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Syllables and Morphemes: Contrasting Frequency Effects in Spanish

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Three types of sublexical units were studied in Spanish visual word recognition: the syllable, the basic orthographic syllabic structure (BOSS), and the root morpheme. In Experiment 1, using a lexical-decision task, a typical inhibitory effect of the first-syllable frequency was found (while keeping constant the BOSS frequency) as well as the word-frequency effect. Experiment 2 examined the role of both the BOSS frequency and the word frequency, also in a lexical-decision task. Syllable frequency was controlled. Both the BOSS frequency and the word frequency showed facilitatory effects. However, in Experiments 3A and 3B, a facilitatory effect of the root frequency (when controlling for BOSS frequency) and a null effect of BOSS frequency (when controlling for root frequency) were found, suggesting that the BOSS effect is in fact reflecting a morpheme effect. A review of the current models shows that it is difficult to integrate syllables and morphemes in a unique model.

One of the most debated questions in the field of visual word recognition is whether words are recognized holistically or decomposed into sublexical components. A great amount of research has been devoted to whether sublexical units are entailed in the analysis of the input and, if so, what sublexical units are functionally relevant in word processing. In fact, for some models of word recognition, access can be achieved directly, without any parsing stage prior to whole-word recognition (e.g., Morton, 1969), whereas for others, lexical access occurs from an initial partial description of the input (e.g., Forster, 1976). Among the proposals that argue for a decomposition or sublexical processing of the visual stimulus, several studies have found support for the syllable and syllable-based units as psychologically relevant structures. Thus, there is some evidence in English suggesting that the syllable plays a role in the process of lexical access (Lima & Pollatsek, 1983; Millis, 1986; Prinzmetal, Treiman, & Rho, 1986; Rapp, 1992; Spoehr & Smith, 1973; Taft & Forster, 1976; Tousman & Inhoff, 1992). Moreover, some syllable-based structures have also received empirical support, such as Vocalic Center Groups (Spoehr & Smith, 1973) and the subsyllabic components of onset and rime or body (e.g., Taft, 1992; Treiman & Chafetz, 1987; Treiman, Mullennix, Bijeljac-Babic, & Richmond-Welty, 1995).

Most of these studies share the notion that the initial part of a word is crucial for visual lexical access, although this initial part can be defined in different ways, depending on what unit is assumed to be psychologically functional. Within this context, proposals based on the initial phonological syllable have faced serious problems in a language such as English. There is no single accepted linguistic theory about how words must be syllabified in English because syllable boundaries are not well defined. Syllable boundaries tend to be modified by stress, and cases of ambisyllabicity (phonemes that could belong either to the preceding or to the following syllables) are common (Selkirk, 1982). In addition, syllabification does not always preserve morphological structure (e.g., *eating* has the syllabic structure *ea* + *ting* that cuts across the morphological structure *eat* + *ing;* see Sánchez-Casas, 1996; Taft & Forster, 1976) and several studies have found that morphology is computed when processing words (see, e.g., Sandra, 1994, for a review). To avoid this problem, Taft (1979a) proposed that lexical entries are accessed through the morphographic initial syllable of the word. Whereas other authors have opted for the orthographic realization of the syllable defined in phonological terms (e.g., Spoehr & Smith, 1973), Taft argued that the important unit for access purposes in reading is the orthographically and morphologically defined first syllable of the word, regardless of the phonologically defined syllable structure. This unit was called the BOSS (basic orthographic syllabic structure), and it is the first part of the root morpheme of a word, including all consonants following the first vowel, but without creating an illegal consonant cluster in its final position. For example, although the word *virus* is phonologically syllabified as *vi* + *rus,* the BOSS analysis gives the first unit as *vir,* which is also the case for *viral* and *virile.*

There is evidence that supports the notion of the BOSS as an access code in visual word recognition, at least in English (e.g., Taft, 1979a, 1986, 1987, 1992; Taft & Forster, 1976; see Taft, 1991, for a review). Several of the aforementioned studies have found that stimuli with a division (spatial or temporal) immediately after the BOSS are recognized faster than stimuli segmented elsewhere in the word. Nevertheless, other studies have failed to replicate these findings: Lima and Pollatsek (1983), for instance, did not find any superiority of the BOSS division over morpheme

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division or phonological-syllable division. Thus, the picture in English is unclear.[1]

In contrast to English, Spanish is a transparent orthography with a very close grapheme-to-phoneme correspondence. Perhaps more importantly, it has a very regular syllabic structure with clearly defined syllable boundaries that are resistant to stress movement (Harris, 1983; Sánchez-Casas, 1996), and there is almost no ambisyllabicity.

Although the BOSS and the syllable (henceforth, referring to the *phonologically defined syllable*) sometimes coincide in English (notably when the first vowel is short and stressed, as in the *hab* of *habit*), there is no such correspondence in Spanish. For instance, in the word *cocina* (kitchen), the BOSS is *coc*, although the first syllable is *co*. Similar to the studies of Lima and Pollatsek (1983) in English, studies comparing syllables and BOSSes in Spanish have not found any superiority of the BOSS (see Sánchez-Casas, 1996, for a review).

In contrast, there is considerable evidence that syllables play a role in visual word recognition in Spanish. Most of this evidence assessing the importance of the syllable in reading words has been obtained by manipulating the token positional syllable frequency, an index based on the number of times that a syllable appears in a particular position in a word. This index has been calculated from a corpus or database of printed words extracted from different samples of natural texts (Alvarez, Carreiras, & de Vega, 1992; Cobos et al., 1995). For example, the syllable *de* is of higher frequency in first position (as in the word *derecho*—right) than is *ci* (as in *cigarro*—cigarette). It has been shown that syllable frequency influences reading times for words embedded in texts (de Vega, Carreiras, Gutiérrez, & Alonso, 1990), lexical-decision times (Alvarez, Carreiras, & de Vega, in press; Alvarez, de Vega, & Carreiras, 1998; Carreiras, Alvarez, & de Vega, 1993; Domínguez, Cuetos, & de Vega, 1993; Perea & Carreiras, 1998), naming times (Carreiras et al., 1993; Domínguez et al., 1993; Perea & Carreiras, 1998), and recognition latencies in progressive demasking (Perea & Carreiras, 1995).

