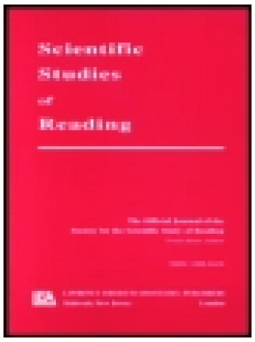

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Syllabic Strategy as Opposed to Coda Optimization in the Segmentation of Spanish Letter-Strings Using Word Spotting

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ABSTRACT
A word-spotting task is used in Spanish to test the way in which polysyllabic letter-strings are parsed in this language. Monosyllabic words (e.g., *bar*) embedded at the beginning of a pseudoword were immediately followed by either a coda-forming consonant (e.g., *barto*) or a vowel (e.g., *baros*). In the former case, the embedded word corresponds to the first spoken syllable, whereas it cuts across the syllable boundary in the latter case. Unlike a previous study in English using the same methodology (Taft & Álvarez, 2014), the embedded word was found to be easier to detect when followed by a consonant than a vowel, at least for low-frequency words. It was concluded that phonological recoding is more important in the parsing of Spanish words than English words, where maximization of the coda dominates instead.

The way in which the orthographic structure of a word is analyzed when reading may well depend on the characteristics of the language being processed. Two of these properties that are potentially relevant are orthographic transparency (i.e., the consistency of the relationship between graphemes and phonemes) and the nature of the different sublexical structures of each language (see Frith, Wimmer, & Landerl, 1998; Goswami, Ziegler, Dalton, & Schneider, 2001, for differences in processing between English and German in children, or Seymour, Aro, & Erskine, 2003; Ziegler & Goswami, 2005). Regarding the first property, some languages have a shallower (i.e., more regular) relationship than others between their orthographic form and their phonology (e.g., Katz & Frost, 1992), and this might lead to a greater emphasis being placed on the phonological characteristics of the words when reading. This is the case in Spanish, a transparent orthography with a close correspondence between graphemes and phonemes, being almost a one-to-one translation from print to sound during reading.

The second characteristic that could determine the strategies used to analyze visually presented polysyllabic words is the way in which those words are broken down into sublexical structures. In the case of Spanish, this appears to be based on the syllabic structure of the spoken word, even when reading is silent. Spoken syllable boundaries are clear-cut in Spanish (e.g., Álvarez, Carreiras, & Taft, 2001; Harris, 1983; Sebastián-Gallés, Dupoux, Segui, & Mehler, 1992), and experiments that have manipulated syllable frequency in visual lexical decision point to the involvement of the spoken syllable in reading Spanish (e.g., Álvarez, Carreiras, & Perea, 2004; Álvarez et al., 2001; Carreiras, Álvarez, & de Vega, 1993; Perea & Carreiras, 1998). In particular, the higher the frequency of the first syllable of both bi- and trisyllabic words, the slower the lexical decision response. These results have been explained in terms of competition among words sharing their first syllable (i.e., more competitors provoking longer times). It seems that such an effect arises after orthography is sublexically recoded into phonology during silent reading (e.g., Álvarez et al., 2004; see also Conrad, Grainger, & Jacobs, 2007, in German). This segmentation strategy based on phonological syllables agrees with the principle of maximization of the consonantal onset of the second syllable

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(e.g., Fallows, 1981; Pulgram, 1970). Thus, a Spanish word such as *carbón* ("coal") would be segmented into the phonological syllables *car* and *bón*, such that the second syllable begins with a consonantal onset (*b*).

However, in English, which has a deeper orthographic system, there is little evidence that words are sublexically structured in terms of the spoken syllable. Using the same methodology as in the Spanish experiments, Macizo and Van Petten (2007) reported a facilitatory, rather than an inhibitory, effect of syllable frequency on lexical decision responses for both the first and second syllable of bisyllabic words, which they ascribed to orthographic similarity. Other studies of visual word recognition have also come out in favor of syllabification in English based on principles that are not phonological, namely, the Basic Orthographic Syllabic Structure (BOSS; e.g., Chen & Vaid, 2007; Taft, 1979, 1987, 1992, 2001, 2002; Taft & Kougious, 2004). The BOSS adopts a principle of maximal coda whereby the consonantal coda of the first syllable is made as large as possible in order to optimize the informativeness of the first sublexical unit (e.g., giving the structures *cert-ain, vir-us*, and *mund-ane*). This can be contrasted with the application of the maximal onset principle that appears to be important in Spanish, where the onset of the second syllable would be maximized in accordance with phonological rules (giving *cer-tain, vi-rus*, and *mun-dane*).

