effective than the visually dissimilar prime *moseda* (567 vs. 568 ms, respectively; i.e., there was no visual similarity effect); furthermore, the visually similar prime *moñeda* was less effective than the identity prime *moneda* (567 vs. 548 ms, respectively). This pattern (i.e., SIM = DIS; ID < SIM) not only extends the findings of Perea et al. (2016, 2018) in the Arabic script to the Latin script, but also the findings of Chetail and Boursain (2019) and Cuetos and Domínguez (2018) from vowels to consonants in the Latin script. Importantly, the pattern of findings was different for *MUÑECA*-type words. The visually similar prime *muneca* was more effective at activating the target word *MUÑECA* than the visually dissimilar prime *moseda* (545 vs. 565 ms, respectively; i.e., SIM < DIS). That is, when the critical letter in the prime did not contain a diacritical sign, we found a sizeable visual similarity effect (see Marcet & Perea, 2017, 2018a, for behavioral evidence; see Gutiérrez et al., 2019, for electrophysiological evidence).

Indeed, the visually similar prime *muneca* was highly effective and produced slightly faster word identification times than the identity prime *muñeca* (a non-significant 9 ms difference)—as indicated above, we prefer to remain cautious about this small difference and prefer to interpret it as a null effect (i.e., ID=SIM; see Perea et al., 2008, for a similar pattern). We now discuss the consequences of these findings for neural and computational models of word recognition.

The present experiment reconciles several seemingly conflicting findings in the literature regarding how visual letter similarity modulates word processing and it also offers new insights on the processing of words containing consonants with diacritical signs. On the one hand, the current experiment showed that, for prime stimuli with no letters containing diacritical signs, visually similar primes are more effective than visually dissimilar primes at activating a target word (e.g., *muneca-MUÑECA* faster than *musca-MUÑECA*), thus providing further empirical evidence to the idea of perceptual noise at encoding letter identities in the first moments of word processing (i.e., initially, the letter *n* may be initially processed as the letter *ñ*), as proposed by the Bayesian Reader model (Norris & Kinoshita, 2012). On the other hand, the current experiment showed that prime stimuli containing a letter with diacritical sign (i.e., a visually salient feature) are processed differently from their counterparts without those signs, and comparably to other visually dissimilar letters (e.g., for the target word *MONEDA*, the prime *moñeda* is not more effective than the control prime *moseda*). Taken together, this dissociative pattern strongly suggests that the abstract letter detectors activated by a consonantal letter with diacritical signs are not the same as those activated by the base letter without diacritical signs (i.e., “*ñ*” does not activate “*n*”), but at the same time the base letter without the diacritical sign does activate its accented



counterpart (i.e., “*n*” activates “*ñ*”). This pattern poses some limits to the generality of the effects of visual similarity and it stresses the importance of the encoding of diacritical signs in the first moments of processing.

The present data also allow us to reinterpret the findings from Perea et al. (2016, 2018) in Arabic: the lack of an advantage of the visually similar replaced-consonant prime *صحفية* over the visually dissimilar replaced-consonant prime *سكفية* at activating the target word *صحفية* is not due to the singular role of diacritical signs in Arabic script, as Perea et al. (2016, 2018) proposed. A more parsimonious explanation is that the lack of visual similarity effects with primes containing letters with diacritical signs is a more general phenomenon: it occurs not only in Arabic, but also in the Latin-based orthographies with accented vowels (*tâper-TAPER* = *tuper-TAPER*; Chetail & Boursin, 2019; Domínguez & Cuetos, 2018) and with consonant letters (*moñeda-MONEDA* = *moseda-MONEDA*), as in the current experiment.

We acknowledge that the present experiment comes with several limitations. First, although most effects obtained with the masked priming paradigm have been extended to a sentence reading using, for instance, Rayner’s (1975) boundary, it is important to examine in future research the role of diacritics in a standard reading scenario (e.g., see Johnson, Perea, & Rayner, 2007, for evidence of transposed-letter similarity effects during reading; see also Marcet & Perea, 2018b, for evidence of visual similarity effects during reading)—ideally, this could be combined with a co-registration of the fixation-related potentials (see Degno et al., 2019). Second, Spanish orthography only contains one consonant letter with diacritical signs (i.e., *ñ*) and this may limit the generality of the findings—this would also be the case of other languages such as French (the only

