

# The Effect of Phonological Structure on Visual Word Access in Bilinguals

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**Abstract** Two experiments examined if visual word access varies cross-linguistically by studying Spanish/English adult bilinguals, priming two syllable CVCV words both within (Experiment 1) and across (Experiment 2) syllable boundaries in the two languages. Spanish readers accessed more first syllables based on within syllable primes compared to English readers. In contrast, syllable-based primes helped English readers recognize more words than in Spanish, suggesting that experienced English readers activate a larger unit in the initial stages of word recognition. Primes spanning the syllable boundary affected readers of both languages in similar ways. In this priming context, primes that did not span the syllable boundary helped Spanish readers recognize more syllables, while English readers identified more words, further confirming the importance of the syllable in Spanish and suggesting a larger unit in English. Overall, the experiments provide evidence that readers use different units in accessing words in the two languages.

**Keywords** Bilingualism · Spanish/English · Reading · Visual word activation · Priming

Previous research investigating visual word access of multisyllabic words has suggested that English and Spanish may differ in their use of the syllable as a unit of

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lexical access, with all evidence pointing to the syllable playing a key role in Spanish and with evidence for the syllable being somewhat more mixed in English. This paper reports two experiments directly comparing English and Spanish word access while reading, with the goal of elucidating the differences between the two languages in their use of syllables during reading.

Current phonological theory, backed by linguistic evidence, advocates the prosodic approach, in which phonological representations are depicted as multi-layered hierarchical structures (Blevins, 1995; Jensen, 2000; Nespor & Vogel, 1986; Selkirk, 1982). Based on phonological evidence, the theory posits strictly layered prosodic categories (with those that apply to words outlined in (1)). One or more units of each category may be contained in the next higher unit (Jensen, 2000).

(1) *Prosodic hierarchy:*

- Prosodic Word ( $\omega$ )
- Foot (F)
- Syllable ( $\sigma$ )
- Mora (m)
- Segment

A legitimate problem in researching reading is whether visual word access proceeds via the same representational structures as speech, which would entail a conversion of orthographic representations into phonological ones. Obviously, written text can be converted into phonological codes since it can be read aloud, but the questions are if conversion occurs automatically, at what stage in the process, or if the use of phonological codes can vary. For example, much debate has centered on how much readers take a holistic or whole word approach to reading, if they break the script down into constituent parts while reading, or if the unit of analysis varies according to reading skill (Coltheart, Curtis, Atkins & Haller, 1993; Coltheart, Rastle, Perry, Langdon & Ziegler, 2001; Plaut, McClelland, Seidenberg, & Patterson, 1996).

While some researchers have adopted the position that reading automatically makes use of phonological processes (e.g., Perfetti, Zhang, & Berent, 1992), few reading researchers have started from the theoretical perspective of investigating if reading exploits pre-existing phonological representations. Most researchers who have explicitly adopted the prosodic approach to phonology to study visual word access have investigated the segmental level (e.g., Berent, Bouissa, & Tuller, 2001; Berent, Shimron, & Vaknin, 2001), while Ashby and Rayner (2004) examined the syllabic level. The goal of the present research is to further study the syllabic level, by comparing visual word access cross-linguistically to see if languages vary in their use of syllables during reading or if some other prosodic level may be implicated in early word recognition processes.

As previously mentioned, prior research results suggest that Spanish and English differ in their use of syllables in lexical access during reading, perhaps following from Spanish being a syllable-timed language, with relatively equal syllable weight and clearly defined syllable structure (Carreires, Alvarez, & de Vega, 1993; Harris, 1983; Sánchez-Casas, 1996), while English is a stressed timed language, with alternation between strong and weak syllables and less well defined syllables (Jensen, 2000; Kahn, 1976; Rubach, 1996; Selkirk, 1982).

In Spanish many empirical results suggest that readers exploit the syllabic level of the prosodic hierarchy as a key unit of visual lexical access. Empirical findings

consistently demonstrate that highly frequent syllables have an inhibitory effect on lexical decision times (Álvarez, Carreiras, & de Vega, 2000; Álvarez, Carreiras, & Perea, 2004; Álvarez, Carreiras, & Taft, 2001; Álvarez, de Vega, & Carreiras, 1998; Carreiras & Perea, 2002; Carreiras et al., 1993; Domínguez, de Vega & Cuertos, 1997; Perea & Carreiras, 1998), and naming times (Carreiras et al., 1993; Domínguez et al., 1997; Perea & Carreiras, 1998).

This inhibitory effect of high frequency syllables on lexical decision and naming tasks is most easily explained by assuming a model of lexical activation containing a syllabic level of processing, where syllables activate potential candidates or lexical nodes. High frequency syllables activate a larger cohort of potential candidates (having a larger syllabic neighborhood) and competition among the many candidates results in the inhibitory effect. However, subsequent research has modified this analysis, specifying that inhibition is caused mainly by the number of higher frequency words that share the same first syllable instead of the number of syllabic neighbors alone (Perea & Carreiras, 1998), meaning that inhibitory effects are always larger for low frequency words (Álvarez et al., 1998, 2000; Perea & Carreiras, 1998; Carreiras et al., 1993)—an interpretation that is wholly compatible with an activational model positing a syllable level.

Follow-up research indicated that while more frequent words presented as syllable primes had an inhibitory effect on target identification, non-word primes had a facilitatory effect, and masked partial identity primes that corresponded to the syllable boundary speeded response time on a lexical decision task in comparison to those that did not, clear evidence that the syllable is a key sub-lexical unit in visual word access in Spanish (Carreiras and Perea, 2002). For example, in their fourth experiment, Carreiras & Perea (2002) used a partial identity priming task with lexical decision to probe the importance of the syllable boundary in Spanish. The targets were six letter words with either CV•CV•CV or CVC•CVC structure. The primes either corresponded to the first syllable of the word or did not (e.g. *pa\*\*\*\*-PA•SI•VO* versus *pas\*\*\*-PA•SI•VO* and *pa\*\*\*\*-PAS•TOR* versus *pas\*\*\*-PAS•TOR*). Comparing primes that corresponded to the syllable boundary to those that did not, CV•CV•CV words were responded to faster when preceded by CV primes than by CVC primes and CVC•CVC words had quicker response times when preceded by CVC primes than by CV primes, offering further clear evidence that suggests that the syllable is a key unit in lexical access in Spanish.

Studies have demonstrated that the empirical syllable frequency effects cannot result from such potentially confounding factors as bigram frequency (Carreiras et al., 1993), orthographic neighborhood density/neighborhood frequency (Perea & Carreiras, 1998), and stress placement (Álvarez et al., 2002). More recently, experimental results using non-word primes that have the same phonological form but a different orthographic form as a target (i.e. *bi.rel-VI.RUS*) suggest that the syllable priming effect is phonological in nature and not orthographic (Álvarez, Carreiras, & Perea, 2004). In fact, all results lead to the conclusion that the syllable-based priming effect is real and that the syllable truly is an important unit of lexical access in Spanish.

In contrast to Spanish, evidence for the appropriate unit of visual word access is somewhat mixed in English. Some syllable-based structures such as Vocalic Center Groups (where consonants are grouped around vowels to form pronounceable units) (Spoehr & Smith, 1973) and sub-syllabic components of onset and rime (Bowey, 1990; Treiman, 1986; Treiman & Chafetz, 1987) have received empirical support as units of lexical access. In contrast, studies using short-term memory techniques have

found that subjects are not consistent in their syllabification judgments of English words, with stress, vowel quality (tense versus lax), and the sonority of the consonant affecting syllabification (Treiman & Danis, 1988a,b; Treiman, Straub, & Lavery, 1994). Syllabification that varies according to context could be interpreted as meaning that syllables are a less reliable source of information, meaning that readers would rely on them less in word access.

In a study using an illusory conjunctions technique, Prinzmetal and associates concluded that syllables were a perceptual unit in reading based on subjects generally reporting the color of a target letter as being the same as that of the syllable in which it was a part, even when the color was different (Prinzmetal & Millis-Wright, 1984; Prinzmetal, Treiman & Rho, 1986). Seidenberg (1987) challenged Prinzmetal's findings of syllable-based processing, claiming that the results were instead due to orthographic factors. Specifically, the illusion of syllable-based perception arose from bigram troughs, where the low co-occurrence of orthographic letters that span syllables supplied a signal to readers of a syllable boundary. In turn, Rapp (1992) challenged the bigram trough hypothesis, using the same task as Prinzmetal, Treiman & Rho (1986) with stimuli controlled for bigram frequency and demonstrating sensitivity to syllabic structure.

