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Effects of Syllable Frequency and Syllable Neighborhood Frequency in Visual Word Recognition

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Three experiments were carried out to analyze the role of syllable frequency in lexical decision and naming. The results show inhibitory effects of syllable frequency in the lexical decision task for both high- and low-frequency words. In contrast, the effect of syllable frequency is facilitatory in the naming task. A post hoc analysis revealed the important role played by the number of higher frequency syllabic neighbors (words that share a syllable with the target) in the lexical decision task and the role of the frequency of the first syllable in the naming task. Experiment 3 manipulated the neighborhood syllable frequency directly by comparing words with few higher frequency syllabic neighbors and words with many higher frequency syllabic neighbors in the lexical decision task; an inhibitory neighborhood syllable frequency effect was found. The results are interpreted in terms of current models of visual word recognition and word naming.

Since the seminal study by Howes and Solomon (1951), we know that one of the most powerful predictors of performance in recognizing a given word is its frequency of occurrence (see Monsell, 1991, for a review). However, a number of recent studies have shown the important role played by other factors, such as the orthographic neighborhood (e.g., Andrews, 1989, 1992; Forster & Taft, 1994; Grainger, O'Regan, Jacobs, & Seguí, 1989, 1992; Johnson & Pugh, 1994) and syllable frequency (Carreiras, Álvarez, & de Vega, 1993; de Vega, Carreiras, Gutiérrez, & Alonso, 1990).

Most current models of visual word recognition (see Jacobs & Grainger, 1994, for a review) assume that word identification involves the selection of the appropriate lexical item from a relatively small set of word candidates whose specifications are roughly consistent with the perceptual analysis of the stimulus. Previous studies (e.g., see Andrews, 1989; Forster, 1989; Forster & Shen, 1996; Grainger, 1992; Johnson & Pugh, 1994; Paap & Johansen, 1994) have equated this candidate set with Landauer and Streeter's (1973; see also Coltheart, Davelaar, Jonasson, & Besner, 1977) definition of an *orthographic neighbor:* Any word that can be created by changing one letter of the stimulus word while preserving letter positions. In other words, presentation of the word *house* would activate lexical units such as *horse, mouse,* and so forth. The index N (or Coltheart's N) is typically used to refer to the number of orthographic neighbors of a word or to the size of the initial cohort of candidates.

A number of studies have found that words having higher frequency orthographic neighbors are recognized more slowly than words with no higher frequency orthographic neighbors (*the neighborhood frequency effect;* see Grainger, 1990; Grainger & Jacobs, 1996; Grainger et al., 1989, 1992; Grainger & Seguí, 1990; Perea & Pollatsek, in press; however, see Forster & Shen, 1996; Sears, Hino, & Lupker, 1995). This neighborhood frequency effect can be explained in terms of lexical inhibition among the words in the set of candidates in which the most frequent words enjoy the most activation for a brief period of time (i.e., the interactive activation [IA] model of McClelland & Rumelhart, 1981, and the multiple read-out model of Grainger & Jacobs, 1996) or in terms of a frequency-ordered search of the candidate set (i.e., the activation-verification [AV] model of Paap, Newsome, McDonald, & Schvaneveldt, 1982), in which higher frequency words are checked before lower frequency words.

However, the definition of orthographic neighborhood seems to apply especially to short monosyllabic words rather than to longer multisyllabic words, in which most of the words do not have any orthographic neighbor. In fact, sublexical units such as the syllable may play an important role not only in auditory word recognition (e.g., Cutler, Mehler, Norris, & Seguí, 1986; Mehler, Dommergues, Frauenfelder, & Seguí, 1981) but also in visual word recognition, at least in languages with regular grapheme–phoneme rules (i.e., shallow orthographies) and well-defined syllable boundaries (see Ferrand, Seguí, & Grainger, 1996). A recent study of Carreiras et al. (1993) examined the role of

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syllable frequency in visual word recognition in Spanish. They found that bisyllabic words containing high-frequency syllables were recognized more slowly than those containing low-frequency syllables in both the lexical decision and the naming task. Carreiras and colleagues suggested that the initial cohort of word candidates might be formed not only by orthographic neighbors but also by syllabic neighbors (i.e., words that share a syllable in the same position with the target). That is, the stimulus word *laca* would activate both orthographic neighbors (e.g., *lata, loca, lana, saca, vaca,* etc.) and syllabic neighbors[1] (e.g., *lado, lago, lápiz, lavar, labor, roca,* etc.). Consequently, syllabic neighbors can be slightly shorter (or longer) than the stimulus word (*laca–lavar*). In fact, the existence of a set of candidate words formed only by words of the same length has recently been called into question (Forster, 1989; Frauenfelder, Baayen, Hellwig, & Schreuder, 1993; Grainger & Seguí, 1990; Massaro & Cohen, 1994).

Carreiras and colleagues (1993) proposed that syllabic neighbors inhibit word recognition in much the same way as orthographic neighbors. In general, words with high-frequency syllables access or activate a larger initial set of candidates than words with low-frequency syllables (and the set is more likely to contain higher frequency words). Assuming that the subsequent selection process is time-consuming, it will take longer to select a word with high-frequency syllables than a word with low-frequency syllables. The search model (Taft, 1979; Taft & Forster, 1976) can be used to explain Carreiras et al.'s results. Specifically, the access to the lexicon in this model occurs by means of the first syllable, so that the set of candidates (the so-called bin) is reduced to those words sharing the first syllable. That is, the word *casa* ("house") would share the bin with words such as *caro* ("expensive"), *caja* ("box"), *cama* ("bed"), and so on. Because the search process is frequency ordered and words with high-frequency first syllables tend to have higher frequency syllabic neighbors than do words with low-frequency syllables, the effect of syllable frequency should be inhibitory.

In addition, parallel models can also accommodate the syllable frequency effect. In a recent article, Ferrand et al. (1996) presented a model in which there were syllable-sized units in the sublexical input phonology and in the sublexical output phonology. Ferrand and colleagues explained the inhibitory effects of syllable frequency found by Carreiras et al. (1993) in the lexical decision task by assuming that the syllabic representations located at the level of sublexical input phonology would send activation to whole-word representations, so that words that share one syllable can influence the process of word recognition (by means of lexical inhibition). As a result, words with many higher frequency syllabic neighbors are recognized more slowly than are words with few higher frequency syllabic neighbors in tasks in which resolution of the candidate set is needed, such as the lexical decision task (i.e., assuming that the processing of the stimuli is deep; see Grainger & Jacobs, 1996). In contrast, the effects of syllable frequency in the naming task may be facilitatory because of the faster computation of the articulatory output in the sublexical output phonology, in which high-frequency syllables can be synthesized more rapidly than low-frequency syllables (see Levelt & Wheeldon, 1994).

In contrast, other models of visual word recognition that do not grant a role to the syllable cannot accommodate Carreiras et al.'s (1993) results. For instance, in the IA model (McClelland & Rumelhart, 1981), the activation of lexical units that differ by more than one letter from the stimulus word is very low. The AV model assumes a set of candidates more restrictive than the set of candidate words in the IA model (see Paap et al., 1982). In the AV model, even orthographic neighbors of the stimulus word do not enter the set of candidate words when the mismatching letter cannot be readily confused with the letter actually presented. As for parallel distributed processing (PDP) models (Seidenberg & McClelland, 1989; Seidenberg, Plaut, Petersen, McClelland, & McRae, 1994), they are still limited to monosyllables, and as Seidenberg et al. (1994) pointed out, "extensions to multisyllabic words are nontrivial" (p. 1189).

