Psicológica (2018), 39, 198-222
doi: 10.2478/psicolj-2018-0009

Priming effects in the recognition of simple and complex words and pseudowords

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Whether morphological processing of complex words occurs beyond orthographic processing is a matter of intense debate. In this study, morphological processing is examined by presenting complex words (*brujería* -> *brujo* –witchcraft -> witch), as well as simple (brujaña->brujo) and complex pseudowords (brujanza ->brujo), as primes in three masked lexical decision tasks. In the first experiment, the three experimental conditions facilitated word recognition in comparison to the control condition, but no differences emerged between them. Given the importance of the surface frequency effect observed, a second experiment was conducted. The results fully replicate those observed in the first one, but this time with low frequency targets. In the third experiment, vowels were removed from the stems of primes to reduce the orthographic overlap between primes and targets and, therefore, the influence of the embedded stem effect. The results show facilitative effects only for complex words. However, paired comparisons show no differences between experimental conditions. The overall results show the central role played by the processing of stems in visual word recognition and are explained in terms of current models of morphological processing.

In the field of morphological processing, there are few things on which the literature agrees (see Amenta & Crepaldi, 2012 for a review). One of the most controversial issues in this respect is the relative role of semantics and orthography in morphological decomposition. The evidence is inconclusive and, therefore, more research is clearly needed to shed light on this essential theoretical issue.

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[*]**Acknowledgements**: We acknowledge the helpful comments of Dr. Joana Acha as well as the relevant queries raised by reviewers and editor to a previous version of this manuscript.
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Experimental studies conducted to examine this issue tend to carry out masked priming lexical decision tasks, typically with 50 ms prime presentation, in which control –unrelated conditions (breaker-> lightness) are compared to: a) semantically transparent conditions (walker -> walk), b) semantically opaque conditions (corner -> corn), and, c) orthographic conditions (brothel -> broth) with no suffix in the prime. The rationale for this design is clear: if morphological processing occurs regardless of semantics, semantically opaque and transparent conditions should show similar facilitative effects regarding the control condition. By contrast, if morphological decomposition of complex words occurs when taking semantic content into account, semantically transparent conditions should show a significant facilitative effect as compared to opaque conditions. In the case of orthographic conditions, the rationale is similar. If morphological decomposition has an orthographic nature, morphological and orthographic conditions should be alike, showing similar facilitative effects. On the contrary, if morphological decomposition occurs beyond orthography, then morphological conditions should show more facilitation than the orthographic condition. The design is straightforward and shows that the orthographic condition, unlike the transparent one, does not produce priming -with the results for the opaque condition being more controversial (see Rastle & Davis, 2008 for a review).

Another approach to study this issue is by making use of pseudowords as primes. The rationale is similar but the use of pseudowords presents certain advantages, as suggested by Hasenäcker, Beyersmann and Schroeder (2016). By using complex and simple pseudowords, researchers can better control for relevant variables -among others those related to orthography. For instance, researchers can control for word-ending frequencies of suffixed and simple stimuli much better than by using real words as we will discuss later.

Longtin and Meunier (2005) were the first to employ pseudowords as primes in a masked priming study assessing morphological processing. These authors, in a lexical decision task, presented for 47 ms primes consisting of complex pseudowords (*rapidifier* "quickify") as well as real complex words, and observed that complex pseudowords produced similar facilitative effects to real complex words. In the same study, Longtin and Meunier (2005) observed that the mere orthographic overlap between primes and targets did not produce facilitation i.e., pseudowords with real stems but non-morphemic endings (simple pseudowords) did not produce facilitation in comparison to the unrelated condition, that is (catatropherge - > catastrophe [when erge is not a suffix] produced the same response latencies as astrologique - > catastrophe. The lack of significance for the orthographic condition found by Longtin and Meunier (2005), however, contradicts other well-conducted studies. For example, Hasenäcker et al., (2016), mimicked the design of Longtin and Meunier (2005) in a sample of German adults and obtained contrasting results. These authors presented complex pseudowords (kleidtum -> kleid), complex words (kleidchen-> kleid) and simple pseudowords (kleidekt-> kleid) as primes, as well as unrelated controls (träumerei -> kleid), finding facilitation for simple pseudoword primes compared to controls, although this effect was significantly lower than in the case of complex stimuli. Therefore, unlike Meunier and Longtin, the simple pseudowords generated significant priming effects, albeit of less magnitude than complex stimuli. Furthermore, making use of the same design, Morris, Porter, Grainger and Holcomb (2010), in the English language, found another pattern of results. In particular, they found that the orthographic condition (flexint->flex) produced facilitation of the same magnitude as that of complex stimuli –words (flexible->flex) and pseudowords (flexify -> flex). Lastly, Giraudo and Voga (2016), in an experimental series, observed that complex words facilitated target recognition while complex pseudowords did not (experiment 4), and also that simple and complex pseudowords can prime words if no complex words are presented in the experiment (experiment 5). See Table 1 for an overview of the findings reviewed.

Table 1. Summary of results for complex words and pseudowords as well as for simple pseudowords in the literature

		Effect		
Study	**Language**	**Complex Word**	**Complex Pseudow.**	**Simple Pseudow.**
Longtin et al (2005)	French	facilitation	facilitation	null
Morris et al., (2010)	English	facilitation	facilitation	facilitation
Hasenäcker et al (2016)	German	+ facilitation	+ facilitation	facilitation
Giraudo et al (2016) Exp. 4	French	facilitation	null	NA
Giraudo et al (2016) Exp. 5	French	NA	facilitation	facilitation

There exist different possibilities to explain why such divergent results have been observed, of which we highlight the lack of a proper control over word-ending frequencies (WEF hereafter). As can be seen in Table 2, the studies mentioned do not match the WEF of the stimuli, and non-morphemic endings are of lower frequency than suffixed endings. A derivational suffix, similarly to a non-morphemic ending, is after all, a chain of letters that appears recurrently in the language. However, suffixes are attached to stems (papel-era “paper bin”, papel-ería “stationery”) while non-morphemic endings are not (maña “ability”, caña “cane”). From our perspective, the WEF can be considered a confounding variable with an unknown influence in previous research.