In addition, naming experiments examining syllables as units of visual access have produced inconsistent results. For example, Jared & Seidenberg (1990) studied the effects of word frequency, spelling consistency, and number of syllables on the speed of naming multisyllabic words where they presented words as either wholes or broken into syllables. They concluded that readers do not always segment or decompose words into syllables. Several of their research findings suggest that readers were not breaking words into sub-units for lexical access: first, the naming of higher frequency words was not affected by spelling inconsistency, favoring a whole word lexical access interpretation; second, in comparison to a whole word presentation, subjects shown both high and low frequency words with a syllable by syllable division experienced increased naming latencies, suggesting that subjects do not use syllables for lexical access, since breaking words down into syllables actually impeded response times; and third, word length (number of syllables) only affected naming latencies for lower frequency words, also casting doubt on the consistent use of syllables in visual word access.

In a masked priming experiment, Ferrand, Seguí & Humphreys (1997) compared the effect of CV and CVC primes on the naming of words with a clear syllable boundary to those with an ambisyllabic boundary. They found that syllable-based priming effects vary according to the clearness of the syllable boundary, suggesting that English readers vary in their use of syllables and do not consistently segment words into syllables or that syllables come into play in a later stage involving phonological encoding. Primes corresponding to the first syllable speeded naming of multisyllabic words with a clear first syllable boundary, but had no effect when the boundary was not clear. In contrast, the results of Experiment 5 in Ferrand, Seguí & Humphreys (1997) hinted that syllables may aid word recognition. In this experiment, they found that CV primes had a greater facilitative effect on the naming of words where the first syllable corresponded to CV than CVC primes, leading them to conclude that the facilitation was due to syllabic overlap and not due to phonological or orthographical overlap.

Replicating the materials, design and procedure of Experiment 5 from Ferrand, Seguí & Humphreys (1997), Schiller (2000) failed to find any statistical difference between CV, CVC, and neutral primes on the naming latencies of words beginning with CV syllables, with CV and CVC primes having equal effect and testing only

a millisecond faster than neutral primes. Schiller (2000) also failed to replicate by increasing statistical power, having each participant complete all three experimental blocks two times—meaning that each participant saw every target six times. Only CVC primes facilitated naming of targets in comparison to neutral primes, suggesting that the facilitation was due to segmental overlap rather than syllables. Overall, the results from naming experiments are contested and do not clearly support an important role for syllables in visual word access.

Relatively few experiments have used lexical decision to examine the importance of syllables to visual word recognition in English. Ferrand, Seguí & Humphreys (1997) failed to find any effect of syllable-based primes on lexical decision times. This result led them to conclude that syllable-based effects were in output instead of lexical access processes.

Recently, Ashby and Rayner (2004) used eye-tracking in two experiments to examine if syllable information was used to read words (with either a CV or CVC first syllable) presented as a part of a continuous text. In the first experiment, they compared the effect of syllable matching, non-syllable matching, and neutral primes presented just before eye saccades reached the target word, finding that target words were read faster when preceded by CVC primes regardless of the syllable boundary. In their second experiment, they used the same materials, but changed the technique, having the primes constantly present in the text while the subjects were reading, and the presentation of the whole word being triggered by saccades just prior to reaching the target. With the changed technique, subject's first fixations on target words were shorter when primes corresponded to the syllable boundary, leading Ashby and Rayner to claim that readers do use syllabic information while reading. They further argued that Experiment 2 focused on later processes of word recognition and that syllable structures come into play in these later stages of word recognition in English, having to do with spoken output or short-term memory storage. They suggest that this use of syllabic information in later stages involving phonological assembly accounts for the previous inconsistent experimental results for syllables in visual word access in English, with some methods tapping into early processes and others into later ones.

All in all, the experimental evidence supporting the role the syllable in visual lexical access in English is not entirely consistent and suggests that its use may come at a later stage, in marked contrast to Spanish—suggesting that the two languages differ in their use of prosodic representations in visual word access. In fact, the precise unit of visual word access in English is a matter of some contention, with some proposing a larger orthographically and morphologically based unit (Taft, 1979), others arguing against pre-lexical morphological decomposition (Butterworth, 1983; Cole, Beauvillain & Seguí, 1989, 2000; Lukatela, Gligorijevic, Kostic & Turvey, 1980), others claiming full morphological decomposition (Taft, 1994; Taft & Forster, 1975, 1976), and some claiming a mixed model dependent on prior knowledge of the word (Chialant & Caramazza, 1995). Recently, Ziegler & Goswami (2005) put forward that the access unit in English can vary greatly in grain size, with readers flexibly making use of both small size units and larger units owing to the degree of orthographic inconsistency. Overall, the unit of reading lexical access in the two languages appears to vary, with Spanish readers clearly exploiting the syllabic level of the prosodic hierarchy and English readers more commonly exploiting a larger unit.

To further examine if English and Spanish differ in their use of phonological representations in visual word access, a direct comparison of the two languages may be helpful. Bilinguals offer the most direct comparison of reading in the two languages

since the same subject is reading in both languages. Such subjects will also allow an investigation into whether bilinguals vary their reading practices in their two languages, a question that has received scant prior attention. Most research that has examined bilingual readers has focused on testing if script differences between alphabetic, syllabic, or logographic writing systems affect lexical access in a second language—with results that suggest that the nature of an L1 script may affect phonological access in L2 reading (e.g., Koda, 1989; Saito, Inoue, & Nomura, 1979; Wang, Koda & Perfetti, 2003; Wang, Perfetti & Liu, 2003). Generally, very little research has examined bilingual readers in both languages to see if their reading varies in them. Some have examined the speed and ease of bilingual readers in both their languages, finding that their reading was generally superior in L1 (e.g., Favreau, Komoda, & Segalowitz, 1980; Favreau, & Segalowitz, 1983), but that this difference in speed can be affected by the nature of the scripts (Shimron & Sivan, 1994). Recently, research examining English/Hebrew bilingual dyslexics in both languages suggested that the reading deficits manifest themselves in both languages, but that the specific nature of the scripts causes the degree of the deficit to be different in both languages (Oren, & Breznitz, 2005).

Therefore, the goal of the present research is to examine visual word access in bilingual readers to see if differences in phonological structure between two languages cause readers to lexically activate words in different manners in the two languages, thereby revealing the nature of visual word access in both languages and in bilingual readers.

## Experiment 1

Priming within the first syllable of similar words in both languages will test whether bilingual readers differ in their use of syllables in lexical access in reading in the two languages and if bilingual readers vary in their use of phonological representations as they access words. We predicted that bilingual readers would access differing information while reading in their two languages, with readers in Spanish decomposing words into syllables in lexical access and readers in English using some larger phonological unit. Priming the first syllable in Spanish should help readers gain access to the first syllable, but not any larger chunk of the word. In contrast, in English, syllabic information seems to be accessed later in word recognition processes and previous research suggests that readers use some undetermined larger unit for lexical access—meaning that priming the first syllable will help readers identify a larger unit. For this reason, we will compare bilingual readers' accuracy in recognizing syllables (CV) and all possible larger units, including first consonant/first vowel/second consonant (CVC) and word, predicting that priming will help Spanish readers identification of CV and that English readers' identification of CVC or word will be facilitated.

## Method

### *Subjects*

Twenty-six Bilingual English and Spanish readers recruited at Northwestern University and in the Chicago metropolitan area participated in the experiment. They were paid \$ 8 for the hour-long experiment. Two subjects were excluded from analysis

**Table 1** Bigram token frequency

Bigram	Language	Mean	SD	Significance
CVxx	English	935.4	792.5	$p = .226$
	Spanish	1279.6	2041.7	
xVCx	English	951.4	1228.2	$p = .335$
	Spanish	1223.2	1792.5	
xxCV	English	946.5	973.9	$p = .000$
	Spanish	2185.9	2126.0	

because their standardized reading scores fell two standard deviations below the norm in either English or Spanish, leaving 24 subjects. The sample included 12 men and 12 women. The average age of participants was 30.9-years-old.