There is evidence favoring the BOSS over the spoken syllable (henceforth referred to as the Syllable), mainly in English and coming from lexical decision experiments where polysyllabic words are presented with either their BOSS or their Syllable separated from the rest of the word (e.g., Chen & Vaid, 2007; Taft, 1979, 1987, 2001, 2002). In general, the BOSS items (e.g., *spid-er*) were found to be easier to recognize than the Syllable items (e.g., *spi-der*), though seemingly only for adult readers who performed most accurately in a reading comprehension test (Taft, 2001, 2002).

It is apparent, then, that the processing in silent reading of the internal structure of English is quite different to that of Spanish. The former seems to optimally use a structure that maximizes the informativeness of the first orthographic subunit, whereas the latter seems to structure the word into phonologically defined subunits. That is, the processing of Spanish engages phonological recoding more than does the processing of English, presumably because of the deeper relationship between print and sound in English. This cross-language contrast was directly tested by Taft, Álvarez, and Carreiras (2007) in a lexical decision experiment where words that could be used in both English and Spanish were presented with a gap either after their BOSS (e.g., *plaz a, pensión*) or after their Syllable (e.g., *pla za, pensión*). Although the responses of monolingual Spanish adults were faster in Spanish to the Syllable condition than to the BOSS condition regardless of reading proficiency (as determined by a multiple-choice reading comprehension test and based on an accuracy measure), only the poorer English monolingual readers showed such a pattern in English. The responses of better English readers tended to favor the BOSS condition. Not only did the English data show a correlation between the BOSS/Syllable difference and reading ability, but those factors interacted when examined factorially. Thus it was argued that only poorer English readers are reliant on phonological processing.

The present study adopts a different paradigm, a "word-spotting" task, to examine whether there is a bias toward maximization of the coda or of the onset when analyzing a polysyllabic Spanish word. Adapted from the speech recognition domain (see McQueen, 1996, for an overview), this task was recently used by Taft and Álvarez (2014) with English materials. Polysyllabic pseudowords were presented, and participants had to decide by key-press whether they began with a real word. Embedded words ended in a single consonant (e.g., *slam*) and were followed by either a vowel or another consonant, which either did or did not form a complex coda with the consonant that followed it. When the two consonants formed a complex coda (e.g., the *mp* of *slampora*, referred to as the coda condition), word detection was harder than when the embedded word was followed by a vowel (e.g., *slamorpa*) or by another consonant that did not create a complex coda (e.g., the *mc* of *slamcora*, referred to as the onset condition). This outcome supports a bias toward maximization of the coda when segmenting an English polysyllabic letter-string because the word would be obscured in items like *slampora* only if the two consonants were being treated as a complex coda rather than as a simple coda plus simple onset.

The reason for adopting the word-spotting task is that it explicitly requires sublexical information to be extracted from the letter-string (i.e., the embedded word), tapping into the factors that affect the ease of extracting that information, in particular, the nature of the letters that follow the embedded word. If a lexical decision task were to be used instead, the impact of the sublexical information would be tapped into only indirectly. For example, the ease of accessing the embedded word might be seen in delayed classification of the whole letter-string as a nonword (see, e.g., Taft, Xu, & Li, 2017). However, such responses would also be affected by the general word-likeness of the whole letter-string, which is a factor that is irrelevant in the word-spotting task where only the embedded word need be identified.

The word-spotting experiment to be reported here examines whether it is onset maximization that holds in Spanish rather than coda maximization. A comparison is again made between items that have the embedded word (e.g., *bar*, meaning "end" in Spanish) followed by a consonant that can create a complex coda (e.g., *barto*) and items that have the embedded word followed by a vowel (e.g., *baros*), following the same logic as the experiment by Taft and Álvarez (2014). If Spanish is processed differently than English, as is suggested, a different pattern of results should be observed. In particular, if Spanish is processed according to phonological principles (i.e., with syllabification based on the maximal onset principle), the word should be harder to detect when followed by a vowel than by a consonant rather than what was found in English, where it was harder to detect the embedded word in the coda condition than the vowel condition. For example, the Spanish word *bar* corresponds to the first phonological syllable of *barto*, whereas it straddles the first and second syllables of *baros* (i.e., *ba-ros*) and hence does not correspond to a single structural unit.