Table 2. Control for word ending frequencies in different studies with words and pseudowords as primes

Study	Control
Longting & Meunier (2005)	Orthographic endings appearing in at least five existing French words
Morris et al., (2010)	In both experiments “Suffixes and nonsuffixes differed in type frequency and productivity, but did not differ in token frequency” –despite enormous differences (831,19 vs.46,385 in the first and 66,823 vs. 37,089 in the second experiment)
Hasenäcker et al., (2016)	Suffixes were of high normalized type frequency (M = 1281) and low normalized type frequency (M = 173). Likewise, non-morphemic endings were of high type frequency (M = 599) and low type frequency (M = 141)
Beyersman et al., (2014)	The mean word final position frequency for low-frequency suffixes was 109.8 and was 153.8 for high-frequency suffixes. The mean word final position frequency for low-frequency non-morphemic endings was 167.8 and was 4.4 non-morphemic endings
Giraudo et al., (2016)	No mention at all

Differences between morphemic and non-morphemic word endings are important and can be exploited to further assess morphological processing. For instance, Grainger and Beyersmann (2017) have recently postulated that morphological priming effects can be explained in terms of an embedded stem effect. In this approach, morphological decomposition is driven by the stems being presented in primes and targets. The role for suffixes is secondary to stems and no influence from suffixes is expected when stems are at play. From this perspective, the same results for complex words and pseudowords and simple pseudowords are expected given the fact that in all conditions primes and targets share the stems. However, as shown in table 1, the results do not always support this view. To test the findings of Grainger and Beyersmann (2017), we believe the first step must be the comparison of all experimental conditions matching word ending frequencies. By doing so, any possible difference between complex and simple words may not be explained in terms of frequency, but in terms of an opposition between suffixes and non-morphemic endings, which would be of great interest at theoretical level.

This study presents three experiments to assess whether complex words and pseudowords, as well as simple pseudowords, prime their bases and whether the effects are similar or different from each other. This series is carried out in Spanish, an interesting language given its extremely shallow orthography (in contrast to English and French) and its highly productive derivational system. Previous evidence in Spanish has shown an important role for suffixes in word recognition (Duñabeitia, Perea & Carreiras, 2008; Lázaro & Sainz, 2012; Lázaro, Illera & Sainz, 2015), but this evidence was not obtained in the context of pseudoword priming. With the overall existing evidence, assumptions about the role of morphology within this experimental paradigm cannot be straightforward because i) totally divergent results have been obtained in previous studies; ii) the previous studies were carried out in languages other than Spanish –with different morphological and orthographic features; and iii) other studies did not control for the WEF, a potentially confounding variable.

EXPERIMENT 1

In the first experiment, we carry out a lexical decision task with a masked prime of 50 ms in which complex words (brujería -> brujo “witch”), complex pseudowords (brujanza -> brujo), and simple pseudowords (brujaña) prime their bases. Let us note that the word-ending "aña", although relatively frequent in Spanish, does not constitute a real affix. This control is the cornerstone of this experiment.

Although previous evidence has shown similar priming effects in Spanish for complex words and pseudowords –stimuli with transposed letters (Beyersman, Duñabeitia, Carreiras, Colheart & Castles, 2013), to the best of our knowledge, this is the first time in this language that stems are primed by complex words and pseudowords they form part of, as well as by pseudowords with orthographic overlap.

METHOD

Participants. A total of 34 students (30 women) aged between 20 and 23 from the Complutense University of Madrid participated in the experiment in exchange for course credits. All participants had normal or corrected-to-normal vision.

Stimuli. Four different experimental lists were created to present 60 stems to participants. As already mentioned, stems were primed by complex words, complex pseudowords, simple pseudowords and unrelated stimuli. Critically, all three experimental conditions were controlled in terms of orthographic and suffix frequency. To control for the suffix frequency, the morphological database of Lázaro, Acha, Illera and Sainz (2016) was employed. Fortunately, there are some sufficiently frequent orthographic endings to match for suffix frequency, (*España* Spain, *araña* spider, *patraña* humbug, *calaña* ilk etc., end in *aña,* which is not a suffix but is certainly frequent). To calculate frequencies of non-morphological word endings the Espaldata base (Duchon, Perea, Sebastián-Gallés, Martí & Carreiras, 2013) was downloaded and the words ordered in reverse order –starting from the last letter to the first, allowing us to easily locate and calculate frequencies of certain orthographic endings. With this approach, we ensure that any difference between suffixed and non-suffixed stimuli is not due to word-ending frequencies. Other variables such as number of letters of primes and the orthographic overlap between primes and targets were also controlled for (see Table 3). Mean frequency of targets is 47 appearances per million.

Table 3. Descriptive statistics of the experiment 1

PrimeType	(Token) Ending freq.	Letter lenght	Letters overlaped	N	Frequency per million
Suffixed Word	562 (101; 197-1079)	8.5 (.3; 7-11)	5.6 (.9; 4-7)	.1 (0; 0-2)	47.89 (60;1-175)
Complex Pseud.	563 (193; 151-1698)	8.4 (.3; 7-10)	5.6 (.9; 4-7)	0	
Simple Pseud.	547 (196, 214-906)	8.4 (.2; 7-11)	5.6 (.9; 4-7)	0	

Note: SD and range in parentheses

Another set of 60 pseudowords was created and presented to make the lexical decision task possible. As in the case of words, simple pseudowords (*solto*) were primed by words with orthographic overlap and a suffix (*soltero*, single), pseudowords with orthographic overlap and a suffix (*soltible*), pseudowords with orthographic overlap without suffix (*soltama*) and an unrelated pseudoword prime (*retroba*). See Annex 1 for stimuli.

Procedure. We conducted a standard masked priming lexical decision task. Participants were asked to judge as quickly as possible whether the letter string presented was a real word or not. When the letter string was a real word, participants were required to press the "m" key on the keyboard; when the letter string was not a real word, participants were required to press the "z" key. Participants sat about 70 cm. from a personal computer screen in a quiet room. The screen showed a series of hash marks (#######) for 500 ms, followed by the prime presentation in lower-case "courier new" 22 self-spaced font size letters for 50 ms, (3 ticks of 16.68 ms in a 60 Hz screen) and the target stimuli in capital letters for two seconds or until the response was made. Participants were not informed about the presentation of primes. DMDX display software (Forster & Forster, 2003) was used for the stimuli presentation.