### *Design and Materials*

This study used a partial identity masked priming task. Equivalent materials in both languages for all test conditions were developed. The stimuli consisted of two syllable words phonologically fitting the schema of CVCV, with stress on the first syllable. Orthographically, 30 words in English fit the pattern CVCV and 30 fit the pattern CVCVC. All 60 Spanish stimuli fit the orthographic and phonological pattern CVCV. The orthographic difference between English and Spanish arose from the limited number of orthographic CVCV words in English with stress on the first syllable. Obvious cognates were excluded from the stimuli in both languages. (See Appendix for a list of the stimuli used.)

The stimuli were controlled for their word frequency and bigram frequency using the CELEX database for English (Baayen, Piepenbrock, & Gulikers, 1995) and the Diccionario de frecuencias de las unidades lingüísticas del castellano (Alameda, & Cuetos, 1995) for Spanish. The word sets showed no significant difference between the two languages for word frequency and for token frequency for the first two bigrams (Table 1)<sup>1</sup>. The difference between the two languages for the last bigram's token frequency follows from the fact that relatively few letters can appear in word final position in Spanish. For this reason, we will confine our statistical analyses to the first two bigrams.

Additionally, all stimuli were controlled for the token transitional probabilities of letters, with no significant difference between languages (Table 2). Within both languages, there was a significant difference between the transitional probability of the first two letters and the second two letters in both word sets ( $p < 0.001$ ), but no significant difference existed between languages in either word set for this difference.

### *Procedures:*

Testing took place in a sound isolation booth on Northwestern University's Evanston campus. The test session lasted about an hour for each subject. Subjects were

<sup>1</sup> The two sets of stimuli did have a significant difference in type frequency between the different bigrams. The mean type frequency for the first bigram for English was 37.37 and for Spanish was 9.80, yielding a significant difference of  $p < .001$ . For the second bigram, the mean in English was 27.55, and in Spanish it was 8.43 ( $p < .001$ ). For the last bigram the mean type frequency for English was 29.33 and for Spanish 14.28 ( $p < .001$ ). While both type and token frequency are important, token frequency, or how much the bigrams appear together in actual discourse, is more important than type frequency since it is an estimate of how much people in reality see the two letters.

**Table 2** Token transitional probability

Bigram	Language	Mean	SD	Significance
CVxx	English	.21	.16	$p = .169$
	Spanish	.25	.19	
xVCx	English	.07	.08	$p = .380$
	Spanish	.09	.13	

**Table 3** Experimental conditions in Experiment 1

Status	Prime	Target
Test Conditions	S###	sofa
	#O##	sofa
	SO##	sofa
Control	####	sofa

randomly assigned to whether they completed the English or the Spanish part of the testing first. When they were in either the Spanish or the English condition, the experimenter spoke to them in only that language. Before beginning the experiment in each language, the subjects took standardized tests in both languages to determine their reading level. In English, the Letter Word Identification (LWI) and the Passage Comprehension (PC) sub-tests from Woodcock Reading Mastery Test were used, while in Spanish the equivalent sub-tests from the Bateria Woodcock–Muñoz were adopted (Woodcock, 1987; Woodcock & Muñoz-Sandoval, 1995).

Subjects viewed all stimuli for the priming task on a SVGA monitor in a darkened room, with a desk lamp on the floor providing background ambient lighting. The Apple computer used Psyscope software designed to control the priming experiment (Cohen, MacWhinney, Flatt & Provost, 1993). Subjects pressed an external button device to see the next presentation, controlling the stimulus presentation rate and recording their responses by writing on a test sheet.

Subjects saw different primes that corresponded to the first consonant of the word (C###), the first vowel (#V##), the first syllable (CV##), or, in the control condition, a series of number signs. The primes and the targets matched up in the manner demonstrated in Table 3. Additionally, four counterbalancing conditions were presented at random to different subjects. The different counterbalancing conditions varied the primes that were shown with different words. Balanced presentation of stimuli ensured that each participant saw each condition equally often and that each item was preceded by each prime type equally often. Subjects viewed stimuli within each counterbalancing condition in a randomized order of presentation.

Subjects viewed primes and targets on a standard black background with white letters. The subjects first saw a fixation cross on the computer screen before each trial, and the participant was asked to press an external button box to begin each trial. When they triggered the trial, they then saw the prime in upper case letters and the target in lower case letters flash on the computer screen for 16 ms each followed by a series of number signs for an additional 500 ms. The presentation of lower and upper case letters helped ensure that the task was not simply visual priming, but instead accessing abstract letter representations. The rate of presentation ensured interpretable accuracy levels (Berent & Perfetti, 1995; Lukatela & Turvey, 2000; Perry & Ziegler, 2002). Previous findings have held that less than 40% accuracy for word identification precludes strategic processing with this technique (Xu & Perfetti, 1999).

**Table 4** Results of standardized tests for Experiment 1

Letter Word ID—English	Passage Comp—English	Letter Word ID—Spanish	Passage Comp—Spanish
110.29 (18.65)	112.58 (20.09)	101.08 (12.96)	98.46 (15.36)

Before beginning each part of the experiment, subjects completed a practice set of four examples. The subject read instructions presented on the computer screen and the experimenter discussed them with the subject to ensure understanding before beginning the practice set. Subjects were instructed to do their best to guess even if they were uncertain of what they had seen. They were reminded of the importance of writing words with the appropriate number of letters for all trials. After completing the experiment, the researcher asked them questions about their language background, recording their answers on a Language Background Questionnaire.

## Results

### *Subjects*

The results from the standardized tests of reading show that the subjects who participated in this experiment were overall English dominant and are summarized in Table 4 below, reporting the mean Standardized Score (SS) and the SD for the subjects on each sub-test. The SS on this test is based around 100, with half the participants in a particular age range scoring either higher or lower during norming. The SD of the sample population during norming was 15 points. Using the SD value from the normed test, we defined language dominance according to the following criteria: English and Spanish dominants had scores greater than 2/3 of a SD on both the LWI and PC in their dominant language, while balanced bilinguals had scores on at least one test with less than 2/3 of a SD between the two languages or scores greater than 2/3 of a SD on both tests, but with one test greater in each language. According to this analysis, 11 subjects were English dominant, 11 were balanced bilinguals and 2 were Spanish dominant. The subjects' English dominance was confirmed by *t*-tests comparing their scores in the two languages, with a significant difference in scores for the PC sub-test ( $t(46) = 2.74, p = .009$ ) and with the difference in scores approaching significance for the LWI sub-test, ( $t(46) = 1.99, p = .053$ ).

Similar results were obtained from the Language Background Questionnaire, which was administered to each subject after they completed the experiment. Their responses are summarized in Table 5. From the questionnaire, 14 subjects' first language was Spanish, while 8 learned English first and 2 Portuguese. The average age when subjects learned their second language was 13-years-old. Most subjects had spent far

**Table 5** Results from the Language Background Questionnaire for Experiment 1

L1	Age learned L2	Years in English country	Years in Spanish country	Self-proficiency rating (1–6)
14 Spanish, 8 English, 2 Portuguese	13.0 (8.0)	20.3 (16.1)	8.8 (11.7)	English 5.3, Spanish 5.0

**Table 6** Accurate responses according to prime types (with SE)

Language	Prime	CV	CVC	WORD
English	C###	23.07(2.19)	3.01 (.87)	28.91 (4.78)
	#V##	12.37(1.61)	1.38 (.56)	15.36 (3.28)
	CV##	49.33(4.78)	3.76 (1.04)	36.79 (5.35)
	####	8.55(1.69)	0.60 (.41)	15.07 (3.68)
	C###	32.37(3.30)	2.72 (.77)	26.64 (5.57)
Spanish	#V##	11.76(2.31)	3.05 (.90)	16.70 (4.07)
	CV##	59.90(4.22)	3.39 (.83)	29.65 (4.24)
	####	9.00(1.87)	1.86 (.71)	16.48 (4.30)

more time in an English speaking country than in a Spanish speaking one (20.3 vs. 8.8 years). Finally, subjects' self-rating of their language proficiency in English was higher than their rating of their proficiency in Spanish (5.3 versus 5.0).