diacritical consonant in French *is ç*). Further research is necessary to examine whether the present pattern of findings also hold in Latin-based languages that contain multiple consonants with diacritical signs (e.g., Czech contains eight consonants with diacritical signs: *č, d', ñ, ř, š, t', ý, ž*)—this may also be tested in other scripts that also employ diacritical signs (e.g., Thai, Japanese Kana, among others). Third, the diacritical sign of the letter *ñ* in Spanish is placed above its base letter (*n*). Given that the upper part of letters/words play a special role during word recognition and reading in Latin-based orthographies (e.g., Huey, 1908; Perea, 2012), it is important to further examine whether there are differences between the processing of diacritical letters and their counterparts when the diacritics are placed above or below their base letters (e.g., *č* vs. *ç*).

In sum, the dissociative pattern of priming effects depending on whether the visually similar substituted-letter contains diacritical signs (e.g. *moñeda-MONEDA* vs. *muneca-MUÑECA*) constrains the links between the “feature” and “letter” levels in models of written word recognition—note that the vast majority of European languages contain letters with diacritical signs. When implementing a computational model of word recognition (e.g., using the easyNet software; see Adelman, Gubian, & Davis, 2018) in languages with diacritical letters, it is necessary to include both the original (base) letters and their diacritical counterpart as separate units at the letter level. Furthermore, at least in Spanish, the base letters should be confusable with their accented counterpart during the first moments of word processing (i.e., *n* would provide some evidence consistent with the letter *ñ*: a visual similarity effect), but the letters with diacritical signs should not be confusable with their base letters (i.e., *ñ* would not activate *n*). Further research in orthographies with multiple diacritical consonants (e.g.,

Czech) is necessary to examine whether this pattern is modulated by the distinctiveness of the diacritical sign ~ in Spanish.

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Table 1. Mean Lexical Decision Times (ms) and Accuracy (proportion) for Word and Nonword Targets in Each Condition

Prime Type	Target without diacritics (MONEDA)	Target without diacritics (MUÑECA)
Word Targets		
Identity	548 (0.920)	556 (0.909)
Visually Similar	567 (0.912)	545 (0.900)
Visually Dissimilar	568 (0.904)	565 (0.897)
Nonword Targets		
Identity	654 (0.876)	666 (0.867)
Visually Similar	657 (0.893)	672 (0.851)
Visually Dissimilar	672 (0.904)	670 (0.852)

## Footnotes

1. In Arabic, there are also supplementary diacritical signs that correspond to short vowels and are usually omitted in print (see Lallier et al., 2018, for a comparison of non-vowelized vs. fully vowelized Arabic).

2. An advantage of this approach over linear mixed models is that it allows researchers to use the raw, untransformed RTs. Bear in mind that linear mixed models require a normal distribution in the data, and the use of non-linear transformations (e.g.,  $-1000/RT$ ) to reduce the skew of RT distributions may create some interpretative difficulties (see Lo & Andrews, 2015, for discussion).

3. A post hoc analysis revealed that only 57% of participants showed an advantage of the visually similar condition over the identity condition (see Perea, Duñabeitia, & Carreiras, 2008, for a similar pattern when using primes composed of digit-like letters [*M4T3R14L*] as visually similar primes). Thus, we prefer to remain cautious about this small, unexpected non-significant advantage of the visually similar condition.

## Appendix. List of words and pseudowords in the experiment

The stimuli are presented as quadruplets: identity prime, visually similar prime, visually dissimilar prime, and TARGET