The first aim of this study was to examine the effects of syllable frequency in Spanish words while controlling for orthographic neighborhood (number of orthographic neighbors and number of higher frequency orthographic neighbors). Carreiras et al. (1993) did not control for neighborhood frequency, and because syllable frequency and neighborhood frequency are highly correlated (words with high-frequency syllables tend to have more higher frequency orthographic neighbors than do words with low-frequency syllables), the syllable frequency effect might have been a simple by-product of neighborhood frequency. To keep the conditions similar to those used by Carreiras et al., we manipulated both syllable frequency and word frequency in the lexical decision task (Experiment 1) and in the naming task (Experiment 2).

The second aim of this study (assuming that the syllable frequency effect is real) was to investigate the factor(s) responsible for that effect. For that reason, a post hoc analysis of the data of Experiments 1 and 2 was conducted to find out which variables (syllable frequency, number of syllabic neighbors, number of higher frequency syllabic neighbors) seem to be responsible for the syllable frequency effect in lexical decision and naming. As a consequence, we conducted Experiment 3 to examine directly the role played by the number of higher frequency syllabic neighbors in the lexical decision task.

Experiment 1

Carreiras et al. (1993, Experiments 3–5) used bisyllabic words (four to five letters long) in which the mean number of higher frequency orthographic neighbors was 2.1 for words with high-frequency syllables and 0.7 for words with low-frequency syllables. The lack of control of neighborhood frequency could, at least in part, have caused the

[1] In the case of bisyllabic words, two words are syllabic neighbors when they share the first or the second syllable, although the first syllable is probably the most important (Taft & Forster, 1976).

inhibitory effects of syllable frequency in the lexical decision task.

To obtain an appropriate control for orthographic neighborhood, and assuming that the first syllable of a multisyllabic word provides more information than the following syllables (Taft & Forster, 1976), we only manipulated the positional frequency of the first syllable (high vs. low) in bisyllabic words (the second syllable was always of low frequency). In contrast, Carreiras et al. (1993, Experiments 3–5) compared bisyllabic words with two high-frequency syllables to bisyllabic words with two low-frequency syllables. We decided to manipulate the frequency of the first syllable because if the frequency of both syllables was factorially manipulated while controlling for orthographic neighborhood, the number of words per cell would be too small. Assuming that syllabic neighbors inhibit word recognition in much the same way as orthographic neighbors, we expected an inhibitory effect of syllable frequency in the lexical decision task.

Method

Participants. Twenty-six students from introductory psychology courses at the Universitat de València participated in the experiment either to earn extra course credit or to fulfill a course requirement.

Design and materials. We selected 64 two-syllable Spanish words, all of them four or five letters long (20 and 44, respectively), from the Universitat de València's computerized word pool (Algarabel, Ruíz, & Sanmartín, 1988) by combining two variables (syllable frequency of the first syllable: low vs. high; word frequency: low vs. high) in a 2 × 2 within-subjects but between-items design. The characteristics of the selected words are presented in Table 1.[2] We selected syllables according to their token frequency in the dictionary of frequency of syllables in Spanish (Álvarez, Carreiras, & de Vega, 1992) from a sample of 25,000 Spanish words. We considered syllables to be of high frequency when they had a minimum frequency of occurrence of 100 and to be of low frequency when they had a maximum frequency of occurrence of 60. The positional frequency of each syllable refers to the number of times that the syllable (weighted by lexical frequency) appeared in that word position (first, second, final, etc.). In all cases, the second syllable was of low frequency (i.e., with a maximum frequency of occurrence of 60). Words were matched across conditions for the number of orthographic neighbors; none had higher frequency orthographic neighbors. Words were also matched across conditions for initial sound (in terms of initial class: nasal, vowel, etc.) and length.

In addition, we constructed 64 orthographically legal nonwords by replacing a letter of a Spanish word (other than one of the experimental set). None of the stimuli had an orthographic neighbor in the experimental set.

Procedure. We tested participants in groups of 2 or 3 in a quiet room. We controlled presentation of the stimuli and recording of latencies by means of Apple Macintosh Plus microcomputers. In each trial, a "ready" symbol (> <) was presented for 300 ms on the center of the screen. Next, an uppercase letter string (word or nonword) was presented centered until the participant responded. We instructed participants to press one of two buttons on the keyboard to indicate whether the letter string was a Spanish word or not. This decision was to be made as rapidly and as accurately as possible, although accuracy was stressed in the instructions. The intertrial interval was 1,500 ms. Each participant received 24 practice trials prior to the 128 experimental trials. Stimulus presentation was randomized, with a different order for each participant. The whole session lasted approximately 11 min.

Results and Discussion

Incorrect responses (3.2%) and reaction times (RTs) less than 300 ms or greater than 1,500 ms (0.72% of the data[3]) were omitted from the latency analysis. Mean reaction times and error data were then submitted to separate analyses of variance (ANOVAs), with syllable frequency (low vs. high) and word frequency (low vs. high) as within-subjects but between-items variables. The ANOVAs were performed for participants ($F1$) and for items ($F2$). The mean lexical decision time and error rate in each condition are shown in Table 2.

The ANOVA on the latency data revealed a main effect of word frequency, $F1(1, 25) = 63.29$, $MSE = 1{,}184$, $p < .001$, $F2(1, 60) = 29.10$, $MSE = 1{,}750$, $p < .001$, in which high-frequency words were responded to faster than low-frequency words (589 vs. 643 ms, respectively). The main effect of syllable frequency was significant by participants, $F1(1, 25) = 8.36$, $MSE = 849$, $p < .008$, and marginally significant by items, $F2(1, 60) = 3.02$, $MSE = 1{,}750$, $p < .10$; words with low-frequency syllables were responded to faster than words with high-frequency syllables (607 vs. 624 ms, respectively). The Syllable Frequency × Word Frequency interaction was not statistically significant, $F1(1, 25) = 1.60$, $F2(1, 60) = 0.74$.

For errors, there was a significant effect of word frequency, $F1(1, 25) = 15.91$, $MSE = 19.2$, $p < .001$, $F2(1, 60) = 7.24$, $MSE = 24.7$, $p < .01$; high-frequency words were responded to more accurately than low-frequency words (1.69 vs. 5.12%, respectively). The main effect of syllable frequency approached statistical significance by participants, $F1(1, 25) = 3.67$, $MSE = 24.2$, $p < .10$, $F2(1, 60) = 2.02$. The Word Frequency × Syllable Frequency interaction was significant by participants, $F1(1, 25) = 5.00$, $MSE = 22.4$, $p < .04$, and approached statistical significance by items, $F2(1, 60) = 2.84$, $MSE = 24.7$, $p < .10$. The effect of syllable frequency was significant for low-frequency words, $F1(1, 25) = 6.33$, $MSE = 31.6$, $p < .02$, $F2(1, 60) = 5.02$, $MSE = 24.7$, $p < .03$, but not for high-frequency words (both Fs < 1).