Results. The mean global error rate was low: 2.6% for simple words, 2.1% for complex words, 2.1% for complex pseudowords and 2.6% for controls. All the participants' error rates were below 20%, and no words had error rates above 20%, so they were all included (34 subjects / 60 items) in the analysis. None of the RTs were below 200ms. RTs greater than 2.5 standard deviations in absolute values from the subject means were removed for each subject separately (2.3% of the data) in order to reduce the effect of outliers in the analysis.

The RT analyses were performed using linear mixed-effects modeling and regular maximum-likelihood estimation, as implemented in *lme4* 1.1–10 package (Bates, Maechler, Bolker and Walker, 2015) with inverse RTs (*invRT*, -1000/RT) as a dependent variable to meet the assumption of normality and 3 fixed effects: *PrimeType* with four levels (*complex word (cw), complex pseudoword (cp), simple pseudoword (sp), control (ct)*), *target log-frequency* (*LogFreq*) as a covariate and the interaction between them, *PrimeType*LogFreq*. As the maximal-random effects model (Barr, Levy, Scheepers, & Tily, 2013) did not converge, the model included random intercepts for subjects and items and random slopes for subjects. The preliminary nested model comparison analysis indicated that *PrimeType*LogFreq* did not reach significance, although it yielded a close value, $\chi^2\ (3) = 7.0346,\ p = .078$. The final model was (in *lme4* syntax):

$$invRT \sim PrimeType + LogFreq + (PrimeType|Subject) + (1|Item).$$

The model was refitted after the trimming of outliers with standardized residuals greater than |3|. This led to the removal of 2 data points. There were thus 1920 data points for the analysis.

The nested model chi-square test of the *PrimeType* main effect was significant, χ^2 *(3) = 25.55, p<.0001*, as was the *LogFreq* main effect, χ^2 *(3) = 16.687, p<.0001*. Post-hoc pairwise contrasts computed using the *multcomp* package (Hothorn et al., 2008) with Bonferroni adjustments of *p-values* for *PrimeType* indicated that the three critical priming conditions differed significantly with respect to the non-related control condition (*cw: t=5.33, p<.001; cp: t=5.36, p<.001; sp: t=4.161, p=.001*), but no differences emerged between experimental conditions (*all |t| < 2)*. The mean response times were 614 ms for the control primes, 581 ms for the complex word primes, 582 for the complex pseudoword primes and 588 for the simple pseudoword primes. The error data were analyzed using logit mixed model (Jaeger, 2008) but no significant results were obtained.

Discussion. The results of mean response times show priming effects for all conditions. Moreover, the priming effect observed for simple pseudowords was not significantly different from that of complex stimuli – words and pseudowords. This result replicates that obtained by Morris et al., (2010) in English targets. As described in the introduction section, previous evidence shows no conclusive pattern of results. Our data fail to support a differential role of suffixes and non-morphemic endings, in contrast to the results of other related studies conducted in Spanish. However, our results support the findings of Grainger and Beyersman (2017), where the role of suffixes is secondary to stems. However, the significant target frequency effect (and the marginally significant interaction between surface frequency and primetype), makes it possible to argue that the surface frequency of targets played a role by which recognition of frequent words did not benefit from the morphological decomposition of primes. In other words, the holistic recognition of frequent words could explain the absence of morphological effects (despite the evidence showing the same priming effects for frequent and infrequent words primed by real words -McCormick, Brysbaert & Rastle, 2009). Following this rationale, the difference between experimental conditions may only be observed when low frequent targets are used. Because of the lack of factorial control over this variable and the impossibility of an appropriate post hoc manipulation, this hypothesis should be specifically tested in a new experiment.

EXPERIMENT 2

This second experiment replicated the first one but making use of target words of low frequency. As explained above, to support the embedded stem priming effect as described by Grainger and Beyersman (2017), it is first necessary to rule out the possibility of suffixes having played a role for low frequency words but not for high frequency words, thus precluding the emergence of differences between complex and simple stimuli. By making use only of low frequency words, we expect to obtain data to further shed light on this issue.

The control over WEF as well as over other key variables was maintained as in the first experiment (see Table 4).

METHOD

Participants. A total of 32 students (27 women) aged between 21 and 27 from the Complutense University of Madrid participated in the experiment in exchange for course credits. All participants had normal or corrected-to-normal vision and did not participate in the first experiment.

Stimuli. As in the first experiment, four different experimental lists were created to present 60 stems to participants. Low-frequency targets were primed by complex words, complex pseudowords, simple pseudowords and unrelated stimuli. The same controls as in the first experiment were used. See Annex 2 for stimuli. Mean frequency of targets is 5.4 appearances per million.

Table 4. Descriptive statistics of the experiment 2

PrimeType	(Token) Ending frequencies	Letter lenght	Letters overlaped	N	Frequency per million
SuffixedWord	666 (55; 197-1299)	8.7 (.2; 7-11)	5.7 (.9; 4-7)	0.1 (0; 0-2)	5.4 (4.1; .2-15)
ComplexPseud.	665 (99; 121-1698)	8.6 (.4; 7-11)	5.6 (.9; 4-7)	0	
SimplePseud.	666 (96; 485-906)	8.6 (.3; 7-11)	5.5 (.9; 4-7)	0	

Note: SD and range in parentheses

Another set of 60 pseudowords was created, mimicking the ones in the first experiment.

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

Results. We followed the same procedure for the analysis as in Experiment 1. This time, 3 subjects with more than 20% of errors and 2 items [*EXCELSO* (excellent), *CALUMNIA* (slander)] with more than 40% of errors were removed from the analysis. The mean global error rate was 1.3% for complex words, .7% for complex pseudowords, .5% for simple pseudowords and .7% for controls. None of the RTs were below 200ms. Data above 2.5 standard deviations from the mean RT were trimmed, leading to the removal of 2.5% of the data.

Due to the control of the frequency of the target words, the preliminary nested model comparison analysis indicated that neither the *LogFreq* nor the *PrimeType*LogFreq* interaction was significant, χ^2 *(1) =.35, p=.55;* χ^2 *(3) =.91, p=.821,* so they were dropped from the final model. The final model was:

$$invRT \sim PrimeType + (PrimeType|Subject) + (1|Item)$$

It was refitted after the trimming of outliers with standardized residuals greater than |3|. This led to the removal of 8 data points. There were thus 1582 data points for the analysis.