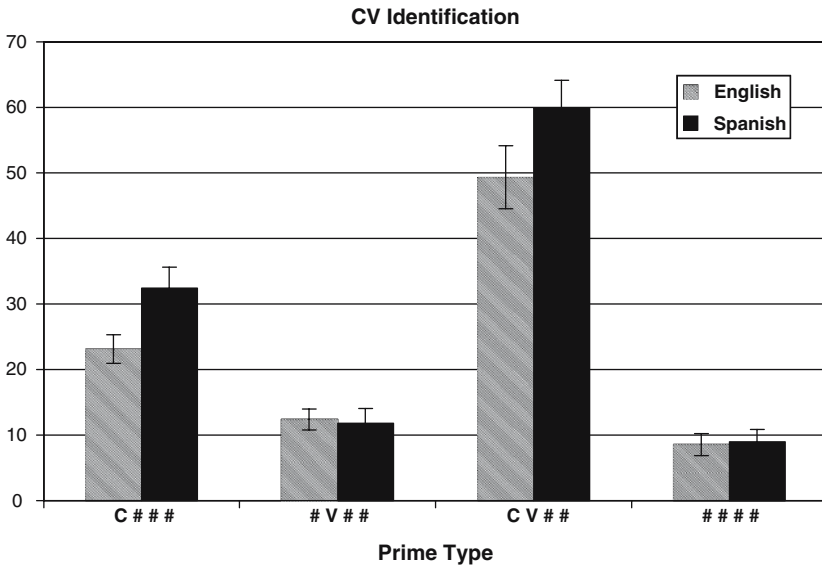
### Priming Task

For each language and prime type accuracy levels in identifying first consonant/first vowel (CV), the first consonant/first vowel/second consonant (CVC), and words were calculated and averaged according to subjects and items. While Table 6 reports subject data, giving the accuracy of recognizing the different units and the standard error in parentheses, we report statistically significant findings for both the subject and the item analyses. We analyzed independent identification of all three units to see if they were identified on their own. Independent identification means that we are defining identification of the CV, for example, as being when uniquely those letters together were correctly recognized, without being a part of any larger unit.

$2 \times 2 \times 2$  ANOVAs (First consonant primed versus Unprimed  $\times$  First vowel primed versus Unprimed  $\times$  English versus Spanish) examined accuracy of identification of CV, CVC and word units, with language as a within subject factor and a between item factor.

For CV identification, all three main effects were significant. The main effect of priming C was significant according to subjects ( $F(1, 23) = 146.56, p < .001$ ) and items ( $F(1, 118) = 272.01, p < .001$ ). The main effect of priming V was also significant according to subjects ( $F(1, 23) = 40.24, p < .001$ ) and items ( $F(1, 118) = 94.83, p < .001$ ). In addition, CV identification was greater in Spanish, with the main affect of language significant according to subjects ( $F(1, 23) = 4.62, p = .042$ ) and marginally significant according to items ( $F(1, 118) = 3.48, p = .064$ ). The interaction between C Primes and V Primes was significant according to subjects ( $F(1, 23) = 35.17, p < .001$ ) and items ( $F(1, 118) = 70.69, p < .001$ ), with CV## primes (and to a lesser extent C### primes) resulting in greater recognition of CV in comparison to the other primes. Finally, the interaction between C primes and language was significant according to subjects ( $F(1, 23) = 7.21, p = .013$ ) and items ( $F(1, 118) = 7.14, p = .009$ ) —with C Primes leading to increased identification of syllables in Spanish in comparison to English.

In order to tease apart the interaction between C primes and language and to examine the effect of individual primes, we ran paired sample *t*-tests for subjects and independent sample *t*-tests for items and present the identification rates of CV based on different prime types in Fig. 1. The *t*-tests show that both C### and CV##



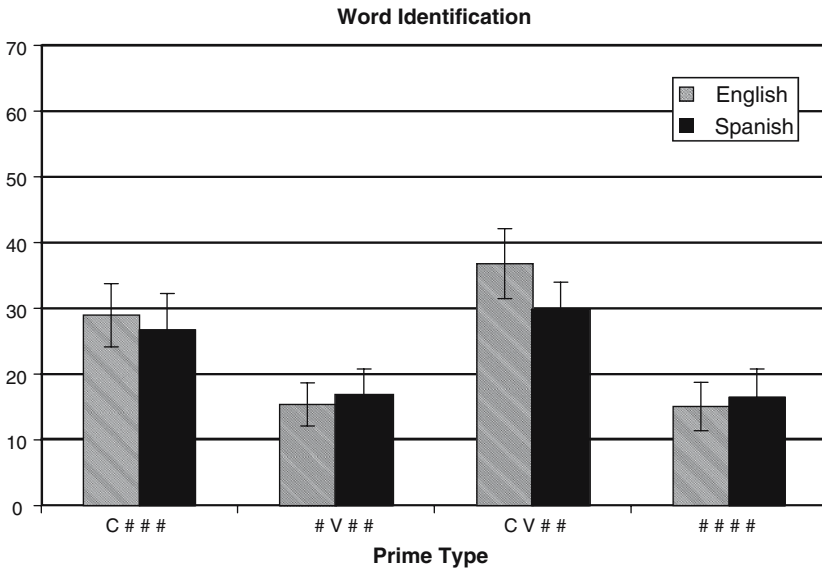
**Fig. 1** Accuracy of identification of CV (+SE) according to prime type in English and Spanish

primes result in significantly greater accuracy of identification of syllables in Spanish. For C### primes, CV identification was significantly greater in Spanish according to both subjects ( $t(23) = -2.41, p = .012$ ) and items ( $t(118) = -2.30, p = .012$ ). Also CV## primes resulted in significantly greater identification of CV in Spanish according to both subjects ( $t(23) = -2.19, p = .02$ ) and items ( $t(118) = -2.17, p = .016$ ). In contrast, #V## primes and #### primes did not result in significantly different identification of CV between languages (Fig. 1).

Turning to identification of CVC the only significant result was the main effect of C primes which significantly affected accuracy in identifying CVC according to subjects ( $F(1, 23) = 5.69, p = .026$ ) and items ( $F(1, 118) = 4.05, p = .046$ ).

For word identification, the main effect of C primes was significant according to subjects ( $F(1, 23) = 53.83, p < .001$ ) and items ( $F(1, 118) = 68.14, p < .001$ ). According to both subjects ( $F(1, 23) = 3.82, p = .063$ ) and items ( $F(1, 118) = 3.48, p = .064$ ), word identification was marginally aided by V primes. The interaction between C Primes and V Primes was significant according to subjects ( $F(1, 23) = 5.44, p = .029$ ) and marginally significant according to items ( $F(1, 118) = 3.27, p = .073$ ), with C### and CV## primes resulting in greater recognition of the word than the other primes. Finally, the interaction between C Primes and Language approached significance for both subjects ( $F(1, 23) = 3.20, p = .087$ ) and items ( $F(1, 118) = 3.32, p = .071$ ), with greater priming effect of C primes in English.

Paired sample *t*-tests for subjects and independent sample *t*-tests for items further tested the interaction between C primes and language and looked at the effect of the different prime types. The effect of the individual primes is demonstrated in Fig. 2, which presents identification rates of words based on different prime types. According to the *t*-tests, CV## primes resulted in marginally significantly greater word recognition in English according to subjects ( $t(23) = 1.370, p = .092$ ) and items



**Fig. 2** Accuracy of identification of word (+SE) according to prime type in English and Spanish

**Table 7**  $\chi^2$  Table for C### primes

Language		CV	Word	Total
English	Count	83	103	186
	Expected	93	93	186
Spanish	Count	116	96	212
	Expected	106	106	212
Total	Count	199	199	398
	Expected	199	220	398

( $t(118) = 1.538, p = .064$ ). Other prime types did not result in statistically significant different rates of word identification between languages.

In order to further test if subjects were more likely to recognize words over syllables in English and more likely to recognize the syllable as opposed to a larger unit in Spanish, we examined the recognition totals for CV and Word in a  $\chi^2$  test statistic for all prime types. For C### primes, the actual counts and the expected counts are reported in Table 7 and  $\chi^2(1, 398) = 4.04, p = .045$ , providing evidence to conclude that the units that are recognized are different in the two languages. For CV## primes, the actual counts and the expected counts are reported in Table 8 and  $\chi^2(1, 633) = 6.11, p = .013$ , leading to the conclusion that unit recognized varies in the two languages. For both #V## primes and #### primes, this result was not significant (respectively  $\chi^2(1, 204) = .28, p = .598$  and  $\chi^2(1, 176) = .033, p = .857$ ), allowing us to conclude that there is no difference in recognition unit given these primes in either language.

