

Methods

Participants. Thirteen native speakers of Spanish (12 female, 19-30 years of age, mean age 21) participated in the experiment. All were healthy, right-handed undergraduate or graduate students from Boston area universities. All were paid for their participation, and gave informed consent in a manner approved by the Human Studies Committee of Massachusetts General Hospital and the Harvard University Committee on the Use of Human Subjects in Research.

The participants were all Spanish-English bilinguals who learned both languages before the age of seven; the mean age of first exposure to Spanish and English was 0.1 and 3.4. Most had some knowledge of other languages, but Spanish and English were by far their primary languages. Because the relative dominance of a language can shift, particularly for tasks requiring literacy skills, participants rated their proficiency in each language on a scale ranging from 1 (*almost none*) to 7 (*like a native speaker*). They reported high levels of proficiency in both languages, but judged their reading and writing abilities as slightly better in English than Spanish (Table 1). Similarly but based on a different 7-point scale (1 = *every day*, 7 = *almost never*), participants reported that they read publications (e.g., newspapers, magazines, books) more frequently in English (mean 1.1) than Spanish (mean 3.6).

Reading Measures. Participants were administered the Word Identification, Word Attack, and Passage Comprehension subtests from the English and Spanish forms of the Woodcock Language Proficiency Battery-Revised (WLPB-R). The Word Identification test requires the pronunciation of familiar regular and irregular words within a 5-second time limit per word. The Word Attack test measures phonological decoding skill by assessing the ability to apply grapheme-phoneme rules and word analysis skills to the pronunciation of unfamiliar words (i.e., phonetically regular nonwords or low-frequency words). The passage comprehension test requires a subject to read sentences that are missing a word that is important to the meaning of the passage, and to supply the missing word. Participants were also given the Sight Word Efficiency and Phonemic Decoding Efficiency subtests of the Test of Word Reading Efficiency (TOWRE). Both of these require the identification of as many words as possible within a span of 45 seconds, but Sight Word Efficiency requires the pronunciation of real words and Phonemic Decoding Efficiency the pronunciation of nonwords. Since these tests are only available in English, Spanish versions were developed for the study.

Paired-sample t tests were used to compare performance between languages on each of the relevant reading measures. No significant differences were found between English and Spanish on Word Identification, indicating that the ability to read familiar words in each language was equivalent. In contrast, performance on Word Attack was significantly higher in Spanish than English, suggesting that phonological decoding may be easier in Spanish than English, an interpretation that is consistent with the view that Spanish is orthographically transparent compared to English. Passage comprehension performance was significantly higher in English than Spanish, an advantage that may be, in part, a result of reading connected text more frequently in English, as indicated by the self-ratings. Without norms for the Spanish version of the TOWRE no comparison of standard scores with the English version was possible; however percent correct for Sight

Word Efficiency (English .91 and Spanish .93) and Phonemic Decoding Efficiency (English .94 and Spanish .91) were comparable in each language. Overall, the results show that participants were highly proficient in both Spanish and English, and point to areas of relative dominance in each language.

Stimulus Materials. The stimuli for the study consisted of 384 English words and their Spanish translations. English words were selected from the Medical Research Council (MRC) Psycholinguistic Database (Wilson, 1988), and consisted of 192 abstract nouns and 192 concrete nouns. The mean concreteness rating was 3.18 (SD = 0.43) for abstract words and 5.89 (SD = 0.33) for concrete words based on a scale from 1 to 7. Abstract words were between 3 and 12 letters in length (mean = 6.51, SD = 2.01) with a mean word frequency in English of 80 occurrences per million, and concrete words were between 3 and 11 letters in length (mean = 5.60, SD = 1.59) with a mean word frequency in English of 44 occurrences per million (based on Kucera & Francis, 1967).

All English words were translated into Spanish and checked for accuracy using the Larousse Diccionario Español-Inglés (1998). Translation pairs that included ambiguous words such as interlingual homographs were replaced, as were cognates, words that are highly similar in sound and spelling, so as to limit stimuli to noncognate translations. Abstract Spanish words were between 3 and 14 letters in length (mean = 7.19, SD = 2.17) with a mean word frequency of 71 occurrences per million, and concrete Spanish words were between 3 and 11 letters in length (mean = 6.14, SD = 1.59) with a mean word frequency of 45 occurrences per million (based on Alameda & Cuetos, 1995). Although no concreteness ratings were available for the Spanish words in the study, research with Dutch and English noun translations suggests that concreteness is highly correlated between languages (e.g., .94), at least when concreteness is assessed according to word imageability (De Groot, Dannenburg, & Van Hell, 1994).

Behavioral Procedures. There were two types of item presentation, the initial presentation of a word in either language (Novel English and Novel Spanish), and the repetition of a word, either in the same language (English Repetition and Spanish Repetition) or in the other language (English Translation and Spanish Translation). Therefore, stimuli were defined by *item type* (novel or repeated), *language* (English or Spanish), *concreteness* (abstract or concrete) and *repetition* (within-language or across-language).

Each participant was presented with a total of 384 pairs of words. Word pairs were either identical, in English or in Spanish, or were translation equivalents, presented first in Spanish or first in English. Half the items were concrete, half abstract. Presentation lists of 48 pairs were selected from the total pool of 384 items such that each list consisted of an equal number of similarly constructed word pairs, i.e., English-English, Spanish-Spanish, Spanish-English, and English-Spanish. Presentation lists were counterbalanced so that across participants each item appeared once in each of the four repetition conditions. However, individual participants viewed each item in only one repetition condition. The presentation and order of lists was also counterbalanced across participants.

Participants received 8 scans during each of which 96 trials occurred. On each trial, a single word was displayed, and participants were instructed to press one of two

keys to indicate whether the item was abstract or concrete. Words were displayed for 1.5 s, followed by a period of visual fixation (“+”) lasting 1 to 6 s, as determined by an optimization algorithm (Dale, 1999). The order of trials within and across scans was determined by optimizing the efficiency of the design matrix (Dale, 1999), with the lag between novel and repeated items ranging from 0 to 33 intervening items.

Image Acquisition. A 3T Siemens Allegra system with a standard volume coil was used to acquire high resolution T1-weighted (MP-RAGE) anatomical images and T2*-weighted gradient echo-planar functional images (TR = 2000 ms, TE = 30 ms, 21 axial slices 5 mm thick, 1 mm inter-slice gap, 200 mm FOV, 64 X 64 matrix, 200 volumes per run). To minimize differences in image contrast four additional volumes were collected at the start of each run and discarded prior to analysis.

Table 1
Mean (SD) Proficiency Ratings and Standard Scores

Test	Spanish	English
Self-Ratings ^a		
Auditory comprehension	6.9 (0.6)	6.8 (0.6)
Speaking ability	6.7 (0.8)	6.6 (0.8)
Reading Ability	6.7 (0.6)	6.9 (0.4)
Writing Ability	6.5 (0.8)	6.9 (0.4)
WLPB-R ^b		
Word identification	122.5(12.2)	114.5(15.8)
Word attack	136.3 (16.4)	117.0 (11.8)
Passage comprehension	96.0 (10.1)	106.3 (9.5)
TOWRE		
Sight word efficiency	-	98.7 (10.3)
Phonemic decoding efficiency	-	110.8 (9.9)

^aBased on a scale (1 = almost none: 7 = like a native speaker).

^bBased on n = 12 due to missing data from one participant.