The nested model chi-square test of the *PrimeType* main effect was significant, χ^2 *(3) = 14.747, p=.002.* Post-hoc pairwise contrasts indicated that the three critical priming conditions differed significantly with respect to the non-related control condition (*cw: t=2.957, p=.0318; cp: t=3.343, p<.0112; sp: t=3.919, p=.0022*). Again, none of the comparisons between the three critical priming conditions was significant (*all |t| < 2).* The mean response times were 712 ms for the controls, 686 ms for the complex word primes, 680 for the complex pseudoword primes and 680 for the simple pseudoword primes. Error analysis showed no significant effects.

Discussion. The results of this second experiment show longer reaction times than in the first experiment (≈ 100 ms), as expected, given the lower frequencies of the target words. However, these results replicate those of Experiment 1 by showing significant facilitative effects for all three experimental conditions. This means that the frequency of targets played no role in the first experiment and that therefore the hypothesis by which differences between complex and simple stimuli appear in low frequent stimuli is not supported. The significant facilitative effects for simple and complex pseudowords in Experiments 1 and 2 fits perfectly with the previously mentioned findings of Beyersman and Grainger (2017). From this theoretical perspective, the stem effect can by itself account for the effect observed in the present study. An interesting point in relation to this account is that it does not deny a role for suffixes although it is considered secondary to the process of stems. In fact, it is stated that when the processing of word activation is hindered then suffixes can be decisive to word processing. An interesting way to further assess this prediction is therefore to hinder stem processing, but how? A possibility is to follow the procedure of Duñabeitia and Carreiras (2011) in which vowels were removed from the primes to reduce the orthographic overlap between primes and targets. In this study, it was shown that the facilitative effects reported with standard primes persisted with primes in which vowels were substituted by hyphens. However, by making use of these primes, we expected to reduce the influence of the stem embedded in primes and targets and to generate an experimental context in which the effects associated to word ending lexical constraints could emerge.

EXPERIMENT 3

In this experiment, we assessed the word and pseudoword priming effects when the vowels were removed from the stems and substituted by hyphens.

METHOD

Participants. A total of 50 students (42 women) aged between 20 and 31 from the Complutense University of Madrid participated in the experiment in exchange for course credits. All participants had normal or corrected-to-normal vision. None of them had participated in the previous experiments.

Stimuli. This time, the vowels were removed from the stems of the primes –but not from suffixes. The overlap between primes and targets therefore decreased, but was still the same for all conditions. Thus, possible differences between conditions could not be explained in terms of different levels of overlap. The stimuli are shown in Annex 3.

Procedure. The same procedure as in the other experiments was followed.

Results. Four subjects with more than 20% of errors and one item with more than 40% of errors [EXCELSO (excellent)] were removed from the analysis. The mean global error rate was 1.9% for complex words, 2% for complex pseudowords, 2% for simple pseudowords and 2.7% for controls. None of the RTs was below 200ms. Data above 2.5 standard deviations from the mean RT were trimmed leading to the removal of 2.7% of the data.

LogFreq and *PrimeType*LogFreq* interaction was not significant, χ^2 *(1) =.12, p=.71;* χ^2 *(3) =3.58, p=.31,* so they were dropped from the model. The final model was the same as in experiment 2 and 3:

$$invRT \sim PrimeType + (PrimeType|Subject) + (1|Item).$$

The model was refitted after the trimming of outliers with standardized residuals greater than |3|. This led to the removal of 6 data points. There were thus 2488 data points for the analysis.

The nested model chi-square test of the *PrimeType* main effect was significant, χ^2 *(3) = 9.15, p=.02.* Post-hoc pairwise contrasts indicated that only the *complex word* priming condition differed significantly with respect to the non-related control condition (*cw: t=2.93, p<.02; cp: t=2.14, p<.1; sp: t=1.629, p=.6*). Once again, none of the comparisons between the three critical priming conditions was significant (*all |t| < 2)*. The mean response times were 654 ms for the controls, 639 ms for the complex words, 642 for the complex pseudowords and 645 for the simple nonwords. Error analysis showed no significant effects.

Discussion. The results show that by reducing the orthographic overlap between primes and targets, the priming effects decrease. In the first two experiments, the benefit of the experimental conditions were of ≈ 30 ms with respect to controls, while in this third experiment the benefit decreased to ≈ 15 ms (see table 5). This was expected, given the manipulation over primes and the consequent reduction of overlap between primes and targets. However, the reduction of the benefit from the embedded stem in primes and targets was not just expected but also desired, since the aim was to decrease the influence of the stem effect to assess whether, in this experimental context, word endings -morphemic or non-morphemic- would acquire a more salient role. Using this design, we observed that complex words were the only ones showing significant differences with respect to controls, but there were no differences in the planned comparisons with respect to the other two experimental conditions. In fact, the effect size was similar for all experimental conditions and therefore it is not clear whether the results really support "cognitive" biased significant differences between conditions, or whether the significant difference could be attributed to any uncontrolled effect. Under this assumption, the results of the third experiment cannot speak in favor of a morphological processing of complex stimuli.

Table 5. Mean RTs and error rates (back-transformed in ms and %) for *Prime Type* for the three experiments.

PrimeType	Control	Complex Word	Complex Nonword	Simple Nonword
EXP 1.	614 (2.6)	581 (1.9)	582 (2.1)	588 (2.2)
EXP 2.	712 (0.7)	686 (1.3)	680 (0.7)	680 (0.5)
EXP 3.	654 (2.7)	639 (1.9)	642 (2.0)	645 (2.0)

GENERAL DISCUSSION

In this study, an experimental series of three experiments was carried out to assess the relationship between orthographic and morphological processing. Instead of using complex and simple words as well as orthographic controls as primes, we used complex words (brujería "witchcraft") and complex (brujanza) and simple (brujaña) pseudowords. By using these stimuli, we were able to strictly control a number of experimental variables while following the same rationale as the other, more extended, design.