One important finding is that the magnitude of the word frequency effect was considerable (54 ms) even when orthographic neighborhood was controlled (see also Grainger, 1990; Grainger & Seguí, 1990; Sears et al., 1995). Serial models that assume that Coltheart's N is an appropriate index of the initial set of candidates (see Forster, 1989; Forster & Taft, 1994; Paap & Johansen, 1994) would predict a null result, because none of the words in the experimental

[2] The list of the stimuli (words and nonwords) is available from Manuel Perea or Manuel Carreiras.

[3] For words, we used a cutoff of 1,500 ms for the lexical decision task (Experiments 1 and 3) and of 800 ms for the naming task. Other cutoff procedures (e.g., excluding RTs that are 2 or 3 above or below a particular condition's mean, other fixed cutoffs, etc.) yielded an analogous pattern of results (see Ratcliff, 1993).

Table 1
Characteristics of Words Used in Experiments 1 and 2

	WF		SF		N		HFSN	
Word class	*M*	Range	*M*	Range	*M*	Range	*M*	Range
High WF/high SF	133	51–260	390	111–925	2.5	0–7	5.1	0–15
High WF/low SF	123	52–192	33	7–46	3.1	0–8	0.1	0–1
Low WF/high SF	12	5–23	334	103–925	2.3	0–7	15.7	2–36
Low WF/low SF	11	5–20	26	3–47	2.1	0–7	4.6	0–19

Note. WF = word frequency based on a count of 500,000 Spanish words (Juilland & Chang-Rodríguez, 1964); SF = positional frequency of a word's first syllable based on the count by Álvarezetal. (1992); N = average number of orthographic neighbors; HFSN = average number of higher frequency syllabic neighbors (in first syllable).

set had any higher frequency orthographic neighbors. On the one hand, it could be argued that N is not an appropriate index of the initial set of candidates (see General Discussion section), or that word frequency effects are influenced by postlexical factors (Balota & Chumbley, 1984). On the other hand, models in which higher frequency words have different resting levels than lower frequency words (Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981) or different weight among connections (Seidenberg & McClelland, 1989) can easily accommodate the word frequency effect even when a word's orthographic neighborhood is controlled.

However, the most important finding of this experiment is that the effect of syllable frequency was significant even when orthographic neighborhood was controlled. In other words, it appears that the syllable frequency effect is not just a by-product of orthographic neighborhood. Additionally, the syllable frequency effect was somewhat stronger for low- than for high-frequency words both in the RT and the error analyses (see also Carreiras et al., 1993, Experiment 3), although the interaction did not reach the classical level for statistical significance.

As can be seen in Table 1, the number of higher frequency syllabic neighbors covaried with syllable frequency; assuming that higher frequency syllabic neighbors can inhibit the processing of lower frequency syllabic neighbors (Carreiras et al., 1993), it is possible that, at least in part, the effect of syllable frequency is due to the number of higher frequency syllabic neighbors. The analysis of the individual item performance for the latency data of this experiment is presented later (see Reanalysis of Experiments 1 and 2).

Table 2
Mean Reaction Times (RT; in Milliseconds) and Percentage of Errors for Words in Experiment 1

	Word frequency			
	High		Low	
Syllable frequency	RT	% error	RT	% error
High	594	1.6	654	7.1
Low	584	1.8	631	3.2

Experiment 2

It is well-known that experimental tasks can be influenced by factors other than lexical processes. For instance, the lexical decision task can be influenced by the familiarity of the letter string (Balota & Chumbley, 1984), and the naming task can be influenced by a number of naming-specific processes (see Paap, McDonald, Schvaneveldt, & Noel, 1987). For that reason, most current studies use a multitask approach to study word recognition processes. The comparison among different tasks permits a more comprehensive analysis of the core processes underlying lexical access.

As we stated earlier, the syllable-sized output units in Ferrand et al.'s (1996) model can facilitate the articulatory response, so that words with higher frequency syllables are pronounced more rapidly than words with lower frequency syllables (unless the inhibitory effects at the lexical level and the facilitatory effects in the sublexical phonological output cancel one another out). Actually, orthographic neighborhood effects tend to be facilitatory rather than inhibitory in naming (e.g., Andrews, 1989, 1992; Grainger, 1990; Treiman, Mullennix, Bijeljac-Babic, & Richmond-Welty, 1995). In fact, Carreiras et al. (1993) found such a facilitatory effect of syllable frequency when participants named nonwords, although the effects of syllable frequency were inhibitory (in the analysis by participants) when participants named words. In contrast, another recent experiment in Spanish showed facilitative effects of syllable frequency for both words and nonwords (Domínguez, Cuetos, & de Vega, 1993). In addition, in a recent production study using another shallow orthography (Dutch), Levelt and Wheeldon (1994) found facilitative effects of syllable frequency for words in the naming task, which were additive to the word frequency effect.

Method

Participants. Twenty-six students from the same population as that in the previous experiment served as participants. None of them had taken part in the previous experiment. One participant's data were removed because of a failure in equipment.

Design and materials. The design and stimuli were the same as those in the previous experiment except that nonword trials were not used.

Procedure. The procedure was identical to that of Experiment 1 except that participants were tested individually and instructed to read aloud the uppercase word as rapidly and as accurately as possible. Naming latencies were collected by a microphone connected to a voice-activated key (Algarabel, Sanmartín, & Ahuir, 1989) interfaced with a digital input–output port of the microcomputer. Both mispronunciations and hesitations were considered to be errors. Each participant received 12 practice trials prior to the 64 experimental trials. The session lasted approximately 7 min.

Results and Discussion

Incorrect responses (0.25%) and RTs less than 300 ms or greater than 800 ms (2.56% of the data) were excluded from the latency analysis. Because very few errors were recorded, only response latency is considered. Mean reaction times were submitted to an ANOVA, with syllable frequency and word frequency as variables. The mean naming time for each experimental condition is displayed in Table 3.

The ANOVA yielded a significant effect of word frequency, $F1(1, 24) = 59.36$, $MSE = 219$, $p < .001$, $F2(1, 60) = 20.47$, $MSE = 368$, $p < .001$; high-frequency words were pronounced more rapidly than low-frequency words (516 vs. 539 ms, respectively). The main effect of syllable frequency was also statistically significant, $F1(1, 24) = 8.97$, $MSE = 240$, $p < .007$, $F2(1, 60) = 4.03$, $MSE = 368$, $p < .05$; words with high-frequency syllables were pronounced more rapidly than words with low-frequency syllables (523 vs. 532 ms, respectively). The interaction between the two factors was not significant (both Fs < 1).

The robust word frequency effect (23 ms), even when controlling for orthographic neighborhood and syllable frequency, is clear evidence of lexical involvement in this task. It seems that skilled adult readers in a language such as Spanish normally use lexical procedures in naming words, even though the orthography is shallow (see Sebastián, 1991).

The syllable frequency effect was not inhibitory but facilitatory and was additive to the word frequency effect (see Levelt & Wheeldon, 1994). That is, words with an initial high-frequency syllable were pronounced more rapidly than words with an initial low-frequency syllable. A similar pattern of effects was found in our lab using a naming task in which words were presented in the same block with nonwords (Perea & Carreiras, 1996). This facilitatory effect could be due to a frequency effect in the mental syllabary involved at the level of the sublexical phonological output (Ferrand et al., 1996).