The most important results are that syllable frequency produced what we call an inhibitory effect: Words with high-frequency syllables produce longer reaction times (RTs) and a higher percentage of errors than words with low-frequency syllables, in tasks such as lexical decision and progressive demasking.[2] This result was explained in the framework of an activational model with a syllabic level of processing, where syllabic units activate lexical nodes. The initial studies assumed that high-frequency syllables activated a larger cohort of lexical candidates (or syllabic neighbors) than low-frequency syllables and the mutual inhibition or competition among activated word nodes explained the syllable-frequency effect. Although the token syllable frequency is the factor that has been manipulated (i.e., the number of times that a syllable appears in a particular position in a word), it could be argued that a type measure (the number of words in which a syllable appears in a particular position) would be more appropriate to reflect this hypothesized competition among word nodes. In any case, a type syllable frequency measure has not been available until recently, and both measures (type and token syllable frequency) are highly correlated.

More recent studies, assuming the same activational framework (e.g., Perea & Carreiras, 1998), have found that the syllable-frequency effect is mainly caused by the number of higher frequency syllabic neighbors that are activated (words that share the first syllable with the stimulus and have a higher frequency), instead of by the number of syllabic neighbors per se. Researchers have tested this inhibitory mechanism using a masked priming paradigm where the prime and target were syllabic neighbors (Carreiras & Perea, 2000; see also Domínguez, de Vega, & Cuetos, 1997, with unmasked priming). Inhibitory priming effects were obtained for stimuli that shared their first syllable, only when the prime was of higher frequency than the target, and they became facilitatory when the same target (a low-frequency word) was preceded by a pseudoword prime.

Although the interaction between word frequency and syllable frequency was only occasionally reliable, the inhibitory syllable-frequency effect has always been larger for low-frequency words (Alvarez et al., in press; Alvarez et al., 1998; Carreiras et al., 1993; Perea & Carreiras, 1998), a result that supports the aforementioned activational-syllabic proposal, because high-frequency words will be less affected by the frequency of the syllabic neighbors than will low-frequency words. The syllable-frequency effect is also fully compatible with other related activational models, such as the theoretical framework adopted by Ferrand, Grainger, and Seguí (1994). In fact, Ferrand, Seguí, and Grainger (1996) explained the inhibitory effect of syllable frequency found by Carreiras et al. (1993) in the lexical-decision task by locating the effect at the level of sublexical input phonology and assuming that this level is syllabically organized. The syllabic units send their activation to the word nodes, and a lexical inhibition process would explain the syllable-frequency effect.

Several studies have demonstrated that the syllable-frequency effect cannot be explained in terms of potentially confounding factors, such as bigram frequency (Carreiras et al., 1993), orthographic neighborhood density and neighborhood frequency (Perea & Carreiras, 1998) and stress position (Alvarez et al., in press). So, the evidence appears to be strong that the syllable is an important unit in the recognition of Spanish words. Furthermore, recent evidence (Alvarez et al., in press; Alvarez et al., 1998) suggests that the initial syllable takes on the main role in activating lexical candidates, a conclusion that has also been assumed by others when focusing on the manipulation of syllable frequency (e.g., Perea & Carreiras, 1998).

However, the results of those experiments that manipulate the frequency of the first syllable could equally be explained in terms of the BOSS. Although the syllable and the BOSS are not confounded as units in Spanish, their frequencies are likely to be correlated. For example, although the *pa* of *parecer* (to look like) is a high-frequency syllable, *par* is a high-frequency BOSS; and although the *ti* of *tiburon* (shark) is a low-frequency syllable, *tib* is a low-frequency BOSS. It is therefore possible that it is the BOSS, and not the syllable, that plays a crucial role in the recognition of Spanish words. Although such an idea draws little support from past research (see Sánchez-Casas, 1996), it needs to be examined

[1] Recent research in Taft's laboratory suggests that whether a BOSS division leads to faster responses than a syllable division might be influenced by reading proficiency.

[2] A null or a reverse effect occurs in naming, a task that "may be sensitive to syllable frequency by both its inhibitory influence on lexical access and its facilitatory influence on construction of phonological output (e.g. faster access to the mental syllabary)" (Perea & Carreiras, 1998, p. 142).

as a possibility because it offers an alternative conclusion. In addition, it is not known whether the BOSS frequency could have inhibitory effects or facilitatory effects. If the effects turn out to be inhibitory, then it is possible that the syllable-frequency effect is in fact a BOSS effect.

Thus, the goal of the present research is to determine whether the frequency of the BOSS has an impact on word recognition in Spanish and, indeed, whether it entirely accounts for the syllable-frequency effect. To this end, we tested trisyllabic words in Experiment 1 by manipulating first-syllable type frequency (i.e., the number of words in which a syllable appears in a particular position) while keeping BOSS frequency constant. Our aim was to ascertain whether any inhibitory effect arises from the syllable itself or from the larger BOSS unit. Type syllable frequency instead of token syllable frequency was manipulated for the reason mentioned above (i.e., it seems to more appropriately reflect the competition among word nodes than does a token measure).

Experiment 1

The BOSS seems an important unit of processing in English, as suggested by the aforementioned work of Taft, and it could be the case that it is also important in other languages. In particular, the BOSS provides a principled way of analyzing a letter string into smaller units, but if a language has a very clear syllabic structure in its phonology, then the syllable already offers this function, and the BOSS is unnecessary. Indeed, Taft and Radeau (1995) found that the syllable and not the BOSS was important in the naming of French nonwords (where there are clear syllable boundaries), in contrast to the similar study by Taft (1992) that found the reverse to be the case in English. For this reason, it is unlikely that the syllable-frequency effect can be accounted for in terms of BOSS frequency, and, therefore, we expect that the effect will be upheld even when this potential confounding factor is held constant.

Method

Participants. Thirty-five undergraduate students from the University of La Laguna took part in the experiment, receiving course credit for their participation.