Although word frequency was not manipulated in the English experiment, it was considered useful to explore in this study because stronger and clearer syllabic effects have been observed in Spanish for low-frequency words compared to high-frequency words (Álvarez et al., 2001; Carreiras et al., 1993; Perea & Carreiras, 1998).

Method

Participants

Forty native speakers of Spanish from the University of La Laguna participated in the experiment for course credit (28 female, 17 male; *M* age = 18;9 years, range = 18;1–22;3). All had normal or corrected-to-normal vision.

Materials

Forty monosyllabic Spanish words of three or four letters were selected. They ended in consonants with the exception of four stimuli ending in *y*, a letter that is associated with a vowel or a consonant sound depending on the following letter. Items were split into two frequency conditions with high frequency (HF) defined as greater than 100 per million according to the Spanish lexical database LEXESP (Sebastián-Gallés, Martí, Carreiras, & Cuetos, 2000) and low frequency (LF) as less than 60 per million. Spanish actually has few monosyllabic words, so as many as could be found were selected for each of the two frequency conditions. There were 21 items in the HF condition (*M* frequency = 799.5, *SD* = 969.3; e.g., *bar, gran, dos*) and 19 in the LF condition (*M* frequency = 14.1, *SD* = 15.6; e.g., *rol, huir, ron*).

In line with the English experiment of Taft and Álvarez (2014), letters were added to the words to create a pseudoword. These formed an ending of two to three letters that was compatible with Spanish orthographic structure and began with either a consonant (where the word coincided with the first syllable, e.g., *barto* beginning with the Spanish word *bar*) or a vowel (where the word coincided with the BOSS and not the syllable, e.g., *baros*). Other examples of such Consonant versus Vowel pairings are *coldus* versus *coluas, ronge* versus *ronol, doscoi* versus *dosuor*, and *buendo* versus *buenul*. Most of the consonant combinations used in Spanish (e.g., *rt, ld*) were the same as those used in the coda condition of the English experiment by Taft and Álvarez (2014). Among the set of 80 pseudowords, seven had stress on the second syllable in the consonant condition (e.g., *clantir*) and five in the vowel condition (e.g., *hoyur*). In addition, three factors related to statistical or distributional properties of the final stimuli were measured to be able to further explore the possible impact on the effects of interest in a post hoc analysis: mean bigram frequency (defined as mean frequency of the bigrams composing each item), frequency of the critical bigram (the bigram corresponding to the transition between the embedded word and the rest of the item), and frequency of the first syllable of the stimuli. These indices were extracted from the program BUSCAPALABRAS (Davis & Perea, 2005). The stimuli can be found in the appendix. For the task to be performed, 40 filler pseudowords were also included. These had the same structure as the experimental items but did not begin with a real word (e.g., *berno, cuelur*).

Two counterbalanced sublists were generated within a Latin Square design such that half of the pseudowords were presented to one subgroup of participants in the consonant condition and the other half in the vowel condition, with the items being rotated through the two conditions for the other subgroup.

Procedure

The pseudoword stimuli were presented in the center of a computer screen, and participants were asked to decide whether any real monosyllabic word appeared at its beginning. Participants were told to respond as quickly but as accurately as possible by pressing one of two keys on the keyboard, labeled “SÍ” (the L key that has to be pressed with a finger of the right hand) or “NO” (the A key, pressed with the left hand). All items were presented in a different random order to each participant with a display duration of 500 ms. A new trial was initiated 500 ms after the participant made their response or after 3,000 ms if no response was made. Reaction times (RT) and error rates were measured. A practice session was carried out prior to the test items, consisting of 10 pseudowords, half of which began with a real word and half did not.

Results

Mean RTs for correct responses and error rates are found in Table 1. Both types of data were analyzed using linear mixed effects modeling (Baayen, Davidson, & Bates, 2008; Bates, 2005), taking participant and item variability simultaneously into account. The analyses were performed using the R statistics software with the package lme4 (Bates & Maechler, 2009). After checking that the factor sublist was not significant (required by the Latin Square and theoretically meaningless), the factors Boundary (consonant vs. vowel) and Word Frequency (high vs. low) were entered as within-group factors. Three covariates were also included in the model, in a first step: mean bigram frequency, frequency of the critical bigram, and first syllable frequency. All the covariates were entered one by one in a multiplicative way (with interaction effects with all repeated measures factors). Because no significant covariate effects were found in this multiplicative approach, an additive effect was tested with just the covariate plus the three fixed effects (two main effects plus the interaction of both factors).