To test if dominance affected performance, we contrasted the balanced bilinguals and the English dominant subjects, entering the results into a  $2 \times 2 \times 2 \times 2$  ANOVA (C-prime  $\times$  V-prime  $\times$  Language  $\times$  Dominance). The two Spanish dominant subjects were excluded from this analysis, to create two clear categories. No main effects of

**Table 8**  $\chi^2$  Table for CV## primes

Language		CV	Word	Total
English	Count	178	133	311
	Expected	193.1	117.9	311
Spanish	Count	215	107	322
	Expected	199.9	122.1	322
Total	Count	393	240	633
	Expected	393	240	633

dominance were significant, nor were any interactions between dominance and any other main effects.

## Discussion

The results of this experiment are consistent with the hypothesis that readers in Spanish access words through syllables, while readers in English use some larger unit. They also support previous research findings demonstrating the importance of the syllable in Spanish for lexical access and further suggest that English readers do not use this level of the prosodic hierarchy in the initial stages of visual word access. Both C### and CV## primes resulted in greater recognition of syllables in Spanish in comparison to English, whereas the results suggest that these primes may aid recognition of larger units in English. However, the results are not unequivocal for English, with ANOVA results that show only marginally significant greater word identification in English – with only marginally significant greater word identification in English given CV## primes confirmed by *t*-tests. Regardless, the chi squared test statistic confirms that readers in English and Spanish are recognizing different units given C### and CV## primes, providing further evidence that readers of English and Spanish use different levels of the prosodic hierarchy for initial lexical access.

Showing subjects C### and CV## primes in Spanish clearly helped them identify the CV or syllable significantly more than English readers, further confirming the importance of the syllable as a sub-unit of lexical access in Spanish, as found in prior experiments (Álvarez et al., 1998, 2000, 2001, 2004; Carreiras & Perea, 2002; Carreiras et al., 1993; Domínguez et al., 1997; Perea & Carreiras, 1998). Because syllables are a key unit of early lexical access and Spanish readers are parsing words into syllables in the early stages of visual word recognition, giving Spanish readers information about the first syllable did not help them identify the word as much as it did English readers. Instead, because Spanish readers exploit the syllabic level of the prosodic hierarchy in early lexical access, priming within the first syllable helped Spanish readers identify significantly more first syllables.

The finding that CV## primes marginally aided English readers to access a larger unit such as the word in comparison to Spanish suggests that experienced English readers are less reliant on parsing words into syllables at an early stage of lexical access and that the precise unit of lexical word access may not be as fixed as in Spanish. This agrees with previous studies that have found inconsistent evidence for the role of the syllable or that the syllable is more important in later stages of visual word access in English (Ashby & Rayner, 2004; Ferrand et al., 1997; Jared & Schiller, 2000; Seidenberg, 1987). The brief identification experimental technique is argued to tap into early word recognition process, as opposed to lexical decision and naming, so the

syllable seems to be not critical for initial processes. In addition, the marginal effect is consistent with the fact that there have been many previous debates disagreeing over the precise unit used for visual word recognition in English (Butterworth, 1983; Chialant & Caramazza, 1995; Cole et al., 1989, Lukatela et al., 1980; Taft, 1979, 1994; Taft & Forster, 1975, 1976; Ziegler & Goswami, 2005). Because English readers may not use the syllabic level of the prosodic hierarchy in initial word access, priming within the syllable has little effect on their recognition of syllables.

## Experiment 2

In order to further probe the differences in lexical access between the two languages and the differing exploitation of the syllabic level of the prosodic hierarchy, we decided to prime across the syllable boundary in Experiment 2, priming the first vowel/second consonant of the word (VC). Following from the differences in the use of prosodic information in early word recognition between the languages, showing readers information across the syllable boundary should have divergent effects in the two languages. In Spanish such priming crosses an important unit of word recognition—the syllable. Because such primes do not respect the level of the prosodic hierarchy used for early word recognition in Spanish, showing them such conflicting information should not aid their identification of syllables. In contrast, since evidence points to English readers' use of some larger unit in the prosodic hierarchy than the syllable in early word access, cross syllable primes should help their recognition of CVC or words.

## Method

### *Subjects*

Twenty-seven Bilingual English and Spanish readers recruited at Northwestern University and in the Chicago metropolitan area participated in the experiment. They were paid \$ 10 for the hour-long experiment. The standardized measures to determine language proficiency and reading level in both languages resulted in the exclusion of one subject from analysis because of standardized scores two standard deviations below the norm in either English or Spanish, leaving 26 subjects. Two additional subjects were unable to perform the experimental task, by not providing complete words in their answers, leaving 24 subjects. The sample included 13 men and 11 women. The average age of participants was 31.5-years-old.

### *Design and materials*

The task and the test words were the same as in Experiment 1. The only differences were in the primes. In the present experiment, subjects saw different primes that corresponded to the first vowel (#V##) of the word, the second consonant (##C#), the first vowel/second consonant (#VC#) together, or, in the control condition, a series of number signs. The primes and the targets matched up in the manner demonstrated in Table 9. The four counterbalancing conditions and the randomization were the same as in Experiment 1.

**Table 9** Experimental conditions in Experiment 2

Status	Prime	Target
Test conditions	#O##	sofa
	##F#	sofa
	#OF#	sofa
Control	####	sofa

**Table 10** Results of standardized tests for Experiment 2

Letter Word ID—English	Passage Comp.—English	Letter Word ID—Spanish	Passage Comp.—Spanish
116.08 (17.85)	117.33 (16.33)	102.63 (14.99)	96.17 (17.29)

**Table 11** Results from the language background questionnaire for Experiment 2

L1	Age learned L2	Years in English country	Years in Spanish Country	Self-proficiency rating(1–6)
12 Spanish, 11 English, 1 Portuguese	12.6 (6.8)	20.8 (15.9)	9.5 (12.7)	English 5.5, Spanish 4.8

*Procedures*

The procedures were identical to Experiment 1.

**Results**

*Subjects*

The results from the standardized tests of reading show that the bilingual subjects who participated in this experiment were overall English dominant and their scores are summarized in Table 10. We used the same criteria to define language dominance as in Experiment 1. According to this analysis, 13 subjects were English dominant, 11 were balanced bilinguals and 1 was Spanish dominant. The subjects’ English dominance was confirmed by *t*-tests comparing their scores in the two languages, with a significant difference in scores for both the PC sub-test ( $t(46) = 4.36, p < .001$ ) and the LWI subtest, ( $t(46) = 2.84, p = .007$ ).

Similar results to the standardized tests were obtained from the Language Background Questionnaire, which was administered to each subject after they completed the experiment. The subjects’ answers are summarized in Table 11. From the questionnaire, 12 subjects’ first language was Spanish, while 11 learned English first and 1 Portuguese. The average age when subjects learned their second language was 12.6-years-old. Most subjects had spent far more time in an English speaking country than in a Spanish speaking one (20.8 vs. 9.5 years). Finally, subjects’ self-rating of their language proficiency in English was higher than in Spanish (5.5 versus 4.8).

**Table 12** Accurate responses according to prime type (with SE)

Language	Prime	CV	CVC	WORD
English	#V##	7.70 (1.42)	1.41 (.58)	15.81 (3.93)
	##C#	0.82 (.45)	2.57 (1.00)	18.23 (3.70)
	#VC#	2.19 (.65)	5.80 (1.38)	24.96 (4.12)
	####	3.83 (1.14)	2.57 (.90)	17.86 (3.94)
	#V##	13.58 (1.78)	2.16 (.74)	10.38 (2.75)
	##C#	1.08 (.50)	2.57 (1.00)	16.48 (3.15)
Spanish	#VC#	0.82 (.59)	6.62 (1.04)	21.91 (3.97)
	####	8.11 (2.15)	1.04 (.49)	10.94 (3.00)