Design and materials. Forty trisyllabic words, six to seven letters long, were selected from the *Dictionary of Frequencies of the Spanish Linguistic Units* (Alameda & Cuetos, 1995), a database of two million words, according to the orthogonal combination of two factors: word frequency (high vs. low) and type positional syllable frequency of the first syllable (high vs. low). The design was a 2 × 2 within-participants but between-items design. Words were considered of high frequency when they had a minimum frequency of occurrence of 20 per two-million and of low frequency when they had a maximum frequency of 10 per two-million. First syllables were considered of high frequency when they had a minimum type frequency of occurrence of 200 and of low frequency when they had a maximum frequency of 96. The syllable frequency was extracted from the *Dictionary of Frequency of Spanish Syllables* (Cobos et al., 1995), a dictionary from the aforementioned database (Alameda & Cuetos, 1995). Words were matched across conditions for length and BOSS frequency (the number of words that share the same BOSS, according to the database of Alameda & Cuetos, 1995). For instance, *madera* (wood) is a high-frequency word, and *madeja* (ball of wool) is low frequency, but both have a high-frequency first syllable (*ma*). The same is true for *helado* (ice cream) and *helice* (helix), but in this case they have a low-frequency first syllable (*he*). However, the frequency of their BOSSes are matched (i.e., *mad* has the same frequency as *hel*). The characteristics of the words are presented in Table 1, together with the token syllable frequency, which is the factor that has been manipulated in previous experiments dealing with syllable frequency. The word items can be found in the Appendix.

In addition, 40 trisyllabic orthographically legal pseudowords (having only legal syllables in Spanish) were constructed matching for length with the words (e.g., *deruti*).

Procedure. Participants were tested individually in a quiet room. They were instructed to pay attention to a string of letters (words and nonwords) presented on the center of a computer screen in lowercase and to make a lexical-decision response as quickly and accurately as possible. The experiment was controlled by an IBM-compatible 386 PC. Each trial started with the presentation of a fixation point (an asterisk) for 600 ms, which was replaced by the stimulus centered in the same place where the asterisk was. The stimulus remained until participants responded by pressing one of two keys: The *L* key when it was a word and the *A* key when it was a nonword (the *L* key was labeled *si*, which means *yes* in Spanish, and the *A* key was labeled *no*). The next sequence followed after a 1 s delay. Eighteen practice trials were followed by the 80 experimental trials. Items (words and pseudowords) were presented in random order. The computer recorded participants' responses and RTs.

Results

Incorrect responses (3% of the data) and RTs more than 2.0 standard deviations above or below the mean for each participant and each condition (1%) were excluded from the latency analyses. Mean RTs and error data on words were submitted to separate analyses of variance (ANOVAs) with word frequency and syllable frequency as within-participants but between-items factors. The mean lexical-decision time and error rate in each condition are presented in Figure 1.

The ANOVAs for the latency data revealed a main effect of word frequency, $F_1(1, 34) = 56.99, p \leq .001$; $F_2(1, 36) = 33.81, p \leq .001$, in which high-frequency words were responded to faster than low-frequency words. In addition, and more interestingly, first-syllable frequency was significant, $F_1(1, 34) = 16.81, p \leq .001$; $F_2(1, 36) = 4.39, p \leq .05$, showing that words with a low-frequency first syllable produced faster RTs than words with a high-frequency first syllable. The interaction between both factors was reliable, though only by participants, $F_1(1, 34) = 9.20, p \leq .01$; $F_2(1, 36) = 2.63, p \leq .1$, indicating that the first-syllable frequency effect was stronger in low-frequency words (a difference of 53 ms) than in high-frequency words (only an 8-ms difference).

Analyses over the error rate showed that the interaction between syllable frequency and word frequency was the only effect significant in the by-participants analysis, $F_1(1, 34) = 27.99, p \leq .001$, and marginally in the by-items analysis, $F_2(1, 36) = 3.19, p \leq .1$. The difference between high- and low-frequency syllable was

Table 1
Characteristics of Words Used in Experiment 1

Syllable and word frequency	SF type		SF token		WF		BF	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
High SF–High WF	364	117	6,056	1,727	112	79	28	13
High SF–Low WF	376	122	5,672	1,940	3	2	27	12
Low SF–High WF	61	24	628	396	32	15	29	13
Low SF–Low WF	68	23	758	573	6	3	30	11

Note. SF = syllable frequency; WF = word frequency; BF = basic orthographic syllable structure (BOSS) frequency.

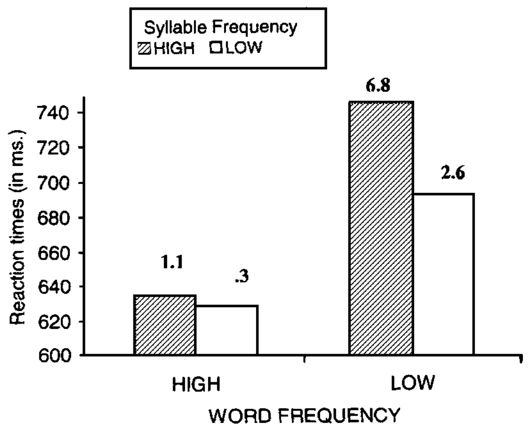

Figure 1. Mean reaction times and error rates as a function of first-syllable frequency (high vs. low) and word frequency (high vs. low) in the lexical decision task (Experiment 1). Error rates are shown at the top of the bars.

greater for low-frequency words (7% and 3%, respectively) than for high-frequency words (1% and 0.3%).

Discussion

The results of this first experiment were totally consistent with previous research on syllable frequency: Words with first syllables of high frequency were recognized more slowly (and with more errors) than words with first syllables of low frequency. The word-frequency pattern was the typical one, with high-frequency words being recognized faster than low-frequency words. In addition, the interaction (only reliable by participants) showed that the inhibitory effect of syllable frequency was larger for low-frequency words than for high-frequency words. This finding has been consistently obtained in previous experiments with lexical-decision tasks (Alvarez et al., in press, Experiments 1, 2, & 3; Carreiras et al., 1993, Experiment 3; Perea & Carreiras, 1998, Experiments 1 & 3). In all of these studies, the interactions between first-syllable frequency and word frequency were nonsignificant, although the magnitude of the syllable-frequency effect was always greater for low-frequency words than for high-frequency words. Given that BOSS frequency was controlled in this experiment, the syllable-frequency effect cannot be explained in terms of units larger than the syllable.

Additionally, the main manipulation of this experiment was type syllable frequency instead of token syllable frequency (which was manipulated in the past research on the topic). The reason for this fact is that the number of words that include a syllable in first position better reflects the competition among word nodes (assumed in the model) than the number of times a syllable appears in first position (a token measure). In any case, both factors are highly correlated and show the same trend, as can be seen in Table 1. On the other hand, Perea and Carreiras (1998; see also Alvarez et al., in press) have found that the syllable-frequency effect is due to the number of syllabic neighbors (words that share the first syllable) of higher frequency than the stimulus and not to the number of syllabic neighbors per se. To test if the syllable-frequency effect was truly related to the number of higher frequency syllabic neighbors, we calculated the Pearson correlation between the number of higher frequency syllabic neighbors and the type syllable frequency in the words used in the experiment and found a correlation of .936, $p < .001$. So the observed effect could just as likely have arisen from the number of higher frequency neighbors as from the total number of neighbors.