Table 1. Means of reaction times (in ms) for correct responses and percentage of errors as a function of type of boundary (consonant vs. vowel) and word frequency (high vs. low).

	High Frequency	Low Frequency
Consonant boundary	RTs: 952 (177)	1003 (177)
	Err: 14 (12)	26 (18)
Vowel boundary	RTs: 987 (156)	1123 (206)
	Err: 15 (10)	27 (18)

Note. Standard deviations are in parentheses. RTs = reaction times; Err = percentage of errors.

Analyses of RT were carried out only for correct responses after those exceeding 2 standard deviations above or below the mean for each participant were replaced by that cutoff value (2.3 % of responses). There were two participants who made at least 50% errors in one condition and were removed from the analyses. We used a fitted mixed-design analyses of variance with Satterthwaite approximation for degrees of freedom. The model was estimated following Barr, Levy, Scheepers, and Tily (2013) with all repeated measures factors as fixed and random slopes across participant. Results revealed a significant advantage on the RT measure for high-frequency embedded words over low-frequency embedded words, $F(1, 25) = 12.09$, $p < .005$, as well as a boundary effect, $F(1, 293) = 12.28$, $p < .001$, where the consonant condition was faster than the vowel condition. The interaction between boundary and word frequency was also significant, $F(1, 399) = 9.33$, $p < .005$. Among the covariates, only syllable frequency was significant, $F(1) = 5.82$, $p < .05$. Thus, the same model with the same factors was analyzed but this time including only syllable frequency as a covariate. The main effects were again significant: boundary, $F(1, 294) = 19.46$, $p < .001$, and word frequency, $F(1, 29) = 9.35$, $p < .005$, as well as the interaction, $F(1, 665) = 10.21$, $p < .005$. The mixed-model post hoc analyses with Hochberg family-wise post hoc Type I error correction (Kuznetsova, Brockhoff, & Christensen, 2013) revealed that the effect of the boundary was restricted to low-frequency words, $t(432) = 5.16$, $p < .001$, being nonsignificant for high-frequency words, $t(502) = 1.12$, $p > .1$. Syllable frequency also yielded significance, $F(1, 72) = 9.54$, $p < .005$, with longer RTs for lower syllable frequencies.

The same statistical procedure and models were applied to analyze error rates but using the mixed model with logit family function for binomial data. The first model including the three covariates showed that only word frequency was significant, $\chi^2(1) = 9.99$, $p < .005$. Because bigram frequency was also significant, $\chi^2(1) = 4.82$, $p < .05$, a model was tested including only that covariate, and again only word frequency was significant, $\chi^2(1) = 8.59$, $p < .005$, with more errors for low-frequency than high-frequency words.

There were actually three characteristics of the stimuli that were not precisely matched between the conditions and that could therefore contribute to some extent to the outcome. The first is that some of the items could be morphemes or very close to real words after the critical bigram. Thus we checked the whole set of stimuli and found that several items in both the consonant condition and in the vowel condition (more in the latter) had their uniqueness point after the critical bigram (i.e., could form a morpheme or be close to a word at that point; e.g., for the item *barto*, there is a Spanish name that is *Bartolo*). Second, in some cases, the word being spotted may have been pronounced somewhat differently when embedded in the stimulus. For instance, the letter *r* could be pronounced as /r/or /ɾ/ in the embedded word or in the stimulus where it was followed by a consonant, but only as /ɾ/ in the stimulus where it was followed by a vowel. Finally, even though bigram frequency was entered as a covariate (with a nonsignificant contribution), some bigram frequencies were very low or even 0, being "special" items, which may have made it especially easy to spot the word.

Thus, a further analysis was carried out with three dichotomous variables, namely, the occurrence of a uniqueness point after or in the critical bigram, the existence of a possible phonological difference between conditions, and the presence of a very low bigram frequency bigram. This further analysis again used linear mixed-effects modeling in a multiplicative and additive way and including these three dichotomous variables. The two main effects of frequency and boundary, as well as their interaction, remained significant, but there was no impact of any of the new variables.

Discussion

As predicted, the obtained pattern of results was different to the outcome of the English experiment by Taft and Álvarez (2014): An advantage for Spanish readers in locating the embedded word arose when it was followed by a potential coda rather than when followed by a vowel, mainly for stimuli that were low-frequency words. The stimulus pairs that behaved in this way are indicated in the appendix. Thus, it is apparent that English and Spanish are segmented and processed differently by native speakers when reading. Whereas English speakers, especially more proficient readers, show a bias toward maximizing the coda when parsing a letter-string, Spanish readers tend to maximize the onset, segmenting the input in terms of the phonological syllables. Moreover, the post hoc analyses show that this advantage for syllabic segmentation cannot be explained by distributional properties or orthographic redundancy like bigram frequency. Nor can it be explained by frequency of the first syllable.