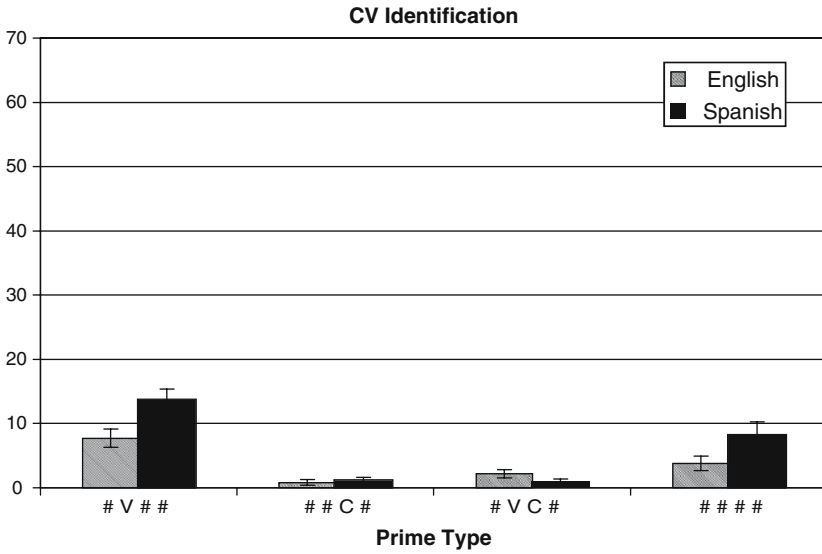
### Priming Task

For each language and prime type accuracy levels in identifying first consonant/first vowel (CV), the first consonant/first vowel/second consonant (CVC), and words were calculated and averaged according to subjects and items. While Table 12 reports subject data, giving the accuracy of recognizing the different units and the standard error in parentheses, we report statistically significant findings for both the subject and the item analyses. We analyzed independent identification of all three units to see if they were identified on their own. Independent identification means that we are defining identification of the CV, for example, as being when uniquely those letters together were correctly recognized, without being a part of any larger unit.

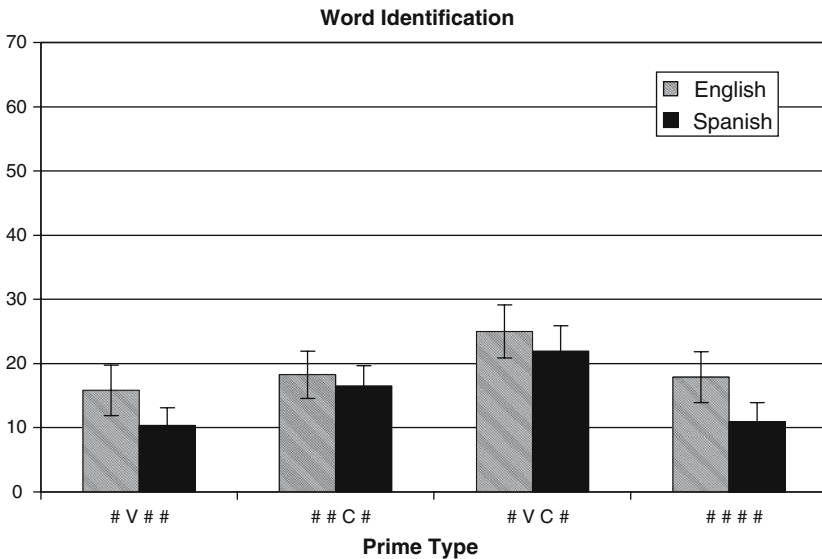
Accuracy of identification of CV, CVC and word units when primed with the first vowel or the second consonant were examined with  $2 \times 2 \times 2$  ANOVAs (First consonant primed versus Unprimed  $\times$  First vowel primed versus Unprimed  $\times$  English versus Spanish) in the two languages, with language as a within subject factor and a between item factor.

For CV identification, all three main effects were significant. The main effect of priming V was significant according to subjects ( $F(1, 23) = 12.60, p = .002$ ) and items ( $F(1, 118) = 11.07, p = .001$ ). The main effect of C primes was also significant according to subjects ( $F(1, 23) = 56.39, p < .001$ ) and items ( $F(1, 118) = 94.84, p < .001$ ). In addition, CV identification was greater in Spanish, with the main affect of language significant according to subjects ( $F(1, 23) = 5.92, p = .023$ ) and items ( $F(1, 118) = 4.98, p = .027$ ). The interaction between V Primes and C Primes was significant according to subjects ( $F(1, 23) = 6.23, p = .020$ ) and items ( $F(1, 118) = 8.52, p = .004$ ), with #V## primes (and to a lesser extent #### primes) resulting in greater recognition of CV in comparison to the other primes. Finally, the interaction between C primes and language was significant according to subjects ( $F(1, 23) = 10.23, p = .004$ ) and items ( $F(1, 118) = 9.47, p = .003$ )—with C Primes leading to lower identification rates of syllables in Spanish in comparison to English.

In order to better understand the interaction between C primes and language and to examine the effect of individual primes, we ran paired sample *t*-tests for subjects and independent sample *t*-tests for items and present the identification rates of CV based on different prime types in Fig. 3. The *t*-tests show that #V## primes result in significantly greater accuracy of identification of syllables in Spanish according to both subjects ( $t(23) = -3.58, p = .001$ ) and items ( $t(118) = -2.13, p = .018$ ). Also #### primes resulted in significantly greater identification of CV in Spanish according to items ( $t(118) = -2.52, p = .007$ ) and approaches significance according to subjects



**Fig. 3** Accuracy of identification of CV (+SE) according to prime type in English and Spanish



**Fig. 4** Accuracy of identification of word (+SE) according to prime type in English and Spanish

( $t(23) = -1.62, p = .059$ ). In contrast, ##C# primes and #VC# primes resulted in similarly low CV identification rates in both languages (Figure 4).

Turning to identification of CVC, the main effect of V primes significantly affected accuracy in identifying CVC according to subjects ( $F(1, 23) = 6.55, p = .018$ ) and items ( $F(1, 118) = 9.34, p = .003$ ). The main effect of C primes was also significant according to subjects ( $F(1, 23) = 13.55, p = .001$ ) and items ( $F(1, 118) = 13.43, p < .001$ ). Finally, the interaction between V primes and C primes was significant

according to subjects ( $F(1,23) = 13.20, p = .001$ ) and items ( $F(1,118) = 7.20, p = .008$ ), with greater identification of CVC with #VC# primes. However, the interactions between the different primes and language were not significant.

For word identification, the main effect of priming V was significant according to subjects ( $F(1,23) = 12.09, p = .002$ ), but was not significant according to items ( $F(1,118) = 2.26, p = .135$ ). According to both subjects ( $F(1,23) = 17.83, p < .001$ ) and items ( $F(1,118) = 26.54, p < .001$ ), the main effect of C primes was significant for word identification. The interaction between C Primes and V Primes was significant according to subjects ( $F(1,23) = 10.10, p = .003$ ) and items ( $F(1,118) = 7.82, p = .006$ ), with #VC# and ##C# (to a lesser extent) primes resulting in greater recognition of the word than the other primes. Finally, neither of the interactions between the different primes and language was significant. Given #V## primes, word identification was significantly greater in English according to an independent samples *t*-tests for items ( $t(118) = 1.68, p = .048$ , but only approached significance according to matched sample *t*-tests for subjects ( $t(23) = 1.50, p = .074$ ). Given #### primes, word identification was significantly greater in English according to both a matched samples *t*-test for subjects ( $t(23) = 2.60, p = .008$ ) and an independent samples *t*-test for items ( $t(118) = 2.30, p = .012$ ). The effect of the various prime types is shown in Fig. 4.

In order to further test if subjects were more likely to recognize a larger unit such as CVC or word over the syllable in English and more likely to recognize the syllable as opposed to a larger unit in Spanish, we examined the recognition totals for CV, CVC/word and other/null in a  $\chi^2$  test statistic for all prime types. For #V## primes, actual and expected counts are reported in Table 13 and  $\chi^2(1,169) = 9.20, p = .002$ , providing evidence to conclude that the units that are recognized are different in the two languages. Also for #### primes, actual and expected counts are reported in Table 14 and  $\chi^2(1,146) = 10.67, p = .001$ , leading to the conclusion that unit recognized varies in the two languages. For both ##C# primes and #VC# primes, the test statistic result was not significant (respectively,  $\chi^2(1,132) = .22, p = .638$  and  $\chi^2(1,180) = 1.58, p = .209$ ), allowing us to conclude that there is no difference in recognition unit given these primes in either language.