In contrast to the above, Carreiras et al. (1993, Experiment 4) found inhibitory effects of syllable frequency (by participants) and null effects of word frequency in the standard naming task. Perhaps some participants' strategies might explain the discrepancy for the word data, as latencies in Experiment 4 of Carreiras et al. were much greater than in our experiment (632 vs. 528 ms, respectively). Nonetheless, after performing a new analysis in which we divided our participants into two equal groups of "slow" and "fast" participants, we did not find any differential effect of word frequency or syllable frequency dependent on the rapidity of participants' responses. In addition, we performed a regression analysis on the latency data by Carreiras et al. in which we used a number of predictors, such as log of word frequency, log of syllable frequency, number of syllabic neighbors, and number of higher frequency syllabic neighbors. Rather surprisingly, none of these variables had a significant relation to naming time ($p > .20$ in all cases). Further, in another experiment with the same materials, Carreiras et al. (1993, Experiment 5) failed to find any syllable frequency effect (or word frequency effect) for words when the words were presented in the same block with nonwords, whereas they found a strong facilitatory effect of syllable frequency for the nonwords. In contrast, the regression analysis on the naming data of our present naming experiment yielded much more consistent results (see section below), and the study by Domínguez et al. (1993) provided additional evidence of facilitative effects of syllable frequency on words, although Domínguez et al. did not control for orthographic neighborhood. Perhaps the inhibitory effect of syllable frequency in the analysis by participants found by Carreiras et al. (Experiment 4) is best attributed to random error.

Table 3
Mean Reaction Times (in Milliseconds) in Experiment 2

	Word frequency	
Syllable frequency	High	Low
High	512	534
Low	520	544

Reanalysis of Experiments 1 and 2

As we said earlier, a tentative explanation for the effects of syllable frequency in the lexical decision task relies on the fact that not only are orthographic neighbors activated in the initial set of candidates but syllabic neighbors as well. This might imply that the first syllable is an access unit (Taft & Forster, 1976) or that there are syllable-size units at the level of the sublexical phonological input that send activation to the word level (Ferrand et al., 1996). In contrast, the facilitatory effects of syllable frequency in the naming task might be due to the faster access to high-frequency syllables in the mental syllabary (Ferrand et al., 1996; Levelt & Wheeldon, 1994).

The aforementioned analysis of Experiments 1 and 2 did not provide, however, any additional information concerning whether the syllable frequency effect arises from the number of syllabic neighbors, their frequency, or the frequency of the first syllable. Therefore, we conducted a regression analysis on the RT data of the two experiments with four predictors (log of word frequency, log of syllable frequency, number of higher frequency syllabic neighbors, and number of syllabic neighbors) to further investigate this issue. The regression analysis on the lexical decision times (see Table 4) showed a significant inhibitory effect of number of higher frequency syllabic neighbors, $F(1, 59) = 31.02$, $p < .001$, and a significant facilitative effect of log of word frequency, $F(1, 59) = 5.87$, $p < .02$. The effect of

Table 4
Pearson Product–Moment (r) and Partial (pr) Correlations Between Reaction Time and Four Predictors

	LDT		Naming	
Predictor	*r*	*pr*	*r*	*pr*
Log word frequency	−.627	−.301*	−.525	−.350*
Log syllable frequency	.165	.055	−.310	−.345*
No. HFSN	.715	.587*	.231	.130
No. syllabic neighbors	.198	−.234	−.150	.106

Note. Log word frequency = logarithm of word frequency; log syllable frequency refers to logarithm of syllable frequency in first syllable; no. HFSN = number of higher frequency syllabic neighbors in first syllable; no. syllabic neighbors = number of syllabic neighbors in first syllable; LDT = lexical decision time.
*$p < .05$.

number of syllabic neighbors was facilitative and was marginally significant, $F(1, 59) = 3.42, p < .07$. Thus, the factor responsible for the inhibitory syllable frequency effect in the lexical decision task appears to be the number of higher frequency syllabic neighbors rather than the number of syllabic neighbors per se, as the effect of number of syllabic neighbors seems to be facilitatory rather than inhibitory. The role of syllable frequency was negligible. Further, in two recent experiments using speeded identification tasks, the regression analyses also showed a similar pattern of results (Perea & Carreiras, 1995).

The regression analysis conducted on the word data in the naming task (see Table 4) showed significant facilitative effects of log of syllable frequency, $F(1, 59) = 8.25, p < .006$, and log of word frequency, $F(1, 59) = 7.99, p < .007$. However, neither the effect of number of syllabic neighbors nor the effect of higher frequency syllabic neighbors approached significance ($p > .20$), which suggests that the facilitatory effects of syllable frequency in naming words might be due to the frequency of the first syllable. It seems that the more frequent the first syllable is, the faster the naming time, which can be related to the concept of mental syllabary introduced by Levelt and Wheeldon (1994) and also used by Ferrand et al. (1996).

To obtain further experimental evidence for the inhibitory influence of the number of higher frequency syllabic neighbors in the lexical decision task, in Experiment 3 we manipulated syllable neighborhood frequency directly (words with few higher frequency syllabic neighbors vs. words with many higher frequency neighbors) as well as word frequency while controlling for orthographic neighborhood. Specifically, we used bisyllabic Spanish words in which we manipulated the number of higher frequency syllabic neighbors in the first syllable (the selected words had no higher frequency syllabic neighbors in the second syllable).

Experiment 3

Method

Participants. Twenty-six students from introductory psychology courses at the Universitat de València took part in the experiment to earn extra course credit. None of them had taken part in the previous experiments.

Design and materials. We selected 48 two-syllable Spanish words, all of them of four or five letters long, from the Spanish word pool of Alameda and Cuetos (1995; Cobos et al., 1995) by combining two variables (word frequency: high-frequency words vs. low-frequency words; neighborhood syllable frequency of the first syllable: words with few higher frequency syllabic neighbors vs. words with many higher frequency syllabic neighbors) in a 2 × 2 factorial design. The characteristics of the words are presented in Table 5. Words were matched across conditions for neighborhood frequency (none of the selected words had higher frequency orthographic neighbors) and length. There was, however, a small difference in the number of orthographic neighbors and syllabic neighbors across conditions that is analyzed in the Results section; similarly, the role of syllable frequency is also analyzed in the Results section. In addition, 48 orthographically legal bisyllabic nonwords matched in length with the target words were constructed.

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

Results and Discussion

As in Experiment 1, incorrect responses (5.9%) and RTs less than 300 ms or greater than 1,500 ms (1.8% of the data) were omitted from the latency analysis. Mean RTs and error data were then submitted to separate ANOVAs, with word frequency and neighborhood syllable frequency as variables. The mean lexical decision time and error rate on the words in each experimental condition are shown in Table 6.