Phonological recoding is therefore the apparent source of the effect in Spanish. Moreover, this preference for a segmentation based on syllables seems restricted to low-frequency words, a tendency also observed in previous research manipulating syllable frequency (Álvarez et al., 2001; Carreiras et al., 1993; Perea & Carreiras, 1998).

Two strategies can be proposed for word spotting in Spanish: The first is left-to-right orthographic parsing, where the system tries to access increasingly larger units beginning from the initial part of the letter-string. This is an account proposed for English by Taft (1979; though see Taft, Xu, & Li, 2017). However, such a mechanism does not differentiate between the consonant and vowel items if the maximal coda principle is not applied in Spanish, unlike English. The embedded word is simply accessed when the appropriate unit is fed into the system, which therefore cannot explain the observed advantage for the consonant condition, at least for low-frequency words. The second possible processing strategy is phonologically based access. This mechanism leads to an advantage when the syllable is isolated, as in the consonant condition, and in fact might even fail to identify the embedded word in the vowel condition because the word detection is disrupted by the syllable boundary.

The argument can then be made that the use of the phonological strategy inhibits the orthographic strategy, but to a lesser extent for high-frequency words because more efficient and more flexible strategies can be used (see Taft & Álvarez, 2014; Taft et al., 2007). The phonological and orthographic "strategies" are activated in parallel, with the former taking longer to get going than the latter. That is, left-to-right parsing can get under way immediately, whereas it takes a while to start generating the phonological representation of a letter-string. However, if the orthographic strategy is slow to identify the embedded word, as will be the case when that word is of low frequency, the phonological strategy will generate its output first. In the consonant condition, that output will provide a syllabification that isolates the first syllable as a word, hence allowing the response to be based on this information. In contrast, the vowel condition does not isolate the embedded word through syllabification, which means that identification of that word can be made only through its orthographic overlap with the initial part of the letter-string. In addition, the effect emerges only on the speed measure, which suggests that the orthographic-based information is always consulted by default even if it takes time to do so.

In fact, it is not surprising that Spanish speakers are insensitive to coda maximization, with little reason for Spanish readers to consider combining two adjacent consonants to form a complex coda. The existence of complex codas is most unambiguously established when they occur at the end of a monosyllabic word (e.g., the *nk* of *bank*, or the *rt* of *cart* in English), and this is how Taft and Álvarez (2014) defined whether two consonants can form a complex coda. Such a structure almost never occurs in Spanish. Although a few syllables in Spanish do include a complex coda (e.g., *trans*), not many words end in a double consonant with the exception of some plurals (e.g., *blocs*) or words coming from English (e.g., *fans* or *cómics*). From this point of view, the consonant condition is actually equivalent to the onset condition of Taft and Álvarez because that condition included consonant pairs that could not be combined to form a complex coda (e.g., the *mc* of *slamcora*). In fact, Taft and Álvarez found shorter latencies and fewer errors to the onset condition relative to the vowel condition (e.g., *slamorpa*), which was the same pattern observed in the Spanish experiment. Thus, even though most of the consonant combinations used in the present experiment were the same as those used in the coda condition of the English experiment of Taft and Álvarez (2014), the consonant condition in the Spanish experiment was treated more like the onset condition in the English experiment than the coda condition. To summarize, Spanish results provide a contrast with

English in that *barto* could potentially be syllabified in the same way in English as in Spanish, but the fact that *rt* exists as a coda in the former but not the latter leads to a different parsing strategy, namely, coda optimization in English and "coda minimization" (or onset maximization) in Spanish (where the latter corresponds to the phonological syllable structure).

Adjacent consonants are unusual in Spanish, which actually provides an alternative explanation for the consonant (syllable) advantage in Spanish. In particular, the bigram frequency of consonant pairs will be lower than that of consonant-vowel pairs. Therefore, if readers are sensitive to bigram frequency (cf. Seidenberg, 1987), they might be inclined to divide letter-strings between the lowest frequency bigrams. In this way, an embedded word corresponding to the syllable will be readily detected, not because phonology is activated but on the basis of the low bigram frequency between the adjacent consonants. Note, however, that for such an orthographic explanation to hold, it would need to be argued that English readers are not as sensitive to bigram frequency as are Spanish readers, as there was no advantage in the English experiment of Taft and Álvarez (2014) for the coda condition despite the fact that consonant pairs bigrams are considerably less frequent than consonant–vowel pairs bigrams in English as well (see, e.g., Solso & Juel, 1980). It is unlikely, however, that Spanish readers are more sensitive to an orthographic factor than are English readers given the fact that Spanish has the shallower orthography. In addition, and more important, neither the frequency of the critical bigram nor total bigram frequency was found to explain the syllable advantage in Spanish.