**Table 13**  $\chi^2$  Table for #V## primes

Language		CV	Word	Total
English	Count	28	55	83
	Expected	37.8	45.2	83
Spanish	Count	49	45	86
	Expected	39.2	46.8	86
Total	Count	77	92	169
	Expected	77	92	169

**Table 14**  $\chi^2$  Table for #### primes

Language		CV	Word	Total
English	Count	14	64	78
	Expected	23	55	78
Spanish	Count	29	43	68
	Expected	20	48	68
Total	Count	43	103	146
	Expected	43	103	146

To test if dominance affected performance, we contrasted the balanced bilinguals and the English dominant subjects, entering the results into a  $2 \times 2 \times 2 \times 2$  ANOVA (C-prime  $\times$  V-prime  $\times$  Language  $\times$  Dominance). The one Spanish dominant subject was excluded from this analysis, to create two clear categories. The dominance main effect was not significant for identification of any of the units, nor were any interactions between dominance and the other main effects except with language for CV identification ( $F(1, 9) = 5.40, p = .045$ ).

## Discussion

##C# and #VC# primes hindered readers' recognition of first syllables (CV) in a similar manner in both English and Spanish. In fact, given these primes, readers in both languages had similar identification rates for all of the key units under study including CV, CVC, and word. However, when presented with primes that did not cross the syllable boundary, readers recognized different units in the two languages. Given #V## and ##### primes, readers in Spanish recognized more syllables and readers of English identified more words. This result suggests that the difficult priming context of cross-syllable, mid-word primes may have disrupted normal word recognition processes in both languages and that readers were able to return to their more normal visual word recognition strategies in the control and first vowel priming conditions.

These findings are consistent with the hypothesis that readers of Spanish use syllables in early word recognition processes and that readers of English use some larger unit—based upon differing exploitation of the prosodic hierarchy in early visual word access in the two languages. The result further confirms prior research indicating that the syllable is a key sub-unit of early lexical access in Spanish (Álvarez et al., 1998, 2000, 2001, 2004; Carreiras & Perea, 2002; Carreiras et al., 1993; Domínguez et al., 1997; Perea & Carreiras, 1998). The greater recognition of words in English with #V## and ##### primes also follows from previous research that suggests that the use of syllables in initial visual word access in English is not as consistent as in Spanish or that use of syllables may come at later stages having to do with phonological assembly (Ashby & Rayner, 2004; Ferrand et al., 1997; Jared & Seidenberg, 1990; Schiller, 2000) and that English readers use some larger unit during the initial stages of visual word access (Butterworth, 1983; Chialant & Caramazza, 1995; Cole et al., 1989; Lukatela et al., 1980; Taft, 1979, 1994; Taft & Forster, 1975, 1976; Ziegler & Goswami, 2005).

Showing Spanish readers the first vowel/second consonant crossed the key prosodic unit of word recognition in Spanish and hindered their ability to identify the first syllable. In the rapid presentation of the VC, Spanish readers perceived the two phonemes together and they were not able to parse them into their respective syllables. The presentation of VC did not correspond to any unit of visual word access in Spanish, violating the key level of prosodic hierarchy for lexical access and leading to greater inhibition of the recognition of the unit with which word recognition processes normally commence—the first syllable. Similarly, just showing them the second consonant distracted them from being able to identify the first syllable—a perfectly understandable result since nothing in the first syllable was primed in this case. However, being given just the vowel in the first syllable in this priming context helped them identify more syllables in Spanish than in English, since a part of this key prosodic unit was primed.

In English, ##C# and #VC# primes did not cross a key prosodic unit of early lexical access. Although recognition rates for CV, CVC and word did not differ significantly

between languages, these primes may have resulted in less inhibition in English because these primes did not cross a key prosodic boundary for lexical word access in English. In contrast, in the control, unprimed condition (####), and to a lesser extent by priming the first vowel (#V##), the natural tendency of English readers to recognize a larger unit instead of the syllable reasserted itself.

Finally, #V## and #### primes had differing results between the first and second experiment. In the first experiment with these prime types, readers showed no difference in recognition rates of the different units in either language, while in the second experiment Spanish readers showed a preference for CV recognition, while English readers tended to identify more words. This difference must arise from the priming context, and will be discussed to a greater extent in the General Discussion below.

## General discussion

These two experiments taken together further the case that readers of Spanish and English depend on different levels of the prosodic hierarchy in visual recognition of words. These results confirm the differing status of the syllable in Spanish and English in visual word access, with readers in Spanish exploiting the syllabic level of the prosodic hierarchy early in the visual word recognition process and readers in English using some larger unit in early word recognition during reading, with the syllable perhaps taking on greater importance in a later stage of activation.

The results from the two experiments corroborate prior findings that the syllable is a key sub-unit of lexical access in Spanish (Álvarez et al., 1998, 2000, 2001, 2004; Carreiras & Perea, 2002; Carreiras et al., 1993; Domínguez et al., 1993; Perea & Carreiras, 1998). While prior research used either lexical decision or naming, the results from the present task complement previous work by demonstrating the importance of the syllable for lexical access in Spanish using a different experimental paradigm and directly comparing Spanish lexical access to English. The partial identity priming experimental method is argued to tap into early word recognition processes, with comparable techniques (e.g., backward masking) being used in previous research to garner evidence for prelexical generation of phonology (Naish, 1980; Perfetti & Bell, 1991; Perfetti, Bell & Delaney, 1988) and the serial nature of phonological assembly processes (Berent & Perfetti, 1995; Lukatela & Turvey, 2000; Perry & Ziegler, 2002). While Perry & Ziegler (2002) noticed that the type of priming technique used in the present experiments is prone to strategic guessing by participants (since they are asked to write down a word even when they are unsure), we controlled for any difference in the ability to guess in the two languages through equating word frequencies, bigram frequencies and the transitional probabilities of the letters between the languages.

The most important finding from Experiment 1 was greater recognition of syllables in Spanish compared to English in response to first C### and CV## primes, which corroborates the syllable as a key unit in early visual word access. Also, because of this fundamental role of the syllable in early word recognition in Spanish, any priming within the first syllable does not robustly activate the entire word. The second experiment further confirmed the importance of the syllable in Spanish in comparison to English, as demonstrated by the greater recognition of first syllables in Spanish when readers were not presented with primes that crossed the syllable boundary (#V## or #### primes). When Spanish readers saw a #VC# or a ##C# prime, they were hindered

in their normal word recognition process. For readers of Spanish this prime did not give them access to the level of the prosodic hierarchy normally used in word access—despite the fact that one letter of the first syllable was supplied by a #VC# prime. Because of the rapid presentation technique, Spanish readers may not have been able to break the VC apart and parse the letters into their respective syllables. They were thus hindered in their recognition of the first CV. Supplying Spanish readers with the VC may have hurt Spanish readers' identification of the first syllable because this ensemble is not a unit or a part of any unit and does not respect the normal pathway of Spanish word recognition.

The results of these experiments further previous research that suggest the use of the syllabic level of the prosodic hierarchy may come later in English visual word recognition (Ashby & Rayner, 2004; Ferrand et al., 1997; Jared & Seidenberg, 1990; Schiller, 2000). In general, the results support proposals that English readers use some larger pre-lexical unit than the syllable in visual word access. In particular, finding that English speakers are more accurate at identifying words based on C### and CV## primes lends support to the claim that they use some larger unit for lexical access. Also while English readers generally reacted to #VC# primes in a similar manner to Spanish readers, they showed slightly less inhibition in CV recognition given these primes, suggesting that primes crossing the syllable boundary did not disrupt the normal English recognition process as much in Spanish. Also with the primes that did not cross the syllable boundary in the second experiment, readers' identification rates of English first syllables increased, but significantly less than in Spanish, further reinforcing the hypothesis that syllables are not as important in early word recognition processes in English. Finally, given #V## and #### primes readers reported the word more in English than in Spanish, thereby giving further support to the hypothesis that a larger unit is of greater importance in the initial processes of visual word recognition in English.