The results of the first experiment showed significant priming effects for complex words and pseudowords as well as for simple pseudowords in comparison to controls. The lack of significance for the comparisons between experimental conditions suggested that primes were not decomposed into stems and suffixes because, in that case, different results for complex and simple stimuli would have been obtained. Instead, the results suggest that the benefit for experimental conditions emerged thanks to the embedded stem effect. The marginal significance for the interaction between surface frequency (treated as a continuous variable) and prime type opened a window to a tentative explanation for the data obtained: frequent targets would have been processed holistically, through a whole word processing, diminishing the influence of morphological parsing of primes and the influence of suffixes. This explanation would fit easily within the family of the dual route models (i.e. Caramazza, Laudanna & Romani, 1988; Schreuder & Baayen, 1995) and, therefore, a new experiment was required to test its viability.

The second experiment was conducted in order to further explore this possible explanation. It replicated the first experiment but making use of low frequency targets. The results, however, again showed significant priming effects for all experimental conditions with no differences between each other. The results of the first two experiments cannot, therefore, be explained in terms of whole word processing of frequent targets. These results were the same as those found by Morris et al. (2011), but different from those in other studies (Giraudo & Voga, 2016; Hasenäcker et al., 2016; Longtin & Meunier, 2005). Morris et al., (2011) proposed an interesting argument to explain why simple pseudowords may facilitate word recognition and therefore why their results –and our results- were different from those of Longtin and Meunier (2005). They argued that while in their study targets were completely embedded in the primes (e.g., flexify-flex), in the study by Longtin and Meunier, the targets did not contain the whole prime (e.g., chambrage-chambre). This orthographic difference between both studies might explain the facilitative –or the null effect– of simple pseudowords. Given that English and French are opaque languages, any alteration at orthographic level can affect phonological representations, so that the difference highlighted at orthographic level could also impact at phonological level. The stimuli we have used are similar to those used by Longtin and Meunier (see annexes). Therefore, given this orthographic explanation suggested by Morris et al., we should have found no effect for simple words, but indeed we found an effect three times. However, the fact that Spanish is an extremely transparent language, unlike French and English, implies that the impact of not presenting the whole base in the primes does not necessarily impact on the results as in French. Nevertheless, it is evident that this explanation does not help to account for our results in Spanish. Moreover, taken collectively, the results of the first two experiments clearly show that the participants' responses are not affected by the surface frequency of targets or by their word ending frequencies, regardless of their lexical status.

It is interesting to note that in Spanish, as we have already mentioned, a suffix frequency effect has been shown, by which complex words with frequent suffixes are recognized faster in an unprimed lexical decision task than complex words with infrequent suffixes. Moreover, it has been shown that suffixes used as primes can generate priming effects, unlike orthographic controls. Therefore, in the language of this study, although with different methodologies, a role for suffixes in visual word recognition has been suggested, that is, a different role than that of non-morphemic endings. Our results fail to show such well-documented effects and we believe the most reasonable explanation is related to the methodologies themselves. When suffixes and non-morphemic endings are presented as primes (dad->

igualdad; Duñabeitia et al., 2008; Lázaro & Sainz, 2012; Lázaro, Illera, & Sainz, 2015a), when complex stimuli are anticipated by unmasked primes (Lázaro, Illera, & Sainz, 2015b), or when complex words are presented as primes sharing or not the same suffixes as targets (brevedad -> igualdad; Duñabeitia et al., 2008), then the role of suffixes in morphological processing becomes evident. However, when complex words and complex and simple pseudowords are presented in a masked priming lexical decision, the role of suffixes and morphological decomposition seems to have no relevance. In this sense, the study by Giraudo and Voga (2016) is important; these authors observed that the context created by the experimental stimuli may play a role. In their fourth experiment, Giraudo and Voga (2016) compared the benefit of complex words and pseudowords and observed that only complex words facilitated the recognition of their stems. However, in their fifth experiment, simple and complex pseudowords were used as primes (without words) and they observed that complex pseudowords indeed facilitated word recognition. The overall results of their fourth and fifth experiments clearly suggest that the context created by the stimuli presented affects the way they are processed.

In our third experiment, we opted for removing the vowels from the stem primes, thus reducing the orthographic overlap between primes and targets. With this manipulation, we expected to reduce the influence of the stem effect, thus creating an experimental context in which any hint of morphological decomposition could emerge. This manipulation worked according to our expectations since the priming effects decreased, but it did not avoid the appearance of significant differences between conditions. This time, in fact, the pattern observed is different from those in the previous two experiments because only complex words showed significant facilitative effects with respect to controls. This could suggest a morpho-semantic processing by which targets are benefited from their lexical status and morphological structure. However, this is not the only possible hypothesis. It can also be stated that in the case of complex words, the whole structure of the stimuli (br-jería) replicates one of those stored in the lexicon (brujería), and that therefore the real word could be retrieved from its *skeleton* presented as a prime, thus generating the facilitative effect already observed. This would be a case of feature interpolation in visual perception as the system tries to recognize an object with certain number of features available (i.e. Kellman, 2003). On the contrary, the structures of pseudowords (br-jama) are not represented in the lexicon and therefore no stimuli can be retrieved from them. Specifically, in the case of complex pseudowords, although their suffixes could theoretically be represented at sublexical level (br-janza), it would be highly difficult to activate any candidate at lexical level because their stems are not related to their suffixes. Therefore, without the explicit presentation of full stems, the retrieval of lexical candidates is only possible for words, and therefore the priming benefit is not obtained for pseudowords. However, we believe that there is another, more plausible, explanation. The lack of significance for paired comparisons between complex words and pseudowords, and even between complex words and simple pseudowords -and the similar effect size of the three experimental conditions, suggests that the results of the third experiment show the same results those observed in the first two experiments. This conclusion does not necessarily mean that these results deny the existence of the well-documented morphological decomposition process. However, it does highlight the central role of orthographic processing within this experimental paradigm. In fact, under this assumption, it can be tentatively stated that by hindering stem processing the influence of word endings started to emerge. However, the manipulation was not sufficiently effective to allow for word ending effects. This is again consistent with the view by Grainger and Beyersman (2017).