Instead of bigram frequencies, however, one might argue that Spanish readers are actually more sensitive to the biphone frequencies after phonological recoding has taken place. However, due to the transparency properties of Spanish, biphone and bigram frequency are essentially the same. Moreover, such an argument is tantamount to saying that syllable boundaries are clearer in Spanish than in English and that spoken syllables therefore play more of a role in orthographic parsing in Spanish. It also concedes the central point that Spanish readers are more likely to activate phonological information than are English readers.

The results obtained in this study are consistent with what has been found in relation to spoken words. Using a task where participants must decide whether a visually presented target (e.g., *BA* or *BAL*) occurs at the beginning of a spoken word (e.g., "*balance*" or "*balcony*"), it has been shown that speakers of languages with clear-cut syllable boundaries (such as Spanish and French) are sensitive to a structure that corresponds to the principle of maximal onset, whereas speakers of English are not (e.g., Bradley, Sánchez-Casas, & García-Albea, 1993; Cutler, Mehler, Norris, & Segui, 1986; Sebastián-Gallés et al., 1992). Therefore, the internal representation of syllabic structure activated by Spanish speakers during orthographic processing seems to correspond to the way in which they process spoken words. In fact, the same might be true for English as well, with Taft and Hambly (1985) having reported evidence for coda maximization in spoken word processing just as in visual word processing. They showed that a spoken syllable was easier to detect when followed by a vowel (e.g., finding /pɪk/in /pɪkəl/, i.e., *pickle*) than when followed by a consonant (e.g., finding /pɪk/in /pɪksiː/, i.e., *pixie*).

The assumption being made throughout this study has been that the word-spotting task tells us something about orthographic parsing during normal reading. In particular, maximization of the onset and the involvement of spoken syllabic structure are going to influence word spotting only if they are available as mechanisms involved in normal reading. However, there are some aspects of word spotting that may be task specific. For example, working memory might play more of a role than in normal reading, leading to greater activation of phonology in performing the task. Against such a position, however, is the fact that, if such a phonological strategy were effective for performing the task, there is no reason why English speakers would not also adopt such a strategy. So, the greater impact of phonology in Spanish than English in the word-spotting task implies that Spanish lexical processing is simply more strongly oriented toward phonology than is English lexical processing. English processing appears to be characterized by maximization of the coda, whereas Spanish processing is characterized by phonological activation.

Conclusions

The present study demonstrates that the way in which a visually presented letter-string is processed differs in accordance with the nature of the language being read. For a language with clear-cut syllable boundaries in its spoken form, such as Spanish, the phonologically defined syllable appears to play an important role in orthographic processing. It seems that the highly reliable relationship between spelling and sound leads to weight being placed on phonological processing when reading Spanish. The evidence from English (Taft & Álvarez, 2014), on the other hand, is that the phonologically determined syllable is less important, and there is, instead, a bias toward maximizing the coda of the first syllable even if this cuts across the spoken syllable boundary.

The fact that the advantage of syllables is not evident in high-frequency words may be more related to flexibility in analyzing the internal orthographic structure of a word, with a greater reliance on visual/orthographic processing when the word can be readily activated via that means. Whether this can be substantiated through the use of other tasks is something that awaits further research.

Our findings have potential implications for efficiency in reading English or Spanish as a second language. If there are different optimal-processing strategies in the two languages, this should be taken into account in the teaching of those languages. Indeed, second-language teachers would likely assume that there is nothing special to focus on when reading in a second alphabetic language, unlike speaking. However, the contrast between the current results in Spanish with those of Taft and Álvarez (2014) in English suggest otherwise.

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References

Álvarez, C. J., Carreiras, M., & Perea, M. (2004). Are syllables phonological units in visual word recognition? *Language and Cognitive Processes*, *19*, 427–452. doi:10.1080/01690960344000242

Álvarez, C. J., Carreiras, M., & Taft, M. (2001). Syllables and morphemes: Contrasting frequency effects in Spanish. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*, 545–555. doi:10.1037/0278-7393.27.2.545

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, *59*, 390–412. doi:10.1016/j.jml.2007.12.005

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, *68*, 255–278. doi:10.1016/j.jml.2012.11.001

Bates, D. M. (2005). Fitting linear mixed models in R. *R News*, *5*, 27–30.