This difference between English and Spanish in their exploitation of the syllabic level of the prosodic hierarchy in visual word access may arise from structural differences between the two languages. In particular, Spanish has readily distinguishable syllables, with very clear boundaries unaffected by stress movement (Harris, 1983; Sánchez-Casas, 1996). Spanish speakers can easily and accurately segment words into syllables, with a large degree of reliability among raters (Carreiras et al., 1993). In contrast, the syllable in English has a less clearly delineated phonology with syllable boundaries modified by such factors as stress, with many cases where a consonant on the border between two syllables has a quality of belonging to both syllables. Different theoretical accounts have attempted to clarify the phonological process at work that account for the structure of such medial consonants including ambisyllabicity (Kahn, 1976; Rubach, 1996), resyllabification (Selkirk, 1982), and the prosodic approach (Jensen, 2000). In general, syllabification of English words is often variable and native English speakers are not consistent in their syllabification judgments (Treiman & Danis, 1988a,b; Treiman et al., 1994). This suggests that syllables may not provide consistent cues for lexical access and that for this reason experienced readers may not initially or consistently exploit this level of the prosodic hierarchy in English. Positing a parser that sometimes exploits the syllabic prosodic level and sometimes not depending on the prosodic structure would seem to be highly inefficient, particularly in the initial stages of word recognition, when a reader is just gaining access to phonological and lexical information. However, recently just such a flexible parser was proposed for English with Ziegler and Goswami's (2005) grain size theory.

The present findings do not settle which unit is commonly exploited in early word recognition processes in English, with the marginally greater word recognition in both experiments a fitting confirmation of the lack of consensus over the precise unit. These experiments clearly argue that some sort of larger sub-lexical unit plays a role in visual word access in English, since readers in English are less likely to segment bisyllabic CVCV words into syllables than they are in Spanish. However, these results do not mediate between the different possibilities that have been theorized in the literature, including orthographically and morphologically based units (Taft, 1979), prelexical morphological decomposition (Butterworth, 1983; Cole et al., 1989; Lukatela et al., 1980), full morphological decomposition (Taft, 1994; Taft & Forster, 1975, 1976), a mixed morphological/whole word model (Chialant & Caramazza, 1995), or a flexible grain size model (Zeigler & Goswami, 2005).

In general, while previous researchers have theorized that some morphological based unit may be important in English visual word access, phonology must also play some role in activating words during reading. While morphologically based units may be important in English visual word access, phonology should also play some role, since words ultimately do have a phonological form. Gaining lexical access implies by its very nature gaining access to the phonological form of a word as well as its other aspects. During the time course leading to full lexical access or identification of the word, is phonology a bystander, while readers exploit other units, such as morphological ones? Our findings support Ashby and Rayner's (2004) argument that the syllable prosodic level is not exploited in initial visual word access and that its importance comes into play in later stages requiring phonological assembly. However, phonology should play some role in early visual word access, since part of the role of letters in an alphabetic system is to provide phonological information. So the key question becomes: if syllable-based units do not play a role in initial word access in English, then do higher levels such as the foot and the word play an earlier role? From a phonological perspective, examining the next levels of prosodic hierarchy, including the foot and the prosodic word, would be helpful. In short, while morphology may play a role in visual word access, a complete model must allow some role for phonology, and if the syllable is not the key unit of lexical access, then larger units in the prosodic hierarchy should be investigated as well.

Answering these questions will help determine the timing and role of phonological representations in visual word access, and how their use may differ from spoken word recognition. In terms of timing, a speech stream already is initially received in a syllabic format (which does not necessarily correspond to actual words due to resyllabification effects), and must then be parsed into words to complete lexical access; whereas, in reading, the print stream (text) is divided into words when it is first encountered and the role of the parser is to divide the words into syllables, in effect giving them a phonological form. This initial difference in the ordering of phonological access makes it clear that the use of syllabic level of phonological representations is quite different in terms of timing between visual and oral lexical access. However, the difference in timing does not speak to whether and how the precise role of phonological representation may vary between spoken and visual word access. While Álvarez, Carreiras, & Perea (2004) suggests that the use of syllables by Spanish readers actually involves accessing phonological representations as opposed to orthographic ones, the same has not been found for English, with some researchers suggesting that English orthographic representations differ from phonological ones (e.g., Rapp, Folk & Tainturier, 2001). For this reason, the role of phonological as opposed to orthographic representations is an

open question in English and exploring the other levels of the prosodic hierarchy and the issue of timing is of fundamental importance to clarify the role of phonological representations in visual word access in English.

Next, #V## and ##### primes had varying effects in the two experiments. In the first experiment, these primes did not result in differing accuracy levels between English and Spanish for any of the studied recognition units. In contrast, in the second experiment, #V## and ##### primes resulted in significantly greater identification CV in Spanish in comparison to English and greater word recognition in English. This difference in results arises from the different presentation contexts, since we controlled all other relevant variables such as subject characteristics and presentation, meaning that the effects of individual primes can vary according to which other primes that they appear with. Due to the serial nature of word recognition processes, primes representing varying positions within the words have differing effects (Berent & Perfetti, 1995; Lukatela & Turvey, 2000; Perry & Ziegler, 2002).

In the first experiment, #V## and ##### primes were the least favorable primes; in comparison, in the second experiment, they were much more favorable—being earlier in the serial letter position in the case of the vowel and in both cases not violating a boundary in the prosodic hierarchy. In the first experiment, subjects followed their natural tendency to fixate on the first consonant and were reinforced by learning that this strategy was helpful. In contrast, in the context of the second experiment, subjects accommodated to the experimental primes by fixating on the first vowel. After a number of trials, subjects began to know that fixating on the first consonant was not helpful and shifted their attention. This difference in fixation led to the different priming effects of #V## primes, with these primes giving subjects more syllables in Spanish and more words in English. The difference in the baseline condition (#### primes) also arose from this difference in fixation. In the second experiment, subjects were concentrating on the first vowel. When presented with ##### primes, the greater fixation on the first vowel boosted its recognition, leading to increased CV recognition in Spanish and greater Word report in English. In English, focusing on the first vowel, further on in serial position in the word, made subjects more likely to get the larger unit. In contrast, in Spanish focusing on the first vowel only gives subjects access to the syllable due to the importance of the syllabic level of the prosodic hierarchy in visual word recognition in Spanish.

Based on these experimental results, bilingual readers seem to adapt to the structure of the language that they are reading in, since differences in accuracy in identifying units of words and words varied in bilingual readers according to the language that they were reading in. Our findings agree with previous research that showed that bilinguals' reading in each of their languages was affected by the nature of the script being read (Shimron & Sivan, 1994; Oren, & Breznitz, 2005). In addition, our findings do not contradict previous research that demonstrated that bilingual readers from a first language background where the script contains less phonological information are less dependent on phonology while reading in a second language in which the script offers greater phonological information (Koda, 1989; Saito et al., 1979; Wang, Koda & Perfetti, 2003; Wang, Perfetti & Liu, 2003). In contrast to the present experiments, these studies did not directly compare bilinguals reading in both of their languages and did not look at the use of phonology in natural reading conditions. However, additional follow-up research directly comparing bilinguals to monolinguals is needed to clarify precisely how bilingual readers adapt to reading in different languages and how they differ in their practices from monolinguals.

All in all, our results support the claim that early visual word access in English and Spanish exploit different levels of the prosodic hierarchy, with the syllable playing a key role in Spanish and a less important role in English. Instead in English, some larger unit plays an important role in the early stages of visual word recognition.

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## Appendix

### Test Stimuli

**Table A1** Examples of Stimuli

#### *English test words*

##### Group 1:

Bevy	Gory	Nosy	Tuna	Wavy	Yoga	Memo	Hazy	Lily	Duly
Pony	Posy	Wary	Rosy	Tidy	Lazy	Zero	Navy	sofa	Vary
Pity	Copy	Holy	Busy	Duty	Tiny	Lady	Baby	Body	Many

##### Group 2:

Savor	Cedar	Diner	Giver	Lager	Mover	Donor	Meter	Rotor	Rover
Sever	Maker	Poker	Finer	Lever	Razor	Ruler	Sober	Safer	Liver
Baker	Vicar	Lover	Fever	Sugar	Cover	River	Paper	Later	Water

#### *Spanish test words*

##### Group 1:

Bono	Gafe	Leño	Jota	Doma	Bobo	Beca	Foro	Cano	Vilo
Coco	Loro	Reja	Mona	Bala	Dale	Rota	Paja	Roca	Tomo
Vela	Hoja	Raro	Loco	Dedo	Luna	Baja	Boca	Cara	Cada

##### Group 2:

Jaco	Gula	Faja	Lego	Faro	Feto	Duna	Nata	Rima	Foca
Pato	Mole	Pala	Lodo	Mago	Mora	Foco	Pera	Lata	Sano
Codo	Lobo	Mono	Raza	Rico	Rato	Mala	Sola	Bajo	Modo

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