Thus, an activation model with a syllabic level (as has also been suggested by Ferrand et al., 1996; Rapp, 1992; and Tousman & Inhoff, 1992) is again supported by the present data. In such a model, high-frequency syllables in first position would activate more syllabic neighbors and, importantly, more higher frequency syllabic neighbors than low-frequency syllables, and the mutual inhibition among word nodes would explain the inhibitory effect of first-syllable frequency. The fact that this effect is greater for low-frequency words is explained in terms of the competition between word nodes having less impact when their resting levels of activation are high (e.g., Alvarez et al., in press; Carreiras et al., 1993; Perea & Carreiras, 1998).

Experiment 2

Experiment 1 demonstrated, once again, that the syllable-frequency effect in Spanish visual word recognition is robust and is not modulated by the frequency of the BOSS. As discussed by Sánchez-Casas (1996), previous studies have failed to find any support for the BOSS as being functional in Spanish. However, these experiments did not find any superiority of the syllable over the BOSS (see the results of Sánchez-Casas, 1988, and Sánchez-Casas, García-Albea, & Bradley, 1991). The results obtained by Sánchez-Casas et al. (1991) stand in clear conflict with the large amount of positive evidence about the role of syllable frequency in Spanish visual word recognition previously discussed. Moreover, in the research by Sánchez-Casas (1988) neither the syllable frequency nor the BOSS frequency were manipulated.

Because BOSS frequency might be highly correlated with syllable frequency, we could provide further evidence for the importance of the syllable by demonstrating no effect of BOSS frequency when syllable frequency is held constant, in contrast to the finding of an effect of syllable frequency when BOSS frequency is held constant. If BOSS frequency was contributing to some extent to the syllable-frequency effect, we should also find an inhibitory effect of BOSS frequency when syllable frequency is held constant. This possibility is explored in the next experiment, where we manipulated BOSS frequency and kept constant syllable frequency in a lexical-decision task.

Method

Participants. Thirty-five students from introductory psychology courses at the University of La Laguna participated in the experiment to earn extra course credit. None of them had participated in the previous experiment.

Design and materials. A total of 56 three-syllable Spanish words, all of them six or seven letters long, were extracted from the Spanish two-million-words pool by Alameda and Cuetos (1995), by combining two factors in a 2 × 2 within-participant design: word frequency (high vs. low) and BOSS frequency (high vs. low). BOSS frequency was the number of different words that shared the BOSS (i.e., type frequency). The word-frequency range was 21–835 for high-frequency words and 1–11 for low-frequency words. BOSSes were considered of high frequency when they had a minimum frequency of occurrence of 40 and of low frequency when they had a maximum frequency of 35. Words were matched across conditions for length and syllable frequency. For example, *pálido* (pale) and *pájaro* (bird) have a BOSS frequency of 137 and 28, respectively. However, the first-syllable frequency is the same (in fact, they share the first syllable). The characteristics of the words are presented in Table 2, together with their token syllable frequency. Items are found in the Appendix.

Procedure. The procedure was identical to that of Experiment 1.

Results

RTs more than 2.0 standard deviations above or below the mean for each participant and each condition (1%) as well as incorrect responses (3% of the data) were excluded from the RTs analyses. Mean RTs and percentage of errors on words were submitted to separate ANOVAs with word frequency and BOSS frequency as within-participants but between-items factors. Mean lexical-decision time and error rate in each condition are displayed in Figure 2.

The ANOVAs on latency data showed a main effect of word frequency, $F_1(1, 34) = 113.50, p \leq .001$; $F_2(1, 52) = 40.21, p \leq .001$, with high-frequency words being responded to faster than low-frequency words. The main effect of BOSS frequency was also reliable, $F_1(1, 34) = 15.77, p \leq .001$; $F_2(1, 52) = 5.32, p \leq .01$, displaying faster RTs for words with high-frequency BOSSes than for words with low-frequency BOSSes. The interaction did not yield significance, both $Fs < 1$.

The same significant effects were obtained in the analyses over error rate: word frequency, $F_1(1, 34) = 51.88, p \leq .001$; $F_2(1, 52) = 9.47, p \leq .005$; and BOSS frequency (only by participants), $F_1(1, 34) = 18.24, p \leq .001$; $F_2(1, 52) = 2.82, p \leq .1$. More errors were observed for low-frequency words than for high-frequency words and for words with low-frequency BOSSes than words with high-frequency BOSSes. The interaction was not significant, $F_1(1, 34) = 3.90, p \leq .1$; $F_2(1, 52) = 2.82, p \leq .1$.

Discussion

First of all, BOSS frequency produced a facilitatory effect (i.e., an effect opposed to that of syllable frequency). This result allows us to conclude that the BOSS-frequency effect is not related to syllable frequency at all. Instead, one now has to explain the facilitatory effect of BOSS frequency because two syllabic units (syllables and BOSSes) acting together as processing units and displaying opposite effects of frequency is highly improbable.

Despite holding syllable frequency constant across conditions, there are still other possible contributing factors that could be related to BOSS frequency that were not controlled. One possibility is orthographic neighborhood size, that is, the number of words of the same length that share all letters except one with the given word (Coltheart, Davelaar, Jonasson, & Besner, 1977), and another is neighborhood frequency (the number of orthographic neighbors of higher frequency). Both factors have been found to have a strong influence in lexical access (see, e.g., Andrews, 1992; Carreiras, Perea, & Grainger, 1997; Grainger, 1990; Grainger & Seguí, 1990). Orthographic neighborhood effects could underlie the BOSS-frequency effect because, in most cases, the letters that compose the BOSS constitute more than half a word. It is likely that a word with a high-frequency BOSS, for instance, also has a large number of orthographic neighbors. Thus, it is conceivable that the BOSS-frequency effect could be, in fact, reflecting neighborhood effects.

Table 2
Characteristics of Words Used in Experiment 2

BOSS and word frequency	BF		WF		SF type		SF token	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
High BF–High WF	96	29	202	249	253	146	3,940	2,507
High BF–Low WF	99	31	5	3	253	146	3,940	2,507
Low BF–High WF	20	9	48	32	253	146	3,940	2,507
Low BF–Low WF	21	10	3	2	253	146	3,940	2,507

Note. SF = syllable frequency; WF = word frequency; BF = basic orthographic syllabic structure (BOSS) frequency.