It is important to keep in mind that this theoretical explanation is not satisfactory to explain other well documented experimental results as the ones reviewed in the first part of the Introduction section. Why then brothel->broth or cash->cashew like stimuli do not produce priming? As stated previously in relation to the paper by Giraudo and Voga (2016), the experimental context might have an important impact on how readers process experimental stimuli. The fact that in these methodologies words as well as pseudowords are used as primes could also impact the processing because lexical competition could have occurred for words used as primes but not for pseudowords. Under this assumption, this lexical inhibition might have limited the benefit of using words instead of pseudowords as primes. This view, however, should be considered in the light of the descriptive statistics showing that the mean N of words in the experimental series is almost zero. In other words, although lexical competition for words -and not for pseudowords- is theoretically possible, our items are well controlled to avoid such bias. It is worth bearing in mind that the number of studies conducted within this methodology is far from large and that comparisons between words and pseudowords have to be made cautiously.

Taking into consideration all the studies carried out with the methodology of the present study, it is clear that almost all possible results have been obtained (see Table 1). However, the results found three times in this study have been reported by Morris et al., in another two experiments. This evidence is much more robust than any other possible results, none of which are replicated, and clearly supports a leading role for the embedded stem effect.

We believe that new studies are necessary, which, for example, i) directly compare different languages because divergent results might reflect configurational differences of the languages studied; ii) systematically manipulate WEF of complex stimuli; iii) directly compare the presentation of the whole stems or part of them in the primes (Morris et al., 2010); iv) use the same materials but in the context of three experimental conditions (complex words and pseudowords and simple pseudowords) or two conditions (Giraudo & Voga, 2016); v) hinder the embedded word effect to assess the role for suffixes in such circumstances; and vi) directly replicate previous studies.

RESUMEN

Efectos de anticipación en el reconocimiento de palabras y pseudopalabras simples y complejas. La cuestión de si el procesamiento morfológico ocurre más allá del mero procesamiento ortográfico continúa siendo objeto de intenso debate. En este estudio se examina el procesamiento morfológico en tres experimentos de decisión léxica con anticipador enmascarado presentando como anticipadores palabras complejas (*brujería* -> *brujo* –witchcraft -> witch), así como pseudopalabras simples (brujaña ->brujo) y pseudopalabras complejas (brujanza ->brujo). En el primer experimento, las tres condiciones experimentales facilitaron el reconocimiento en comparación con la condición de control, pero sin mostrar diferencias entre ellas. Debido a la importancia del efecto observado de la frecuencia de palabra se llevó a cabo un segundo experimento. En él se emplearon únicamente estímulos de baja frecuencia, pero los resultados fueron idénticos a los del primer experimento. En el tercer experimento se eliminaron las vocales de los anticipadores para reducir el solapamiento ortográfico entre anticipador y objetivo y, consecuentemente, la influencia del efecto de repetición de la base. Los resultados mostraron efectos facilitadores solo para las palabras complejas. Sin embargo, las comparaciones por pares no mostraron diferencias entre las condiciones experimentales. Los resultados obtenidos suponen en conjunto un rol muy destacado para el procesamiento de las bases en el reconocimiento léxico y son explicados a la luz de los modelos teóricos actuales sobre procesamiento morfológico.

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(Manuscript received: 24 July 2017; accepted: 6 March 2018)

APPENDIX

ANNEX 1. STIMULI OF THE EXPERIMENT 1.

Suffixed words	**Suffixed pseudowords**	**Simple pseudowords**	**Unrelated**	**Targets**
perruno	Perriego	Perraña	tremuro	PERRO (DOG)
esclavitud	Esclavanza	Esclavama	gepofasta	ESCLAVO (SLAVE)
lujurioso	Lujurieño	Lujurerta	perterosa	LUJURIA (LUST)
chancleta	Chanclaza	Chancluto	retrepafa	CHANCLA (SLIPPER)
pelusilla	Peluseja	Peluserta	broteril	PELUSA (FLUFF)
carboncillo	Carbonitud	Carbonaña	medafarel	CARBÓN (CARBON)
palaciego	Palacible	Palaciama	desoltere	PALACIO (PALACE)
cartilla	Carteño	Carterta	pertilose	CARTA (LETTER)
mantilla	Mantaza	Mantuto	nesfolite	MANTA (BLANCKET)
aceitoso	Aceiteja	Aceitarca	cestrerol	ACEITE (OIL)
carruaje	Carrista	Carraña	ivestel	CARRO (CAR)

plenitud	Plenible	Plenama	resdasar	PLENO (PLEIN)
hambruna	Hambrería	Hambrerta	leropiste	HAMBRE (HUNGER)
crudeza	Crudaza	Cruduto	mertero	CRUDO (RAW)
prontitud	Pronteja	Prontarca	bertila	PRONTO (SOON)
alfombrilla	Alfombroso	Alfombrerta	tresolpefe	ALFOMBRA (CARPET)
tardanza	Tardible	Tardama	lacreto	TARDE (LATE)
tableta	Tableño	Tablaerta	gresope	TABLA (TABLE)
exrañeza	Extrañaza	Extrañuto	miharadaz	EXTRAÑO (STRANGE)
patriota	Patriaeja	Patrarca	nesapore	PATRIA (HOMELAND)
caminata	Caminanza	Caminaña	perotere	CAMINO (PATH)
agudeza	Agudible	Agudama	fresbale	AGUDO (SHARP)
equipazo	Equipeño	Equiperta	mestapose	EQUIPO (TEAM)
cabezota	Cabezaza	Cabezuto	vertadaz	CABEZA (HEAD)
carnaza	Carnisco	Carcarca	mestrel	CARNE (MEAT)
camiseta	Camisoso	Camisaña	restapol	CAMISA (SHIRT)
palabrota	Palabrible	Palabrerta	hasoreter	PALABRA (WORD)
frenazo	Freneño	Frenerta	membrola	FRENO (BRAKE)
melenudo	Monstruaza	Melenurto	masoguca	MELENA (MANE)
agujeta	Agujeja	Agujerta	lastapor	AGUJA (NEEDLE)
bolsillo	Bolseta	Bolsaña	bretaste	BOLSO (BAG)
veraniego	Veranible	Veranama	preforte	VERANO (SUMMER)
tormentoso	Tormenteño	Tormenerta	niportesal	TORMENTA (STORM)
regleta	Regleña	Reglauto	jestufa	REGLA (RULE)
golpazo	Golposo	Golparca	frepoter	GOLPE (KNOCK)
cucharilla	Cucharoso	Cucharaña	maslatrepo	CUCHARA (SPOON)
ruinoso	Ruinible	Ruinerta	brestana	RUINA (RUIN)
colegiata	Colegieño	Colegierta	joprestar	COLEGIO (SCHOOL)
heladería	Heladaza	Heladuto	lofastro	HELADO (ICECREAM)
grasoso	Graceja	Graserta	lacimere	GRASA (FAT)
pedrisco	Pedreja	Pedraña	nolepar	PIEDRA (STONE)
cursillo	Cursible	Cursama	basdoli	CURSO (GRADE)
barbudo	Barbeño	Barberta	lasdetar	BARBA (BEIRD)
mentiroso	Mentiraza	Mentiruto	lasfetupo	MENTIRA (LIE)
latigazo	Latigueja	Latigarca	hesortra	LÁTIGO (WHIP)
paisajista	Paisajoso	Paisajaña	nerplutasa	PAISAJE (LANDSCAPE)
manzanilla	Manzanible	Manzanerta	brestradol	MANZANA (APPLE)
exactitud	Exacteño	Exacterta	trestasoz	EXACTO (EXACT)