**Word targets:** montañero, montanero, montasero, MONTAÑERO; señal, senal, sesal, SEÑAL; pestañas, pestanas, pestasas, PESTAÑAS; castañas, castanas, castasas, CASTAÑAS; tamaño, tamano, tamaso, TAMAÑO; pequeño, pequeno, pequeso, PEQUEÑO; diseñador, disenador, disesador, DISEÑADOR; añadir, anadir, asadir, AÑADIR; leñador, lenador, lesador, LEÑADOR; diseño, diseno, diseso, DISEÑO; gruñón, grunón, grusón, GRUÑÓN; meñique, menique, mesique, MEÑIQUE; bañera, banera, basera, BAÑERA; albañil, albanil, albasil, ALBAÑIL; dañar, danar, dasar, DAÑAR; ermitaño, ermitano, ermitaso, ERMITAÑO; coñac, conac, cosac, COÑAC; compañero, companero, compasero, COMPAÑERO; champiñón, champinón, champisón, CHAMPIÑÓN; hazaña, hazana, hazasa, HAZAÑA; cabaña, cabana, cabasa, CABAÑA; engañar, enganar, engasar, ENGAÑAR; rebaño, rebano, rebaso, REBAÑO; contraseña, contrasena, contrasesa, CONTRASEÑA; cuñado, cunado, cusado, CUÑADO; risueño, risueno, risueso, RISUEÑO; extrañar, extranar, extrasar, EXTRAÑAR; ceñido, cenido, cesido, CEÑIDO; extraño, extrano, extraso, EXTRAÑO; señora, senora, sesora, SEÑORA; compañía, companía, compasía, COMPAÑÍA; telaraña, telarana, telarasa, TELARAÑA; enseñar, enseñar, ensesar, ENSEÑAR; puñetazo, punetazo, pusetazo, PUÑETAZO; puñado, punado, pusado, PUÑADO; niñera, ninera, niserá, NIÑERA; cumpleaños, cumpleanos, cumpleasos, CUMPLEAÑOS; riñón, rinón, risón, RIÑÓN; otoño, otono, otoso, OTOÑO; brasileño, brasileno, brasilesó, BRASILEÑO; rasguño, rasguso, RASGUÑO; migraña, migrana, migrasa, MIGRAÑA; cigüeña, cigüena, cigüesa, CIGÜEÑA; buñuelo, bunuelo, busuelo, BUÑUELO; empeño, empeso, EMPEÑO; pañuelo, panuelo, pasuelo, PAÑUELO; piraña, pirana, piraña, PIRAÑA; tacaño, tacano, tacaso, TACAÑO; preñada, prenatal, presada, PREÑADA; viñedo, vinedo, visado, VIÑEDO; ruiseñor, ruisenor, ruisesor, RUISEÑOR; lasaña, lasana, lasasa, LASAÑA; acompañar, acompañar, acompasar, ACOMPAÑAR; muñeca, muneca, museca, MUÑECA; dueño, dueno, dueso, DUEÑO; cañería, canería, casería, CAÑERÍA; mañana, manana, masana, MAÑANA; sureño, sureno, sureso, SUREÑO; navideño, navideno, navideso, NAVIDEÑO; español, espanol, espasol, ESPAÑOL; cariño, carino, cariso, CARÍÑO; araña, arana, arasa, ARAÑA; puñal, punal, pusal, PUÑAL; carroña, carrona, carrosa, CARROÑA; entrañable, entranable, entrasable, ENTRAÑABLE; desempeño, desempeño, desempeño, DESEMPEÑO; semifinal, semifinál, semifisal, SEMIFINAL; honor, hoñor, hosor, HONOR; doctrina, doctriña, doctrisa, DOCTRINA; remolino, remoliño, remoliso, REMOLINO; bonito, boñito, bosito, BONITO; hermano, hermaño, hermaso, HERMANO; municipal, muñicipal, musicipal, MUNICIPAL; vacuna, vacuña, vacusa, VACUNA; tribuna, tribuña, tribusa, TRIBUNA; senado, señado, sesado, SENADO; laguna, laguña, lagusa, LAGUNA; villano, villaño, villaso, VILLANO; llenar, lleñar, llesar, LLENAR; hormona, hormoña, hermosa, HORMONA; avena, aveña, avesa, AVENA; enamorar, eñamorar, esamorar, ENAMORAR; panel, pañel, pasel, PANEL; camioneta, camioñeta, camioseta, CAMIONETA; purpurina, purpuriña, purpurisa, PURPURINA; molino, moliño, moliso, MOLINO; casino,