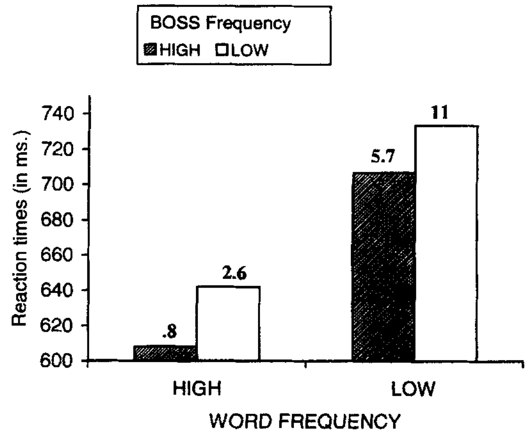

Figure 2. Mean reaction times and error rates as a function of BOSS frequency (high vs. low) and word frequency (high vs. low) in the lexical decision task (Experiment 2). Error rates are shown at the top of the bars. BOSS = basic orthographic syllable structure.

Another possibility is that the BOSS-frequency effect observed in this experiment is actually an effect of morpheme frequency. In many cases in Spanish, the BOSS is the root morpheme, and in others it is not. For instance, the BOSS of *bebedor* (drinker) is *beb,* and because it is found in other words pertaining to *drink,* it can be considered the root of *bebedor.* On the other hand, there are no other words sharing the BOSS *cam* with *camelia* (a kind of flower) that have a similar meaning, and therefore *camelia* would be considered monomorphemic (i.e., the root is *camelia* itself). Several studies (e.g., Taft, 1979b, in English; Burani, Salmaso, & Caramazza, 1984, in Italian) have found that the frequency of the root morpheme influences RTs (though no examination of this in Spanish has been reported). So, it is possible that the putative BOSS effect observed in Experiment 2 arose only from those items whose BOSS was the root morpheme.

To examine the importance of these morphological factors as well as the potential influence of neighborhood factors, we carried out a regression analysis on the RTs for words with five predictors: BOSS frequency, root morpheme frequency (the number of words that share the root, calculated from Alameda & Cuetos, 1995), number of higher frequency syllabic neighbors, number of orthographic neighbors, and number of higher frequency orthographic neighbors.

Results revealed significant effects for only the number of higher frequency syllabic neighbors, $t(50) = 3.14, p \leq .005$, with a Pearson correlation of .50 and a partial correlation of .40, and the root frequency, $t(50) = 2.27$, $p \leq .05$, with a Pearson correlation of −.35 and a partial correlation of −.30. This result suggests that syllable frequency and BOSS are tapping two different processes and that the BOSS frequency effect could actually be interpreted as a morpheme frequency effect. This result also overcomes the problem of having to say that there are two different types of syllabic units used in lexical processing and producing opposite results. However, the previous studies reporting morpheme frequency effects (Bradley, 1980; Burani & Caramazza, 1987; Burani et al., 1984; Colé, Beauvillain, & Seguí, 1989; Colé, Seguí, & Taft, 1997; Taft, 1979b) have manipulated token morpheme frequency, whereas we introduced type root frequency in the regression analysis (to get a direct comparison with the syllable frequency and the BOSS frequency that were type frequency). For this reason, we estimated the token root frequency of the stimuli of Experiment 2 and obtained a correlation with the type root frequency of .62, $p < .001$. This high correlation supports our suggestion about the explanation of the BOSS frequency effect in terms of the morphological frequency and agrees with the previous studies carried out in English and Italian. The purpose of the next experiment was to obtain more direct evidence on this issue.

Experiments 3A and 3B

To test if the root frequency is in fact responsible for the observed facilitatory BOSS frequency effect, we carried out two additional and complementary experiments. In Experiment 3A, we manipulated BOSS frequency while keeping root frequency constant. In Experiment 3B, we reversed this procedure: we manipulated root frequency and kept BOSS frequency constant. If the root frequency is the factor responsible for the BOSS frequency effect, two results are expected: (a) a null effect of the BOSS frequency (when controlling for root frequency) and (b) a facilitatory effect of the root frequency (when controlling for BOSS frequency).

Method

Participants. Sixty students from the University of La Laguna participated to obtain course credits (30 in Experiment 3A and 30 in Experiment 3B).

Design and material. All the critical words were selected from Alameda and Cuetos (1995) database. For Experiment 3A, 28 trisyllabic words were selected according to their type BOSS frequency: 14 words had high-frequency BOSSes and 14 low-frequency BOSSes. Both conditions were matched for length, word frequency, type root frequency, token root frequency, and approximate type syllable frequency of the first syllable. For Experiment 3B, 30 trisyllabic words were selected, but in this case the root frequency (both type and token) was manipulated. Fifteen words had a high-frequency root and 15 had a low-frequency root. Both sets of words were matched for length, word frequency, type BOSS frequency, and approximate type syllable frequency of the first syllable. In addition, 58 trisyllabic pseudowords having only legal syllables in Spanish were matched for length with words (28 for Experiment 3A and 30 for Experiment 3B) for the lexical-decision tasks. The characteristics of the words are presented in Table 3.

Procedure. A lexical-decision task was used in both cases, as in the experiments reported before.

Results

After excluding RTs more than 2.0 standard deviations above or below the mean for each participant and each condition (3% in Experiment 3A and 2% in Experiment 3B) as well as incorrect responses (5% in Experiment 3A and 6% in Experiment 3B), we conducted *t* tests by participants and *t* tests by items over the RTs and over the error rates for words separately in both Experiments 3A & 3B. Mean lexical decision times and error rates are illustrated in Figure 3.

Experiment 3A. There was no significant difference between words with high- (669 ms) and low- (660 ms) frequency BOSSes, $t_1(29) = 1.12$, $p > .05$; $t_2 < .1$. The analyses of the percentage of errors showed slightly more errors observed in words with low-frequency BOSSes (6%) than in words with high-frequency BOSSes (3%), but this result was not significant, $t_1(29) = 1.89$, $p = .068$; $t_2 < .1$.

When the root frequency is held constant, the facilitatory effect of the BOSS frequency disappears, a result that suggests that the pattern of data obtained in Experiment 2 was in fact, due to the root (morpheme) frequency, as also suggested by the regression analysis of those data.