Table 5
Characteristics of Words Used in Experiment 3

	WF		N		NS1		HFSN		SF	
Word class	*M*	Range	*M*	Range	*M*	Range	*M*	Range	*M*	Range
High WF/SNF+	141	82–237	3.5	0–7	81	42–143	11.4	8–18	628	11–3,328
High WF/SNF−	144	92–203	3.0	0–12	33	5–51	2.3	0–3	3,538	751–15,429
Low WF/SNF+	28	1–67	1.1	0–4	51	19–118	13.9	8–30	1,496	5–3,793
Low WF/SNF−	28	1–58	1.3	0–6	22	0–74	1.6	0–4	11,818	110–20,455

Note. SNF+ = words with many higher frequency syllabic neighbors (in first syllable); SNF− = words with few higher frequency syllabic neighbors (in first syllable); WF = word frequency based on a count of 2,000,000 Spanish words (Alameda & Cuetos, 1995); N = average number of orthographic neighbors; NS1 = average number of syllabic neighbors (in first syllable); HFSN = average number of higher frequency syllabic neighbors (in first syllable); SF = positional frequency of a word's first syllable based on the count by Cobos et al. (1995).

The ANOVA on the latency data[4] for words revealed a significant main effect of word frequency, $F1(1, 25) = 77.37$, $MSE = 3{,}261$, $p < .001$, $F2(1, 43) = 14.25$, $MSE = 8{,}734$, $p < .001$, in which high-frequency words were responded to faster than low-frequency words (689 vs. 788 ms). The main effect of syllable neighborhood frequency was also statistically significant, $F1(1, 25) = 48.57$, $MSE = 1{,}597$, $p < .001$, $F2(1, 43) = 4.49$, $MSE = 8{,}734$, $p < .05$; words with few higher frequency syllabic neighbors were responded to faster than those with many higher frequency syllabic neighbors (711 vs. 766 ms, respectively). The interaction between syllable neighborhood frequency and word frequency was also statistically significant by participants, $F1(1, 25) = 27.71$, $MSE = 866$, $p < .001$, $F2(1, 43) = 1.14$; the effects of syllable neighborhood frequency were stronger for low-frequency words than for medium-frequency words (84 vs. 26 ms).

The ANOVA on the error rates yielded a significant main effect of word frequency, $F1(1, 25) = 19.13$, $MSE = 34.1$, $p < .001$, $F2(1, 43) = 6.10$, $MSE = 51.5$, $p < .02$. The main effect of syllable neighborhood frequency approached statistical significance by participants $F1(1, 25) = 3.87$, $MSE = 51.5$, $p = .06$, $F2(1, 43) = 1.95$, $MSE = 51.5$, $p > .10$. The interaction between syllable neighborhood frequency and word frequency was not statistically significant (both $Fs < 1$).

The most important finding of this experiment is that the number of higher frequency syllabic neighbors does have an inhibitory influence on the lexical decision time. As a result, the inhibitory syllable frequency effect in tasks such as lexical decision seems to be mainly caused by the number of higher frequency syllabic neighbors. That is, words such as *robot* ("robot") appear to be inhibited by higher frequency syllabic neighbors such as *roca* ("stone"), *rojo* ("red"), *ropa* ("clothes"), *rosa* ("rose"), or *roto* ("broken").

Because the words with many higher frequency syllabic neighbors tended to have more syllabic neighbors than the words with few higher frequency syllabic neighbors, and because high-frequency words tended to have more orthographic neighbors than low-frequency words (see Table 5), we analyzed the separate contribution of each variable to the lexical decision time by using the general linear model. Thus, we used four predictors in the regression analysis: log of word frequency, number of orthographic neighbors, number of higher frequency syllabic neighbors, and number of syllabic neighbors (see Table 7). The statistical analysis showed significant effects of log of word frequency and number of higher frequency syllabic neighbors, $Fs(1, 42) = 4.59$ and 4.68, respectively, $ps < .02$, whereas the effect of number of syllabic neighbors only approached significance, $F(1, 42) = 3.76$, $p < .09$. That is, the pattern of results was similar to that of the regression analysis on the data from Experiment 1.

Additionally, because the number of higher frequency syllabic neighbors correlates with syllable frequency, it would be interesting to analyze the role of syllable frequency in this experiment (although syllable frequency per se did not play a significant role in the regression analysis of Experiment 1). When the influence of log of word frequency, number of syllabic neighbors, and number of orthographic neighbors was partialed out, the correlation between RT and number of higher frequency syllabic neighbors was still high ($r = .42$, $p < .01$), whereas the correlation between RT and the log of syllable frequency was not significant ($r = -.20$, $p > .15$). That is, the inhibition in Experiments 1 and 3 seems to be caused by the number of higher frequency syllabic neighbors rather than by the syllable frequency per se.

Table 6
Mean Reaction Times (RT; in Milliseconds) and Percentage of Errors for Words in Experiment 3

Syllable neighborhood frequency	Word frequency			
	High		Low	
	RT	% error	RT	% error
SNF+	702	3.5	830	8.7
SNF−	676	1.0	746	5.8

Note. SNF+ refers to words with many higher frequency syllabic neighbors; SNF− refers to words with few higher frequency syllabic neighbors.

Table 7
Pearson Product–Moment (r) and Partial (pr) Correlations Between Reaction Time and Four Predictors

Predictor	*r*	*pr*
Log word frequency	−.589	−.371*
No. orthographic neighbors	−.284	.009
No. HFSN	.274	.382*
No. syllabic neighbors	−.169	−.262

Note. No. orthographic neighbors = Coltheart's N; no. HFSN refers to number of higher frequency syllabic neighbors in first syllable; no. syllabic neighbors refers to number of syllabic neighbors in first syllable.
*$p < .05$.

[4] A low-frequency word with higher frequency syllabic neighbors (*grisú*) showed a high percentage of errors (more than 50%). Before removing the data corresponding to this word, the mean RT for that condition was 833 ms, and the mean percentage of errors was 14.5%. The pattern of results of the latency data without removing the word was identical to that given in the text. The main effect of syllable neighborhood frequency was significant, $F1(1, 25) = 53.79$, $MSE = 1{,}541$, $p < .001$, $F2(1, 44) = 5.37$, $MSE = 8{,}842$, $p < .03$, as was the main effect of word frequency, $F1(1, 25) = 84.17$, $MSE = 3{,}118$, $p < .001$, $F2(1, 44) = 15.84$, $MSE = 8{,}842$, $p < .001$, and the interaction between the two variables in the by-participants analysis, $F1(1, 25) = 27.71$, $MSE = 866$, $p < .001$ ($F2 = 1.14$). As for the error rates, without removing the word, there was a main effect of word frequency, $F1(1, 25) = 36.22$, $MSE = 44.6$, $p < .001$, $F2(1, 44) = 5.39$, $MSE = 138.1$, $p < .03$. The main effect of syllable neighborhood frequency was statistically significant by participants, $F1(1, 25) = 14.52$, $MSE = 55.7$, $p < .001$, $F2(1, 44) = 2.75$, $MSE = 138.1$, $p = .10$, as well as in the interaction between both variables, $F1(1, 25) = 4.86$, $MSE = 53.2$, $p < .04$, $F2(1, 44) = 0.94$.

General Discussion

The main finding of the experiments reported here can be summarized as follows: There is an inhibitory effect due to the number of higher frequency syllabic neighbors (rather than syllable frequency per se) in the lexical decision task. In addition, we found facilitatory effects of syllable frequency in naming (possibly by means of naming-specific processes).