casiño, casiso, CASINO; oxígeno, oxígeño, oxígeso, OXÍGENO; harina, hariña, harisa, HARINA; calcetines, calcetiñes, calcetises, CALCETINES; género, géñero, gésero, GÉNERO; coronar, coroñar, corosar, CORONAR; genética, geñética, gesética, GENÉTICA; clonar, cloñar, closar, CLONAR; persona, persoña, persosa, PERSONA; minuto, miñuto, misuto, MINUTO; teléfono, teléfoño, teléfoso, TELÉFONO; luminoso, lumiñoso, lumisoso, LUMINOSO; oficina, oficiña, oficisa, OFICINA; limonada, limoñada, limosada, LIMONADA; sirena, sireña, siresa, SIRENA; moneda, moñeda, moseda, MONEDA; matrimonio, matrimoñio, matrimosio, MATRIMONIO; enero, eñero, esero, ENERO; túnel, túñel, túsél, TÚNEL; feminista, femiñista, femisista, FEMINISTA; monitor, moñitor, mositor, MONITOR; plátano, plátaño, plátaso, PLÁTANO; reponer, repoñer, reposer, REPONER; matrona, matroña, matrosa, MATRONA; moreno, moreño, moreso, MORENO; propina, propiña, propisa, PROPINA; iguana, iguaña, iguasa, IGUANA; trueno, trueño, trueso, TRUENO; vinagre, viñagre, visagre, VINAGRE; sábana, sábaña, sábasas, SÁBANA; vitamina, vitamiña, vitamisa, VITAMINA; aduana, aduaña, aduasa, ADUANA; bienestar, bieñestar, biesestar, BIENESTAR; escena, esceña, escesa, ESCENA; arena, areña, aresa, ARENA; abanico, abañico, abasico, ABANICO; camino, camiño, camiso, CAMINO; leona, leoña, leosa, LEONA; colonial, coloñial, colosial, COLONIAL; cocinar, cociñar, cocisar, COCINAR; semana, semaña, semasa, SEMANA; lunes, luñes, luses, LUNES; sauna, sauña, sausa, SAUNA; avioneta, avioñeta, avioseta, AVIONETA; fotogénico, fotogéñico, fotogésico, FOTOGÉNICO; aceitunas, aceituñas, aceitusas, ACEITUNAS

**Nonword targets:** mompiñero, mompinero, mompiser, MOMPIÑERO; teñol, tenol, tesol, TEÑOL; pesceñas, pescenas, pescesas, PESCEÑAS; cascina, cascisa, CASCIÑA; tasiño, tasino, tasiso, TASIÑO; pefioño, pefiono, pefioso, PEFIOÑO; misiñador, misinador, misisador, MISIÑADOR; añider, anider, asider, AÑIDER; veñifor, venifor, vesifor, VEÑIFOR; simeño, simeno, simeso, SIMEÑO; pluñón, plunón, plusón, PLUÑÓN; señoque, senoque, sesoque, SEÑOQUE; tuñera, tusera, TUÑERA; arpiñol, arpinol, arpisol, ARPIÑOL; hañar, hanar, hasar, HAÑAR; expetaño, expetano, expetaso, EXPETAÑO; viñac, vinac, visac, VIÑAC; cosmañera, cosmanera, cosmasera, COSMAÑERA; chusdiñón, chusdinón, chusdisón, CHUSDIÑÓN; nafaña, nafana, nafasa, NAFANA; cepiña, cepina, cepisa, CEPIÑA; esviñar, esvinar, esvisar, ESVIÑAR; gepiño, gepino, gepiso, GEPIÑO; conflageño, conflageno, conflageso, CONFLAGEÑO; ciñuda, cinuda, cisuda, CIÑUDA; simuaño, simuano, simuaso, SIMUAÑO; embriñar, embrinar, embrisar, EMBRIÑAR; ciñafo, cinafo, cisafo, CIÑAFO; embriño, embrino, embriso, EMBRIÑO; vuñera, vunera, vusera, VUÑERA; cosgañía, cosganía, cosgasía, COSGAÑÍA; bemacaña, bemacana, bemacasa, BEMACAÑA; empiñor, empinor, empisor, EMPIÑOR; muñitezo, munitezo, musitezo, MUÑITEZO; piñido, pinido, pisido, PIÑIDO; diñeto, dineto, diseto, DIÑETO; cilcheaños, cilcheanos, cilcheasos, CILCHEAÑOS; bañón, banón, basón, BAÑÓN; oxaño, oxano, oxaso, OXAÑO; framigeño, framigeno, framigeso, FRAMIGEÑO; sisfuño, sisfuno, sisfuso, SISFUÑO; pifliña, piflina, piflisa, PIFLIÑA; logüiña, logüina, logüisa, LOGÜIÑA; luñuilo, lunuilo, lusuilo, LUÑUILO; egjeño, egjeno, egjeso, EGJEÑO; sañiolo, saniolo, sasiolo, SAÑIOLO; bugaña, bugana, bugasa, BUGAÑA; tariño, tarino, tariso, TARIÑO; triñeda, trineda, triseda, TRIÑEDA; veñico, venico, vesico, VEÑICO; riabeñor, riabenor, riabesor, RIABEÑOR; tuvoña, tuvona, tuvosa, TUVOÑA; amaspañar, amaspanar, amaspasar, AMASPAÑAR; duñesa, dunesa, dusesa, DUÑESA; gauño, gauno, gauso, GAUÑO; ciñagía, cinagía, cisagía, CIÑAGÍA; pañila, panila, pasila, PAÑILA; dujeño, dujeno,