Experiment 3B. The difference between the two conditions (high vs. low root frequency) was reliable: Longer RTs were found for words with low-frequency roots (692 ms) than for words with high-frequency roots (646 ms), $t_1(29) = 5.05$, $p < .001$; $t_2(28) = 2.90$, $p < .01$. Similarly, the analysis of error rate showed a significant difference only by participants, with more errors in words with low-frequency roots (9%) than in words with high-frequency roots (2%), $t_1(29) = 5.48$, $p < .001$; $t_2(28) = 1.67$, $p > .05$.

The results confirmed the predictions: (a) root frequency produced a facilitatory effect when BOSS frequency was controlled, and (b) there was no difference between words with high- and low-frequency BOSSes when the root frequency was held constant.

Table 3
Characteristics of Words Used in Experiments 3A and 3B

BOSS and root frequency	BF		WF		RF type		RF token		SF type	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
High BF	107	57	8	7	10	10	70	116	292	153
Low BF	19	8	7	6	9	9	73	99	249	143
High RF	70	46	6	4	46	16	947	1,261	208	161
Low RF	69	51	5	4	3	2	9	5	271	136

Note. RF = root frequency; SF = syllable frequency; WF = word frequency; BF = basic orthographic syllabic structure (BOSS) frequency.

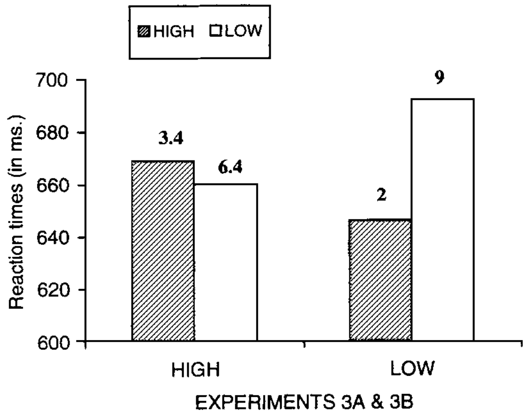

Figure 3. Mean reaction times and error rates as a function of BOSS frequency (high vs. low) and root frequency (high vs. low) in the lexical decision tasks (Experiment 3A and 3B). Error rates are shown at the top of the bars.

General Discussion

The main goal of the three experiments reported here was to study the differential role of frequency in three types of sublexical units on the visual recognition of Spanish words: the syllable, the BOSS, and the root morpheme. First, we examined whether the inhibitory syllable-frequency effect, which has been repeatedly found, could be accounted for or modulated by the frequency of the morphographic syllable (BOSS), though manipulating type syllable frequency instead of token syllable frequency. The first experiment showed that the type frequency of the word's first syllable had an impact on lexical-decision times and errors. This effect was inhibitory: Words with high-frequency first syllables were harder to recognize than words having low-frequency first syllables. In addition, there was a strong tendency for the syllable-frequency effect to be stronger for low-frequency words than for high-frequency words. Finally, the syllable-frequency effect cannot be explained by either the BOSS frequency or orthographic neighborhood factors, but it is related to the number of higher frequency syllabic neighbors. These results are fully consistent with those of previous studies in Spanish using the lexical-decision task (Alvarez et al., in press; Alvarez et al., 1998; Carreiras et al., 1993; Carreiras & Perea, 2000; Domínguez et al., 1993; Perea & Carreiras, 1998), and they provide additional support for the proposal made by these authors that the syllable is an important processing unit in visual word recognition. It is proposed that all words that share the first syllable of the target word receive activation from the syllabic level and thus compete with each other (see also Zhou & Marslen-Wilson, 1994, in relation to spoken word recognition). Words with high-frequency first syllables have a higher probability of activating words (syllabic neighbors) of higher frequency than do words with low-frequency syllables. For that reason, the syllable-frequency effect tends to be stronger in low-frequency words (Alvarez et al., in press; Perea & Carreiras, 1998). Thus, it is the mutual inhibition among activated word nodes that underlies the syllable-frequency effect (Carreiras & Perea, 2000; Domínguez et al., 1997).

In Experiment 2, we explored the possible role of the BOSS in Spanish visual word recognition and found that both the BOSS frequency and the word frequency showed independent effects in lexical decision. However, both of these frequency effects were facilitatory. Thus, the frequency of the BOSS produced the opposite effect to that of syllable frequency, allowing us to conclude that BOSS frequency is unrelated to syllable frequency. A regression analysis carried out in this experiment together with the results of Experiments 3A and 3B indicated that morphological frequency (the root frequency) was the factor responsible for the observed BOSS frequency effect, agreeing with previous research on morpheme frequency effects (Bradley, 1980; Burani & Caramazza, 1987; Burani et al., 1984; Colé et al., 1989). In addition, Experiments 3A and 3B showed that the effect of root frequency was not related to syllable frequency.

To summarize, we have found two reliable results showing opposite trends: Although syllable frequency produces an inhibitory effect, root frequency is facilitatory. Both effects are robust and have appeared several times in the literature (root frequency in English and Italian and syllable frequency in Spanish). Thus, one important conclusion that we can draw from these data is that syllable frequency is not related either to BOSS frequency or to morpheme frequency. Instead, one now has to explain how the system makes use of both syllables and morphemes such that they produce an inverse pattern of data.

There have been several proposals and models that argue for orthographic, phonological, and morphological processing working together (although independently) in visual word recognition. For example, Lima and Pollatsek (1983) suggested that both phonological and morphemic units are entailed in word processing. More specifically, the interactive–activation model proposed by Taft (1991, 1994) is composed of a hierarchy of both orthographic and phonological units, where there is a morphemic level immediately below the whole word level. Orthographic units are linked directly to phonological units at all levels, including the grapheme–phoneme level and the morphemic level. Whether phonological activation is mandatory in orthographic processing is debatable (see Taft & van Graan, 1998), but the likelihood of such activation is at least optimized when the correspondence between graphemes and phonemes is regular, as in Spanish.

These arguments lead us to discuss the role played by syllabic and morphological information in accessing words in Spanish, as well as how they are represented. Therefore, we consider the implications of our results in the light of the current models of representation and access of morphologically complex words.