campanilla	Campanible	Comaladuto	mascapotre	CAMPANA (BELL)
ventanilla	Ventaneja	Ventanuto	nedoterese	VENTANA (WINDOW)
delicadeza	Delicadeño	Delicadaña	mortepelna	DELICADO (DELICATE)
cebolleta	Cebollible	Cebollerta	mopetepra	CEBOLLA (ONION)
picaresco	Picareño	Picaerta	jopretar	PÍCARO(ROGUE)
amplitud	Ampliaza	Ampliuto	colmapia	AMPLIO (WIDE)
ganchillo	Gancheja	Gancharca	mestahosa	GANCHO (HOOK)
novelesco	Noveloso	Novelerta	mertipor	NOVELA (NOVEL)
chulesco	Chulible	Chulama	gusterpo	CHULO (PIMP)
pulcritud	Pulcreño	Pulcrerta	bertazola	PULCRO (NEAT)
pescadería	Pescadaza	Pescaduto	misderatin	PESCADO (FISH)
chivatazo	Chivateja	Chivataña	maspolata	CHIVATO

Annex 2. Stimuli of the experiment 2.

Suffixed words	Suffixed pseudowords	Simple pseudowords	Unrelated	Targets
esclavitud	esclavez	esclavama	gepofasta	ESCLAVO (SLAVE)
lujurioso	lujurieño	lujurerta	perterosa	LUJURIA (LUST)
chotuno	chotiego	chotaña	tremuro	CHOTO (YOUNG GOAT)
chancleta	chanclería	chanclopa	retrepafa	CHANCLA (SLIPPER)
pelusilla	pelusoso	peluselo	broteril	PELUSA (FLUFF)
pepinillo	pepinitud	pepinaña	medafarel	PEPINO (CUCUMBER)
sensatez	sensatible	sensatama	desoltere	SENSATO(REASONABLE)
estampilla	estampeño	estamperta	pertilose	ESTAMPA (STAMP)
mantilla	manteño	mantopa	nesfolite	MANTA (BLANKET)
calumnioso	calumnieja	calumniopa	cestrerola	CALUMNIA (SLANDER)
vasallaje	vasalleta	vasallaña	ivestelo	VASALLO (VASSAL)
alfombrilla	alfombroso	alfombrerta	tresolpefe	ALFOMBRA (CARPET)
brujería	brujanza	brujaña	perolter	BRUJO (WICHT)
camiseta	camisista	camisopa	restapol	CAMISA (T-SHIRT)
bolsillo	bolseta	bolsaña	bretaste	BOLSO (BAG)
cucharilla	cucharoso	cucharopa	maslatro	CUCHARA (SPOON)
barrigudo	barrigueta	barrigelo	noleparel	BARRIGA (BELLY)
piratería	piratoso	piraterta	nerplutas	PIRATA (PIRATE)
delicadeza	delicadeño	delicadaña	mortepena	DELICADO (DELICATE)
languidez	languideño	languidaña	mertipore	LÁNGUIDO (LANGUID)
excelsitud	excelsible	excelsama	resdasaro	EXCELSO(MAGNIFICENT)
ulceroso	ulcerible	ulcererta	lacretole	ÚLCERA (ULCER)
agudeza	agudible	agudama	fresbale	AGUDO (SHARP)
aspereza	asperible	aspererta	hasoreter	ÁSPERO (ROUGH)
peregrinaje	peregrinible	peregrinaña	prefortetra	PEREGRINO (PILGRIM)
ruinoso	ruinible	ruinerta	brestana	RUINA (RUIN)
cigarrillo	cigarrible	cigarrama	basdolipo	CIGARRO (CIGAR)
manzanilla	manzanible	manzanerta	brestradol	MANZANA (APPLE)
cebolleta	cebollez	cebollopa	mopetepra	CEBOLLA (ONION)
chulesco	chulible	chulama	gusterpo	CHULO (PIMP)
rotundidez	rotundería	rotunderta	leropistre	ROTUNDO (OUTRIGHT)
trompeta	trompeño	tromperta	gresorpe	TROMPA (HORN)
machetazo	machetible	machetama	mestapose	MACHETE (MACHETE)
frenazo	freneño	frenerta	membrola	FRENO (BRAKE)
harinoso	harineño	harinerta	niportesal	HARINA (FLOUR)