dujeso, DUJEÑO; gadedeño, gadedeno, gadedeso, GADEDEÑO; esciñel, escinel, escisel, ESCIÑEL; caceño, caceno, caceso, CACEÑO; aciña, acina, acisa, ACIÑA; muñol, munol, musol, MUÑOL; cilleña, cillena, cillesa, CILLEÑA; esgreñadre, esgrenadre, esgresadre, ESGREÑADRE; desabseño, desabseno, desabseso, DESABSEÑO; mesevinal, meseviñal, mesevisal, MESEVINAL; gonel, goñel, gosel, GONEL; siptrino, siptriño, siptriso, SIPTRINO; pemonica, pemoñica, pemosica, PEMONICA; vonato, voñato, vosato, VONATO; fervino, ferviño, ferviso, FERVINO; runecibal, ruñecibal, rusecibal, RUNECIBAL; tavina, taviña, tavisal, TAVINA; clicuna, clicuña, clicusa, CLICUNA; menide, meñide, meside, MENIDE; pogena, pogeña, pogesa, POGENA; fitrino, fitriño, fitriso, FITRINO; blenar, bleñar, blesar, BLENAR; cerlona, cerloña, cerlosa, CERLONA; adeno, adeño, adeso, ADENO; anabopar, añabopar, asabopar, ANABOPAR; manil, mañil, masil, MANIL; canauresa, cañauresa, casauresa, CANAURESA; piedurina, pieduriña, piedurisa, PIEDURINA; socino, sociño, sociso, SOCINO; cicano, cicaño, cicaso, CICANO; ixédeno, ixédeso, IXÉDENO; balana, balaña, balasa, BALANA; caldetunes, caldetuñes, caldetuses, CALDETUNES; cíneva, cíñeva, císeva, CÍNEVA; ceconar, cecoñar, cecosar, CECONAR; benítira, beñítira, besítira, BENÍTIRA; blinar, bliñar, blisar, BLINAR; paslona, pasloña, paslosa, PASLONA; sinuro, siñuro, sisuro, SINURO; helíbono, helíboño, helíboso, HELÍBONO; burenoso, bureñoso, buresoso, BURENOSO; odenica, odeñica, odesica, ODENICA; binolado, biñolado, bisolado, BINOLADO; ticeno, ticeño, ticeso, TICENO; sonuva, soñuva, sosuva, SONUVA; mifledonio, mifledoño, mifledosio, MIFLEDONIO; erena, ereña, eresa, ERENA; súnil, súñil, súsil, SÚNIL; gesenista, geseñista, gesesista, GESENISTA; ponatol, poñatol, posatol, PONATOL; blácino, bláciño, bláciso, BLÁCINO; dovonir, dovoñir, dovosir, DOVONIR; saflona, safloña, saflosa, SAFLONA; soreno, soreño, soreso, SORENO; trubana, trubaña, trubasa, TRUBANA; ivaena, ivaeña, ivaesa, IVAENA; chaeno, chaeño, chaeso, CHAENO; bonicre, boñicre, bosicre, BONICRE; tavina, taviña, tavisal, TAVINA; lumadina, lumadiña, lumadisa, LUMADINA; oguona, oguoña, oguosa, OGUONA; tuenostar, tueñostar, tuesostar, TUENOSTAR; esvuna, esvuña, esvusa, ESVUNA; useno, useño, uso, USENO; amacina, amaciña, amacisa, AMACINA; cacina, caciña, cacisa, CACINA; beono, beoño, beoso, BEONO; canotiel, cañotiel, CANOTIEL; covanar, covañar, covasar, COVANAR; mecina, meciña, mecisa, MECINA; bunis, buñis, busis, BUNIS; taena, taeña, taesa, TAENA; amoinesa, amoiñesa, amoisesa, AMOINESA; fosofínico, fosofíñico, fosofísico, FOSOFÍNICO; amoilenas, amoileñas, amoilesas, AMOILENAS