Because of the different processes involved in lexical decision and in naming tasks (e.g., see Grainger & Jacobs, 1996; Jacobs & Grainger, 1994; Johnson & Pugh, 1994; Paap et al., 1987; Seidenberg & McClelland, 1989), we analyze separately our results in the two experimental tasks. Finally, we analyze the concept of neighbor and the role of syllabic units in the set of word candidates in visual word recognition.

Visual Word Recognition in the Lexical Decision Task

Robust word frequency effects were found for short words (four to five letters long) in the lexical decision and naming tasks when controlling for variables such as orthographic neighborhood and syllable frequency. These results do not support models that assume that word recognition involves a frequency-ordered selection among a set of candidates based on the definition of orthographic neighbor (Coltheart et al., 1977), as can be deduced from the recent work of Forster (1989; Forster & Shen, 1996) and Paap and Johansen (1994). In fact, it is difficult to maintain that the word frequency effect is only due to a decision stage. The only possibility is to argue that the current definition of a word's neighborhood should be modified (see section below). In contrast, models in which word frequency affects either the resting level (Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981) or the weight among connections (Seidenberg & McClelland, 1989) can easily accommodate our results.

In addition, models of visual word recognition in which individual syllables play no role in lexical access cannot satisfactorily explain our results, because we found effects of syllable frequency (and syllable neighborhood frequency) when controlling for orthographic neighborhood. For instance, PDP models (Seidenberg & McClelland, 1989; Seidenberg et al., 1994) are still limited to monosyllables; therefore we must wait until these models are applied to multisyllabic contexts. Because syllabic neighbors typically differ from the stimulus word in at least two letters,[5] the activation of syllabic neighbors will be quite low in the IA model (McClelland & Rumelhart, 1981), and then they are not likely to influence the activation of the stimulus word. Thus, the IA model needs to be modified to accommodate our results. In this context, Rapp (1992) suggested that the word-level representations in the IA model should be changed to morpheme-level representations and that a syllable level should be included between the letter and the morphemic levels. Of course, the question now is whether or not the IA model can be modified to handle the syllable neighborhood frequency effect and still fit the data that it was built to explain. With respect to the multiple read-out model, Grainger and Jacobs (1996) did not include phonological units such as syllables in order to minimize the number of assumptions of the model, although in another recent study (Grainger & Jacobs, 1994), they suggested that sublexical phonological codes (such as syllables) could receive activation from the letter level and send on activation to the word level (see also Ferrand et al., 1996). As a result, the multiple read-out model appears to predict inhibitory effects of neighborhood syllable frequency, although simulations are needed to know what its specific predictions are.

With respect to serial-search models, the activation-verification model (Paap et al., 1982) apparently excludes syllabic neighbors from entering the set of candidate words. In that model, even orthographic neighbors of the stimulus word can fail to enter the set of candidate words when the mismatching letter cannot be readily confused with the letter actually presented. A syllabic level between the letter level and the word level would be needed to accommodate our results (e.g., see Massaro & Cohen, 1994). The search model (Taft & Forster, 1976) can accommodate our results concerning the inhibitory effect of the number of higher frequency syllabic neighbors. However, this model cannot satisfactorily explain the presence of word frequency effects while controlling for both orthographic neighborhood and syllable neighborhood frequency. (Of course, one can always argue that part of the word frequency effect in Experiment 3 might be due to a decision stage in the lexical decision task.)

On the Process of Naming Words

It appears that Spanish readers rely on lexical processes in naming words, because word frequency effects—clear evidence of lexical involvement—were significant in the naming task (23 ms). These results strengthen the "universal hypothesis" (Besner & Smith, 1992), according to which the underlying processes in word naming in different alphabetic languages are relatively similar. As Tabossi and Laghi (1992) pointed out, "the unusual nonlexical strategy is hard and time consuming" (p. 311). Furthermore, semantic priming effects—another sign of lexical involvement—in the naming task have also been found in other languages with shallow orthographies (e.g., Spanish: Sebastián, 1991; Italian: Tabossi & Laghi, 1992; Persian: Baluch & Besner, 1991; Serbo-Croatian: Carello, Lukatela, Peter, & Turvey, 1995).

In the naming task, the syllable frequency effect appears to be facilitatory and similar for high- and low-frequency words. It is possible that word frequency and syllable frequency may affect different processing stages (see Ferrand et al., 1996; Levelt & Wheeldon, 1994). In addition, it seems that the factor responsible for the syllable frequency effect is the frequency of the first syllable rather than the number or frequency of the syllabic neighbors (see Reanalysis of Experiments 1 and 2). Levelt and Wheeldon proposed

[5] For instance, *arroz* ("rice"), *amor* ("love"), and *Abril* ("April") are syllabic neighbors.

that speakers have access to a store of articulatory-phonetic syllable programs called the mental syllabary (a concept also used by Ferrand et al, 1996). Accessing a syllable in the mental syllabary that is frequently used in the language is faster than accessing a syllable that is less frequently used (Levelt & Wheeldon, 1994). It is likely that this assembly process occurs chunk by chunk (e.g., syllable by syllable), so that the phonological description is built up incrementally (see Monsell, Patterson, Graham, Hughes, & Milroy, 1992; Shallice, Warrington, & McCarthy, 1983). When there is no access to lexical items, as happens with nonwords, there is a very strong facilitatory effect of syllable frequency (Carreiras et al., 1993; Domínguez et al., 1993; Perea & Carreiras, 1996). This syllable frequency effect is somewhat diminished for words, possibly because of the inhibitory effects of higher frequency syllabic neighbors at the lexical level by means of the sublexical input phonology. Taken together, these results appear to indicate that the facilitatory effects of syllable frequency are due to a late stage at the level of the sublexical phonological output.

Additionally, within the framework of a multiple-levels model in which the pronunciation can be derived from several sources (e.g., consonant clusters, syllables, morphemes, words; see Norris, 1994; Shallice et al., 1983), the facilitatory effect of syllable frequency could be explained in terms of the higher level of activation of other orthographic–syllabic neighbors whose phonology is, at least in part, consistent with the stimulus (see Glushko, 1979; Kay & Marcel, 1981). Moreover, a multiple-levels model can modify the weights of the different levels to explain strategic shifts between lexical and sublexically based naming, as in dual-route theories (see Norris, 1994). Most important, word naming 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).

Nonetheless, more empirical evidence of the effects of syllable frequency in naming tasks is needed to obtain a comprehensive framework for understanding the influence of syllable frequency and word frequency in word naming in shallow orthographies. Actually, the interpretation of empirical results of naming tasks in shallow orthographies is currently under discussion (e.g., see Besner & Smith, 1992; Carello, Lukatela, & Turvey, 1994, vs. Sebastián, 1994).