Models Based on Obligatory Morphological Mediation

One sort of model assumes that morphological decomposition precedes access to the whole word representation, with stems constituting the lexical entries for affixed words (e.g., Taft & Forster, 1976). In more recent formulations (e.g., Taft, 1991, 1994; Taft & Zhu, 1995), there is a morpheme level between letter and word units so that the words are accessed through activation of their morphemes. Because the access process is exclusively based on morphemes, this proposal does not account for the large evidence provided for the role of syllables in Spanish. However, even though these models do not argue for a role of syllables in access, a syllable level could be located between letters and morphemes. Nevertheless, in Spanish, a syllable and a morpheme are not compatible in terms of their form because morphemes are not composed of one or more complete syllables. Roots usually tend to be the first syllable plus one or two additional letters (e.g., the root of *cogido*—taken—is *cog*, but the first syllable is *co*), and this is a problem if activation of a syllable node is supposed to send activation to a higher morpheme node. Although *co* will partly activate *cog*, it will also partly activate the roots *col, cor, cobr*, etc. In order for the appropriate node (*cog*) to win out over its competitors, one needs to suppose either that partial activation from the second syllable *gi* is sufficient to do this or that letter-by-letter processing is used after the first syllable (thus allowing the *g* to discriminate between the competitors). By this account, a high-frequency root will be accessed faster than a low-frequency one, but there will also be competition between the different roots incorporating the same syllable, and this will be greater for common syllables than for rare ones. It still remains to be independently shown, though, if syllables do activate roots rather than whole words and if partial information from the second syllable is used to discriminate between competitors.

Note that incompatibility of morphemes and submorphemic forms is not a problem if the submorphemic form is defined as the BOSS rather than the syllable. That is, the root of a word in Spanish tends also to be its BOSS. For example, *cog* is both the BOSS and root of *cogido*. This situation means that activation of a BOSS unit provides all the information necessary for activation of the appropriate morpheme unit (just as does the syllable unit in Chinese). Of course, the experiments reported here appear to provide no support for this position because BOSS frequency has no impact on recognition.

Models Based on an Independent or Postlexical Morphological Representation

Some proposals have claimed that morphologically related words are represented as whole undecomposed forms, accepting at the same time that morphology is represented as an independent or a postlexical level. Some of these proposals have suggested that morphologically related words are interconnected through morphological links. Fowler, Napps, and Feldman (1985) proposed a localist network with a syllable level, and the levels below it connected directly to the word nodes and not to the morpheme level, which would be an independent level. Morphological relatives have closer ties to each other than to other words in the lexicon. For Seguí and Zubizarreta (1985), also, morphological information is represented in terms of morphological families, which relate items that share the same root. According to this view, "each morphologically derived form constitutes a lexical entry but it is not an isolated lexical entry" (Beauvillain & Seguí, 1992, p. 378). Also for Lukatela, Gligorijevic, Kostic, and Turvey (1980), lexical entries are organized in a satellite-like structure around a particular central form: the nominative case. However, it is unclear how such accounts handle the effect of root frequency because, to do this, it is necessary to assume that, at some level of word processing, the input has been analyzed into its constituents and those constituents have been accessed.[3] In addition, the whole-word representation models cannot explain some other empirical data, in particular those results that have shown a higher difficulty to reject nonwords as real words when they include real morphemes (e.g., Taft & Forster, 1975; Caramazza, Laudanna, & Romani, 1988), because there is no decomposition at all for this sort of model. Finally, it is not clear what the function is of accessing a morphological family after accessing a member of that family (i.e., the presented word).

Mixed Models: Activation of Both Whole-Word and Morphemic Units

Between the two alternatives above, some proposals have combined the features of the whole-word and the decomposed representation (and access) accounts (e.g., Caramazza et al., 1988; Stemberger & MacWhinney, 1986). We consider here one of these models as a representative example. Caramazza and colleagues have proposed a theoretical framework (the Augmented Addressed Morphology model, AAM) mostly developed in a language very close to Spanish, namely, Italian. According to this model, lexical access to morphologically complex words takes place through whole-word access units for known words and through morphemic access units for unfamiliar morphologically regular words or novel words.

The AAM model has the flexibility to incorporate a syllable level of representation in either of the two routes, namely, in the morphemic route, the whole-word route, or both. In fact, Chialant and Caramazza (1995) suggested that "letter strings activate all the access units that correspond to parts of the stimulus, with constraints as to word and syllable boundaries" (p. 64). However, they did not explicitly go into the details of how syllables could fit into the model. If we assume that syllables activate morpheme units, the problem of the incompatibility of syllable and root forms is again present. Another possibility is that the syllable level is represented as an intermediate level between letters and whole-word forms, and this possibility would explain the competition of word nodes activated by syllables (syllable-frequency effect) as well as the root-frequency effect. However, the implication of the last proposal is that the syllable-frequency effect should only appear in known or frequent words, something that does not happen: The syllable-frequency effect is obtained for all kinds of words, and it is even stronger in low-frequency words (Experiment 1). Additionally, there is evidence that the syllable-frequency effect is also present in pseudowords (e.g., Alvarez et al., 1998; Carreiras et al., 1993).

With respect to the root frequency effect, it is not clear what sort of prediction the AAM model would make according to the characteristics of the words used in Experiment 3B. On the one hand, we found a root-frequency effect when controlling for word frequency, but all of the stimuli were of low (surface) frequency. In fact, the frequency of the roots was higher than the frequency of the words, and further, they were regular forms (predictable orthographic and morphological variations). According to the AAM model, these kinds of words would be processed through morpheme-sized units. On the other hand, 80% of the words used in Experiment 3B were either monomorphemic or derived words, and it is likely (according to the AAM model) that these words are processed through whole-word representations. Thus, it is not clear

[3] Several strategies have been put forward in these type of models to account for the root-frequency effect. If the root acts as an organizer of a cluster of words (as suggested by Seguí & Zubizarreta, 1985; Lukatela et al., 1980) and morphology is represented in an independent or postlexical level, then the root-frequency effect is explained through faster access to large families than to small families. However, this would imply that the access to whole words proceeds through the organizer (the root), also entailing some form of decomposition (see Chialant & Caramazza, 1995, for a comment on this issue).

from this proposal if we should find a root frequency effect (as an indicator of morpheme-based access) or not.

In addition, the model assumes that both access units (whole words and morphemes) are activated in parallel "to an extent which is directly proportional to the frequency of the access unit" (Chialant & Caramazza, 1995, p. 63). For the items in the high-frequency root condition of Experiment 3B, the frequency of the root (cumulative frequency) was much higher than the surface frequency. However, that difference was lower for the low-frequency roots. Because access through whole-word units is faster than through morpheme units, the model would predict shorter RTs for low-frequency roots than for high-frequency roots because most of the former were monomorphemic (where cumulative frequency is equivalent to surface frequency).