Bates, D., & Maechler, B. (2009). *Lme 4: Linear mixed-effects models using S4 classes*. R package version 0.999375-27.

Bradley, D. C., Sánchez-Casas, R. M., & García-Albea, J. E. (1993). The status of the syllable in the perception of Spanish and English. *Language and Cognitive Processes*, *8*, 197–233. doi:10.1080/01690969308406954

Carreiras, M., Álvarez, C. J., & de Vega, M. (1993). Syllable frequency and visual word recognition in Spanish. *Journal of Memory and Language*, *32*, 766–780. doi:10.1006/jmla.1993.1038

Chen, H.-C., & Vaid, J. (2007). Word frequency modulates the Basic Orthographic Syllabic Structure (BOSS) effect in English polysyllable word recognition. *Language and Cognitive Processes*, *21*, 58–82. doi:10.1080/01690960500372717

Conrad, M., Grainger, J., & Jacobs, A. M. (2007). Phonology as the source of syllable frequency effects in visual word recognition: Evidence from French. *Memory and Cognition*, *35*, 974–983. doi:10.3758/BF03193470

Cutler, A., Mehler, J., Norris, D. G., & Segui, J. (1986). The syllable's differing role in the segmentation of French and English. *Journal of Memory & Language*, *25*, 385–400. doi:10.1016/0749-596X(86)90033-1

Davis, C. J., & Perea, M. (2005). BuscaPalabras: A program for deriving orthographic and phonological neighborhood statistics and other psycholinguistic indices in Spanish. *Behavior Research Methods*, *37*, 665–671. doi:10.3758/BF03192738

Frith, U., Wimmer, H., & Landerl, K. (1998). Differences in phonological recoding in German- and English-speaking children. *Scientific Studies of Reading*, *2*, 31–54. doi:10.1207/s1532799xssr0201_2

Goswami, U., Ziegler, J. C., Dalton, L., & Schneider, W. (2001). Pseudohomophone effects and phonological recoding procedures in reading development in English and German. *Journal of Memory and Language*, *45*, 648–664. doi:10.1006/jmla.2001.2790

Harris, J. W. (1983). Syllable structure and stress in Spanish: A nonlinear analysis. In *Linguistic inquiry monograph* (Vol. 8). Cambridge, MA: MIT Press.

Katz, L., & Frost, R. (1992). The reading process is different for different orthographies. In R. Frost & L. Katz (Eds.), *Orthography, phonology, morphology, and meaning* (pp. 67–84). Amsterdam, the Netherlands: North-Holland.

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2013). *lmerTest: Tests for random and fixed effects for linear mixed effect models (lmer objects of lme4 package)*. R-Version: 1.1-0. Retrieved from http://cran.rproject.org/web/packages/lmerTest/index.html

Macizo, P., & Van Petten, C. (2007). Syllable frequency in lexical decision and naming of English words. *Reading and Writing*, *20*, 295–331. doi:10.1007/s11145-006-9032-z

McQueen, J. M. (1996). Word spotting. *Language and Cognitive Processes*, *11*, 695–699. doi:10.1080/016909696387114

Perea, M., & Carreiras, M. (1998). Effects of syllable frequency and syllable neighborhood frequency in visual word recognition. *Journal of Experimental Psychology: Human Perception & Performance*, *24*, 134–144. doi:10.1037/0096-1523.24.1.134

Pulgram, E. (1970). *Syllable, word, nexus, cursus*. The Hague, the Netherlands: Mouton.

Sebastián-Gallés, N., Dupoux, E., Segui, J., & Mehler, J. (1992). Contrasting syllabic effects in Catalan and Spanish. *Journal of Memory & Language*, *31*, 18–32. doi:10.1016/0749-596X(92)90003-G

Sebastián-Gallés, N., Martí, M. A., Carreiras, M., & Cuetos, F. (2000). *LEXESP: Léxicoinformatizado del español*. Barcelona, Spain: EdicionsUniversitat de Barcelona.

Seidenberg, M. S. (1987). Sublexical structures in visual word recognition: Access units or orthographic redundancy? In M. Coltheart (Ed.), *Attention and performance* (Vol. XII, pp. 245–263). London, UK: Erlbaum.