On the Concept of a Word's Neighbor

The definition of a word's orthographic neighbor (Coltheart et al., 1977) is apparently simple. However, the existence of the syllable frequency effect or the fact that, even for short words, initial letters provide more information for lexical access than medial letters (Grainger et al., 1992) strongly suggests that the definition of a word's orthographic neighbors should be modified (see also Pugh, Rexer, Peter, & Katz, 1994). Furthermore, the pattern of errors in speeded identification tasks (Grainger & Seguí, 1990) also suggests that there are lexical units other than orthographic neighbors that play an important part in the process of visual word recognition. It has been suggested that the set of candidates is not limited to lexical entries of the same length as the stimulus word (e.g., see Forster, 1989; Frauenfelder et al., 1993; Massaro & Cohen, 1994; Taft, 1979), and, for the naming task, other definitions of orthographic neighborhood have been proposed (e.g., Treiman et al., 1995).

Future research should take into account the inhibitory effects not only from higher frequency orthographic neighbors (Grainger, 1990; Grainger et al., 1989, 1992) but also from syllabic neighbors (i.e., words that share one syllable with the target) in the lexical decision task. Actually, the current definition of orthographic neighbors can be applied only to short words (four to five letters), because longer words tend to be lexical hermits (words with no orthographic neighbors). Furthermore, words in Romance languages such as Spanish, Italian, or French tend to be longer than in English. For instance, the percentage of monosyllabic Spanish words is quite small (less than 8%), and the average number of letters of Spanish words is more than eight (Algarabel et al., 1988). It is very likely that the influence of sublexical units such as syllables in visual word recognition increases for longer words, whereas the influence of visual factors might decrease.

It can be argued, however, that the observed effects of syllable frequency and syllable neighborhood frequency might not reflect syllable frequency per se but instead the frequency of the words' first bigrams (which in a number of cases correspond to the first syllable in Spanish). Nonetheless, the effects of bigram frequency are clearly elusive in visual word recognition (e.g., see Andrews, 1992), and syllable frequency effects cannot be accounted for by the frequency of co-occurrence of letter patterns (see Carreiras et al., 1993). Logically, the information shared by syllabic neighbors such as *casa* ("house") and *caro* ("expensive") is likely to be greater than that of words that share the first bigram such as *tren* ("train") and *tras* ("after"). In fact, Domínguez, de Vega, and Cuetos (1997) recently carried out a priming study in Spanish in which the related primes were either syllabic neighbors of the target (syllabic condition: *norma–NORTE;* consonant–vowel–consonant [CVC] CV–CVC CV) or not (orthographic condition: *noria–NORTE;* CV CVC–CVC CV). At a 250-ms stimulus onset asynchrony, they found differences between syllabic and orthographic priming effects, a finding which reinforces the role of the syllable in visual word recognition in Spanish.

In summary, this study has provided evidence that the syllable is a sublexical unit that mediates access to the words in a shallow language such as Spanish. It appears that the number of higher frequency syllabic neighbors plays an inhibitory role in the process of activation and selection of word candidates, but in contrast, syllable frequency has a facilitatory role in synthesis of phonological output. More empirical evidence of the influence of the syllable on lexical access is needed, especially to generalize our results to other shallow languages with well-defined syllable boundaries (e.g., French, Italian, Portuguese, or Catalan) and to explore the effects of syllable frequency and neighborhood syllable frequency in "deeper" languages such as English.

References

Alameda, J. R., & Cuetos, F. (1995). *Diccionario de frecuencia de las unidades lingüísticas del castellano* [Dictionary of word frequency in Spanish]. Oviedo, Spain: Servicio de Publicaciones de la Universidad de Oviedo.

Algarabel, S., Ruíz, J. C., & Sanmartín, J. (1988). The University of Valencia's computerized word pool. *Behavior Research Methods, Instruments, and Computers, 20,* 398–403.

Algarabel, S., Sanmartín, J., & Ahuir, F. (1989). A voice-activated key for the Apple Macintosh computer. *Behavior Research Methods, Instruments, and Computers, 21,* 67–72.

Álvarez, C. J., Carreiras, M., & de Vega, M. (1992). Estudio estadístico de la ortografía castellana: 1. La frecuencia silábica [A statistical study of Spanish orthography: 1. Syllable frequency]. *Cognitiva, 4,* 75–105.

Andrews, S. (1989). Frequency and neighborhood effects on lexical access: Activation or search? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 802–814.

Andrews, S. (1992). Frequency and neighborhood effects on lexical access: Lexical similarity or orthographic redundancy? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 234–254.

Balota, D. A., & Chumbley, J. I. (1984). Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage. *Journal of Experimental Psychology: Human Perception and Performance, 10,* 340–357.

Baluch, B., & Besner, D. (1991). Visual word recognition: Evidence from strategic control of lexical and nonlexical routes in oral reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 644–652.

Besner, D., & Smith, M. C. (1992). Basic processes in reading: Is the orthographic depth hypothesis sinking? In R. Frost & L. Katz (Eds.), *Orthography, phonology, morphology, and meaning* (pp. 46–66). Amsterdam: Elsevier.

Carello, C., Lukatela, G., Peter, M., & Turvey, M. T. (1995). Effects of association frequency and stimulus quality on naming words in the presence or absence of pseudowords. *Memory & Cognition, 23,* 289–300.

Carello, C., Lukatela, G., & Turvey, M. T. (1994). Lexical involvement in naming does not contravene prelexical phonology: Comment on Sebastián-Gallés (1991). *Journal of Experimental Psychology: Human Perception and Performance, 20,* 192–198.

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.

Cobos, P. L., Domínguez, A., Álvarez, C. J., Alameda, J. R., Carreiras, M., & de Vega, M. (1995). Diccionario de frecuencia silábica [Dictionary of syllable frequency]. In J. R. Alameda & F. Cuetos (Eds.), *Diccionario de frecuencia de las unidades lingüísticas del castellano* [Dictionary of word frequency in Spanish]. (Vol. 2, pp. 71–114). Oviedo, Spain: Servicio de Publicaciones de la Universidad de Oviedo.

Coltheart, M., Davelaar, E., Jonasson, J. F., & Besner, D. (1977). Access to the internal lexicon. In S. Dornic (Ed.), *Attention and performance VI* (pp. 535–555). Hillsdale, NJ: Erlbaum.

Cutler, A., Mehler, J., Norris, D., & Seguí, J. (1986). The syllable's differing role in the segmentation of French and English. *Journal of Memory and Language, 25,* 385–400.

Domínguez, A., Cuetos, F., & de Vega, M. (1993). Efectos diferenciales de la frecuencia silábica: Dependencia del tipo de prueba y características de los estímulos [Syllable frequency effects depend on type of task and composition list]. *Estudios de Psicología, 50,* 5–31.

Domínguez, A., de Vega, M., & Cuetos, F. (1997). Lexical inhibition from syllabic units in Spanish visual word recognition. *Language and Cognitive Processes, 12,* 401–422.

Ferrand, L., Seguí, J., & Grainger, J. (1996). Masked priming of words and picture naming: The role of syllabic units. *Journal of Memory and Language, 35,* 708–723.

Forster, K. I. (1989). Basic issues in lexical processing. In W. D. Marslen-Wilson (Ed.), *Lexical representation and process* (pp. 75–107). Cambridge, MA: MIT Press.

Forster, K. I., & Shen, D. (1996). No enemies in the neighborhood: Absence of inhibitory effects in lexical decision and categorization. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 696–713.

Forster, K. I., & Taft, M. (1994). Bodies, antibodies, and neighborhood density effects in masked form priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 844–863.