estupidez	estupideño	estupiderta	joprestar	ESTÚPIDO (STUPID)
barbudo	barbez	barbopa	lasdetar	BARBA (BEARD)
exactitud	exactible	exacterta	trestasoz	EXACTO (EXACT)
picaresco	picarez	picaerta	jopretar	PÍCARO (ROGUE)
pulcritud	pulcrería	pulcrerta	bertazola	PULCRO (NEAT)
crudeza	crudaza	crudaña	mertero	CRUDO (RAW)
tibieza	tibiaza	tibiaña	miharad	TIBIO (WARM)
vinagreta	vinagraza	vinagropa	vertadace	VINAGRE (VINEGAR)
melenudo	monstruaza	melenopa	masoguca	MELENA (MANE)
rabieta	rabieña	rabierta	jestufa	RABIA (RAGE)
heladería	heladaza	heladaña	lofastro	HELADO (ICRECREAM)
membranos	membraneño	membranopa	lasfetuta	MEMBRANA(MEMBRANE)
campanilla	campanible	campanopa	mascapde	CAMPANA (BELL)
cacharrería	cacharraza	cacharrama	misderatin	CACHARRO (JALOPI)
beatitud	beateja	beatelo	bertidra	BEATO (BLESSED)
ignorancia	ignoraeja	ingnoruto	nesapore	IGNORANTE (IGNORANT)
aridez	aridible	aridelo	mestrel	ÁRIDO (ARID)
agujeta	agujeja	agujerta	lastapor	AGUJA (NEEDLE)
timbrazo	timbroso	timbropa	frepoter	TIMBRE (BELL)
grasoso	graceja	graserta	lacimere	GRASA (FAT)
latigazo	latigueja	latigaña	hesortra	LÁTIGO (WHIP)
canastilla	canasteja	canastuto	nedoterese	CANASTA (BASKET)
ganchillo	gancheja	ganchelo	mestahosa	GANCHO (HOOK)
chivatazo	chivateja	chivataña	maspolata	CHIVATO (SNEAK)

Annex 3. Simple pseudowords of the experiment 3.

Suffixed words	Suffixed pseudowords	Simple pseudowords	Unrelated	Targets
esclavitud	esclavez	esclavufa	gepofasta	ESCLAVO (SLAVE)
lujurioso	lujurieño	lujuriute	perterosa	LUJURIA (LUST)
chotuno	chotiego	chotufa	tremuro	CHOTO (YOUNG GOAT)
chancleta	chanclería	chancluin	retrepafa	CHANCLA (SLIPPER)
pelusilla	pelusoso	pelusecle	broteril	PELUSA (FLUFF)
pepinillo	pepinitud	pepinufa	medafarel	PEPINO (CUCUMBER)
sensatez	sensatible	sensatasto	desoltere	SENSATO(REASONABLE)
estampilla	estampeño	estampecle	pertilose	ESTAMPA (STAMP)
mantilla	manteño	mantuin	nesfolite	MANTA (BLANKET)
calumnioso	calumnieja	calumnuin	cestrerola	CALUMNIA (SLANDER)
vasallaje	vasalleta	vasallufa	ivestelo	VASALLO (VASSAL)
alfombrilla	alfombroso	alfombrufa	tresolpefe	ALFOMBRA (CARPET)
brujería	brujanza	brujufa	perolter	BRUJO (WICHT)
camiseta	camisista	camisute	restapol	CAMISA (T-SHIRT)
bolsillo	bolseta	bolsuin	bretaste	BOLSO (BAG)
cucharilla	cucharoso	cucharute	maslatro	CUCHARA (SPOON)
barrigudo	barrigueta	barrigute	noleparel	BARRIGA (BELLY)
piratería	piratoso	piradute	nerplutas	PIRATA (PIRATE)
delicadeza	delicadeño	delicadute	mortepena	DELICADO (DELICATE)
languidez	languideño	languidute	mertipore	LÁNGUIDO (LANGUID)
excelsitud	excelsible	excelsufa	resdasaro	EXCELSO (MAGNIFICENT)
ulceroso	ulcerible	ulcerasto	lacretole	ÚLCERA (ULCER)
agudeza	agudible	agudasto	fresbale	AGUDO (SHARP)
aspereza	asperible	asperasto	hasoreter	ÁSPERO (ROUGH)
peregrinaje	peregrinible	peregrinasto	prefortetra	PEREGRINO (PILGRIM)
ruinoso	ruinible	ruinecle	brestana	RUINA (RUIN)
cigarrillo	cigarrible	cigarrufa	basdolipo	CIGARRO (CIGAR)
manzanilla	manzanible	manzanecle	brestradol	MANZANA (APPLE)
cebolleta	cebollez	cebollecle	mopetepra	CEBOLLA (ONION)
chulesco	chulible	chulasto	gusterpo	CHULO (PIMP)
rotundidez	rotundería	rotundasto	leropistre	ROTUNDO (OUTRIGHT)

trompeta	trompeño	trompecle	gresorpe	TROMPA (HORN)
machetazo	machetible	machetasto	mestapose	MACHETE (MACHETE)
frenazo	freneño	frenasto	membrola	FRENO (BRAKE)
harinoso	harineño	harinecle	niportesal	HARINA (FLOUR)
estupidez	estupideño	estupidasto	joprestar	ESTÚPIDO (STUPID)
barbudo	barbez	barbecle	lasdetar	BARBA (BEARD)
exactitud	exactible	exactifa	trestasoz	EXACTO (EXACT)
picaresco	picarez	picarecle	jopretar	PÍCARO (ROGUE)
pulcritud	pulcrería	pulcrecle	bertazola	PULCRO (NEAT)
crudeza	crudaza	crudein	mertero	CRUDO (RAW)
tibieza	tibiaza	tibiorde	miharad	TIBIO (WARM)
vinagreta	vinagraza	vinagrorde	vertadace	VINAGRE (VINEGAR)
melenudo	monstruaza	melenorde	masoguca	MELENA (MANE)
rabieta	rabieña	rabiorde	jestufa	RABIA (RAGE)
heladería	heladaza	heladifa	lofastro	HELADO (ICRECREAM)
membranoso	membraneño	membranorde	lasfetuta	MEMBRANA (MEMBRANE)
campanilla	campanible	campanorde	mascapde	CAMPANA (BELL)
cacharrería	cacharraza	cacharrorde	misderatin	CACHARRO (JALOPI)
beatitud	beateja	beatuin	bertidra	BEATO (BLESSED)
ignorancia	ignoraeja	ignorantuin	nesapore	IGNORANTE (IGNORANT)
aridez	aridible	ariduin	mestrel	ÁRIDO (ARID)
agujeta	agujeja	agujorde	lastapor	AGUJA (NEEDLE)
timbrazo	timbroso	timbrifa	frepoter	TIMBRE (BELL)
grasoso	graceja	grasifa	lacimere	GRASA (FAT)
latigazo	latigueja	latigifa	hesortra	LÁTIGO (WHIP)
canastilla	canasteja	canastifa	nedoterese	CANASTA (BASKET)
ganchillo	gancheja	ganchifa	mestahosa	GANCHO (HOOK)
chivatazo	chivateja	chivatifa	maspolata	CHIVATO (SNEAK)