To summarize, it is not clear if this model could account for our root-frequency data. Additionally, it is unclear if it could incorporate syllable units and explain the syllable-frequency effect.

A Dual-Route Model of Lexical Access

The last model to be considered is a sort of a dual route model, not in the sense of the AAM but in the classical one (i.e. incorporating a phonological route to access the lexical entries: See, e.g., Coltheart, Curtis, Atkins, & Haller, 1993; Grainger & Ferrand, 1996). In this account, the morpheme-frequency effects arise in the orthographic system, whereas the syllable-frequency effects arise in the phonological system. The orthographic input would activate letters, and these grapheme nodes would activate morpheme units on the way to activating the whole word. At the same time, the graphemes are activating phoneme nodes in the phonological system. Assuming that sublexical input phonology is coded syllabically, as suggested by Ferrand et al. (1996), these phonemes will in turn activate syllabic units, which in turn will activate whole-word representations (through the mechanism proposed to explain the syllable-frequency effect). In fact, there is evidence obtained in Spanish suggesting that syllables are processing units in spoken word perception (e.g., Bradley, Sánchez-Casas, & García-Albea, 1993; Pallier, Sebastián, Felguera, Christophe, & Mehler, 1993). However, this hypothesis has to face the issue of why the syllable-frequency effect is inhibitory and the root-frequency effect is facilitatory. The arguments given by Marslen-Wilson et al. (1994) are appropriate in this context because they provide an explanation, though for spoken word recognition. The competition among morphologically unrelated words that belong to the same cohort (in our case, a syllabic cohort, such as *cocina* [kitchen], *cogido* [taken], *cometa* [comet], and *colilla* [ash]) is quite strong because of the lateral inhibition mechanism. However, morphologically related words are mutually exclusive because the same representation (the root morpheme) cannot be interpreted as two different lexical items, with different meanings and different syntactic properties. If we are reading *cogido* (taken), then *cogere* (I will take) is not considered as a competitive candidate. In contrast, *cogido* and *cocina* (kitchen) do not belong to the same lexical region. If we are reading *cogido*, then *cocina* remains in the system as a possible candidate, with its activation level decaying away over time as a result of further sensory information being compatible. However, this account needs to assume that words sharing the root have common connections to the semantic level.

This account can explain the effect of syllable frequency and the effect of root frequency, and it would not have to face the problem of the mapping between syllables and morphemes. Precisely because of the lack of mapping between syllables and morphemes, the latter would be activated directly by letters nodes, even when it is advantageous for Spanish readers (and maybe in other languages with very clear syllable boundaries) to rely on syllabic information. Additionally, assuming this parallel activation of syllabic units, the syllabic effects in visual word recognition do not need to be in conflict with those models of morphological processing that claim for a mandatory activation of morphemes.

The major problem with this approach, however, is that it says that morphemic units are only involved in processing visually presented words and not spoken words. Yet, there is clear evidence of morphological analysis in spoken word recognition (e.g., Marslen-Wilson et al., 1994; Taft, Hambly, & Kinoshita, 1986), and, therefore, this approach does not circumvent the problem of the incompatibility between syllable and morphemic structure.

It is obvious that with the results of the present research, we cannot reduce the uncertainty within the conflictive field of morphology. However, there are some models of morphological representation and access that deal better with a syllable level of representation than others, even when all of them present some advantages and some disadvantages. What seems clear is that any model of lexical access has to incorporate a syllabic level of representation or include the syllable as a sublexical unit of processing in Spanish (not necessarily for other languages such as English, where access based on syllables would possibly not be functional). Additionally, both directions of frequency effect need to be taken into consideration. We have shown that the syllable-frequency effect cannot be explained in terms of morphological or orthographic factors. At the same time, the evidence seems to suggest that morphology is represented in the mental lexicon. One of our tasks for the future is to investigate more deeply how these two types of information are represented and related to each other, as well as fitting with the current models of morphological representation and access.

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Appendix

Words Used In Experiments 1–3B

Experiment 1		Experiment 2		Experiments 3A & 3B	
High SF–High WF	*Low SF–High WF*	*High BF–High WF*	*Low BF–High WF*	*High BF*	*High RF*
Derecho	Cigarro	Posible	Popular	Bebedor	Bañador
Máquina	Lucidez	Pálido	Pájaro	Calamar	Bebedor
Pañuelo	Cautela	Pelota	Pepita	Camello	Montura
Cobarde	Títulos	Herida	Helado	Maratón	Matador
Setenta	Dudoso	Marido	Mágico	Balance	Cobrado
Madera	Dureza	Materia	Madurez	Balazo	Crecida
Cocina	Helado	Jugador	Juvenil	Cabaña	Décimo
Pájaros	Rigidez	Limite	Lírica	Camisón	Ganador
Sótano	Rutina	Cabeza	Cadena	Colador	Girasol
Código	Típico	Diseño	Dibujo	Disipar	Pasador
High SF–Low WF	*Low SF–Low WF*	Catalán	Cazador	Catador	Lavador
Codillo	Cigüeña	Cocina	Cohete	Dilema	Bajista
Maqueta	Helecho	Domingo	Dorado	Merluza	Pasota
Pañales	Dudable	Célula	Cebolla	Módulo	Puntero
Sollozo	Cautivo	*High BF–Low WF*	*Low BF–Low WF*	*Low BF*	Quemado
Cobalto	Tiburón	Polilla	Pollito	Bañador	*Low RF*
Codazos	Honesto	Paleta	Pajizo	Bellota	Calamar
Cayado	Lúcido	Peluca	Pepino	Migraña	Camello
Derivo	Muleta	Hereje	Hélice	Ballena	Maratón
Madeja	Hélice	Marear	Majada	Bodega	Migraña
Sonata	Tinaja	Matador	Mafioso	Bordado	Bellota
		Jugoso	Jubilar	Cajero	Cereal
		Limones	Lípido	Cayado	Maqueta
		Cabaret	Cadete	Cazuela	Batuta
		Disipar	Dimitir	Dibujar	Mancebo
		Catarro	Cazurra	Dimitir	Cretino
		Cocido	Cohorte	Madurar	Maracas
		Domado	Dolido	Mañoso	Camelia
		Celador	Cebada	Mohoso	Macarra
					Malabar
					Palanca

Note. SF = syllable frequency; WF = word frequency; BF = basic orthographic syllable structure (BOSS) frequency; RF = root frequency.

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