Frauenfelder, U. H., Baayen, R. H., Hellwig, F. M., & Schreuder, R. (1993). Neighborhood density and frequency across languages and modalities. *Journal of Memory and Language, 32,* 781–804.

Glushko, R. J. (1979). The organization and activation of orthographic knowledge in reading aloud. *Journal of Experimental Psychology: Human Perception and Performance, 5,* 361–379.

Grainger, J. (1990). Word frequency and neighborhood frequency effects in lexical decision and naming. *Journal of Memory and Language, 29,* 228–244.

Grainger, J. (1992). Orthographic neighborhoods and visual word recognition. In R. Frost & L. Katz (Eds.), *Orthography, phonology, morphology, and meaning* (pp. 131–146). Amsterdam: Elsevier.

Grainger, J., & Jacobs, A. M. (1994). A dual read-out model of word context effects in letter perception: Further investigations of the word superiority effect. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 1158–1176.

Grainger, J., & Jacobs, A. M. (1996). Orthographic processing in visual word recognition: A multiple read-out model. *Psychological Review, 103, 518–565.*

Grainger, J., O'Regan, J. K., Jacobs, A. M., & Seguí, J. (1989). On the role of competing word units in visual word recognition: The neighborhood frequency effect. *Perception & Psychophysics, 45,* 189–195.

Grainger, J., O'Regan, J. K., Jacobs, A. M., & Seguí, J. (1992). Neighborhood frequency effects and letter visibility in visual word recognition. *Perception & Psychophysics, 51,* 49–56.

Grainger, J., & Seguí, J. (1990). Neighborhood frequency effects in visual word recognition: A comparison of lexical decision and masked identification latencies. *Perception & Psychophysics, 47,* 191–198.

Howes, D. H., & Solomon, R. L. (1951). Visual duration thresholds as a function of word probability. *Journal of Experimental Psychology, 55,* 401–410.

Jacobs, A. M., & Grainger, J. (1994). Models of visual word recognition: Sampling the state of the art. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 1311–1334.

Johnson, N. F., & Pugh, K. R. (1994). A cohort model of visual word recognition. *Cognitive Psychology, 26,* 240–346.

Juilland, A., & Chang-Rodríguez, E. (1964). *Frequency dictionary of Spanish words.* The Hague, The Netherlands: Mouton.

Kay, J., & Marcel, A. (1981). One process, not two, in reading aloud: Lexical analogies do the work of non-lexical routes. *Quarterly Journal of Experimental Psychology, 33A,* 397–413.

Landauer, T. K., & Streeter, L. A. (1973). Structural differences between common and rare words: Failures or equivalence assumptions for theories of word recognition. *Journal of Verbal Learning and Verbal Behavior, 12,* 119–131.

Levelt, W. J. M., & Wheeldon, L. (1994). Do speakers have access to a mental syllabary? *Cognition, 50,* 239–269.

Massaro, D. W., & Cohen, M. M. (1994). Visual, orthographic, phonological, and lexical influences on reading. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 1107–1128.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part 1. An account of basic findings. *Psychological Review, 88,* 375–407.

Mehler, J., Dommergues, J., Frauenfelder, U., & Seguí, J. (1981). The syllable's role in speech segmentation. *Journal of Verbal Learning and Verbal Behavior, 20,* 298–305.

Monsell, S. (1991). The nature and locus of word frequency effects in reading. In D. Besner & G. W. Humphreys (Eds.), *Basic processes in reading: Visual word recognition* (pp. 148–197). Hillsdale, NJ: Erlbaum.

Monsell, S., Patterson, K. E., Graham, A., Hughes, C. H., & Milroy, R. (1992). Lexical and sublexical translation of spelling to sound: Strategic anticipation of lexical status. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 452–467.

Norris, D. (1994). A quantitative multiple-levels model of reading aloud. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 1212–1232.

Paap, K. R., & Johansen, L. S. (1994). The case of the vanishing frequency effect: A retest of the verification model. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 1129–1157.

Paap, K. R., McDonald, J. E., Schvaneveldt, R. W., & Noel, R. W. (1987). Frequency and pronounceability in visually presented naming and lexical-decision tasks. In M. Coltheart (Ed.), *Attention and performance XII* (pp. 221–244). Hillsdale, NJ: Erlbaum.

Paap, K. R., Newsome, S. L., McDonald, J. E., & Schvaneveldt, R. W. (1982). An activation-verification model for letter and word recognition: The word superiority effect. *Psychological Review, 89,* 573–594.

Perea, M., & Carreiras, M. (1995). Efectos de frecuencia silábica en tareas de identificación [Effects of syllable frequency in identification tasks]. *Psicológica, 16,* 302–311.

Perea, M., & Carreiras, M. (1996). Efectos de vecindad ortográfica y silábica en la pronunciación de palabras y pseudopalabras [Effects of orthographic and syllabic neighborhood in word and nonword naming]. *Psicológica, 17,* 425–440.

Perea, M., & Pollatsek, A. (in press). The effects of neighborhood frequency in reading and lexical decision. *Journal of Experimental Psychology: Human Perception and Performance.*

Pugh, K. R., Rexer, K., Peter, M., & Katz, L. (1994). Neighborhood effects in visual word recognition: Effects of letter delay and nonword context difficulty. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 639–648.

Rapp, B. C. (1992). The nature of sublexical orthographic organization: The bigram through hypothesis examined. *Journal of Memory and Language, 31,* 33–53.

Ratcliff, R. (1993). Methods for dealing with reaction time outliers. *Psychological Bulletin, 114,* 510–532.

Sears, C. R., Hino, Y., & Lupker, S. J. (1995). Neighborhood frequency and neighborhood size effects in visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 876–900.

Sebastián, N. (1991). Reading by analogy in a shallow orthography. *Journal of Experimental Psychology: Human Perception and Performance, 17,* 471–477.

Sebastián, N. (1994). Phonological, orthographic, and lexical codes: Comment on Carello et al. (1994). *Journal of Experimental Psychology: Human Perception and Performance, 20,* 199–202.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review, 96,* 523–568.

Seidenberg, M. S., Plaut, D. C., Petersen, A. S., McClelland, J. L., & McRae, K. (1994). Nonword pronunciation and models of word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 1177–1196.

Shallice, T., Warrington, E. K., & McCarthy, R. (1983). Reading without semantics. *Quarterly Journal of Experimental Psychology, 35A,* 111–138.

Tabossi, P., & Laghi, L. (1992). Semantic priming in the pronunciation of words in two writing systems: Italian and English. *Memory & Cognition, 20,* 303–313.

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.

Taft, M., & Forster, K. I. (1976). Lexical storage and retrieval of polymorphemic and polysyllabic words. *Journal of Verbal Learning and Verbal Behavior, 15,* 607–620.

Treiman, R., Mullennix, J., Bijeljac-Babic, R., & Richmond-Welty, E. D. (1995). The special role of rimes in the description, use, and aquisition of English orthography. *Journal of Experimental Psychology: General, 124,* 107–136.

Vega, M. de, Carreiras, M., Gutiérrez, M., & Alonso, M. L. (1990). *Lectura y comprensión: Una perspectiva cognitiva* [Reading and comprehension: A cognitive perspective]. Madrid: Alianza Editorial.

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