Seymour, P., Aro, M., & Erskine, J. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology*, *94*, 143–174. doi:10.1348/000712603321661859

Solso, R. L., & Juel, C. L. (1980). Positional frequency and versatility of bigrams for two- through nine-letter English words. *Behavior Research Methods & Instrumentation*, *12*, 297–343. doi:10.3758/BF03201669

Taft, M. (1979). Lexical access via an orthographic code: The Basic Orthographic Syllabic Structure (BOSS). *Journal of Verbal Learning and Verbal Behavior*, *18*, 21–39. doi:10.1016/S0022-5371(79)90544-9

Taft, M. (1987). Morphographic processing. The BOSS re-emerges. In M. Coltheart (Ed.), *Attention and performance* (Vol. XII, pp. 265–279). London, UK: Erlbaum.

Taft, M. (1992). The body of the BOSS: Subsyllabic units in the lexical processing of polysyllabic words. *Journal of Experimental Psychology: Human Perception and Performance*, *18*, 1004–1014. doi:10.1037/0096-1523.18.4.1004

Taft, M. (2001). Processing of orthographic structure by adults of different reading ability. *Language and Speech*, *44*, 351–376. doi:10.1177/00238309010440030301

Taft, M. (2002). Orthographic processing of polysyllabic words by native and non-native English speakers. *Brain & Language*, *81*, 532–544. doi:10.1006/brln.2001.2545

Taft, M., & Álvarez, C. J. (2014). Coda optimization in the segmentation of English polysyllabic letter-strings. *Experimental Psychology*, *61*(6), 488–494. doi:10.1027/1618-3169/a000266

Taft, M., Álvarez, C. J., & Carreiras, M. (2007). Cross-language differences in the use of internal orthographic structure when reading polysyllabic words. *The Mental Lexicon*, *2*, 49–63. doi:10.1075/ml.2.1.04taf

Taft, M., & Hambly, G. (1985). The influence of orthography on phonological representations in the lexicon. *Journal of Memory and Language*, *24*, 320–335. doi:10.1016/0749-596X(85)90031-2

Taft, M., & Kougious, P. (2004). The processing of morpheme-like units in monomorphemic words. *Brain and Language*, *90*, 9–16. doi:10.1016/S0093-934X(03)00415-2

Taft, M., Xu, J., & Li, S. (2017). Letter coding in visual word recognition: The impact of embedded words. *Journal of Memory and Language*, *92*, 14–25. doi:10.1016/j.jml.2016.05.002

Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading acrosslanguages: A psycholinguistic grain size theory. *Psychological Bulletin*, *131*(1), 3–29. doi:10.1037/0033-2909.131.1.3

Appendix

Table A1. Items used in the experiment, presented in pairs ordered by condition.

Syllabic—High Frequency	BOSS—High Frequency	Syllabic—Low Frequency	BOSS—Low Frequency
BARTO	**BAROS**	**BUEYPE**	**BUEYEI**
BIENCU	**BIENAS**	CALCER	CALEUR
BUENDO	**BUENUL**	**CLANTIR**	**CLANUOL**
CIENDE	CIENIL	**CLIPTES**	**CLIPAIN**
CUALFO	**CUALEN**	COLDUS	COLUAS
DOSCOI	**DOSUOR**	**FANSES**	**FANUAR**
FLORTO	FLORUN	**FAZBIN**	**FAZIUS**
GRANFO	**GRANIE**	**FLANVIS**	**FLANEID**
HOYNA	**HOYUR**	**GELGUL**	**GELUOS**
LEYFOIR	**LEYUAID**	**GENFAR**	**GENAUR**
MALPOS	**MALIOR**	**GOLMID**	**GOLION**
MARDIL	MARUES	**HIELCU**	**HIELEI**
MILFAL	**MILUER**	**HUIRBES**	**HUIRAIN**
PANTOI	PANIOS	**MIELVOL**	**MIELOIR**
PLANGED	PLANIOR	**ROLPE**	**ROLUR**
REYGU	**REYUO**	**RONGE**	**RONOL**
SERDER	SERIUL	**RUINVI**	**RUINER**
SOLTON	SOLEIN	VILBUR	VILIOD
SURCUL	SURIEN	**ZARTAS**	**ZARAIR**
TRENDU	**TRENUD**		
TRESPEI	TRESOIL		

Note. Those stimulus pairs that behaved in the expected direction (faster for words with a consonant after the embedded than with a vowel) are highlighted.