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Age of acquisition effects in word recognition and production in first and second languages

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Four experiments explored the age of acquisition effects in the first and second languages of dominant Spanish-English bilinguals. In Experiment 1 (picture naming task) and Experiment 2 (lexical decision task), an age of acquisition effect was observed in a second language acquired after childhood as well as in the first language. The results suggest that age of acquisition effects reflect the order of word acquisition, which may in turn reflect the state of the lexical network when new words are learnt. The results do not support the idea that age of acquisition effects reflect differences between words learned during some critical period in childhood and words learned later in life. In Experiments 3 and 4, the age/order of second language acquisition affected lexical decision latencies regardless of the age at which translation equivalents were acquired in the first language, suggesting that the age of acquisition effect is linked to the acquisition of word forms rather than meanings.

All other things being equal, words learned early in life can be recognised and produced faster than later-learned words. This effect of age of acquisition on lexical processing is independent of differences in such things as the frequency of use of words in adult language, and is observed in a variety of tasks including object picture naming (e.g., Barry, Morrison, & Ellis, 1997; Barry, Hirsh, Johnston, & Williams, 2001; Carroll & White, 1973; Ellis & Morrison, 1998), word naming or reading aloud (e.g., Barry, Hirsh, Johnston, & Williams, 2001; Brown & Watson, 1987; Gerhand & Barry, 1998; Morrison & Ellis, 1995; 2000), visual lexical decision (e.g., Butler & Hains, 1979; Gerhand & Barry, 1999; Morrison & Ellis, 1995; 2000) and auditory lexical decision (e.g., Turner, Valentine, & Ellis, 1998).

The majority of studies of age of acquisition effects, like the majority of studies of language processing in general, have been conducted in English, but age of acquisition effects have now been reported for picture naming in

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Spanish (Cuetos, Ellis, & Alvarez, 1999) and French (Kremin, Hamerel, Dordain, De Wilde, & Perrier, 2000), for word naming in Dutch (Brysbaert, Lange, & Van Wijnendaele, 2000) and for the naming of Japanese kanji characters (Yamazaki, Ellis, Morrison, & Lambon Ralph, 1997). All of these studies have, however, involved participants operating in their native first languages. Hence, the age of acquisition effects observed have typically involved comparisons between words learned in early childhood and words learned in later childhood or adulthood. Those early childhood years have been described by some theorists as a 'critical period' for language acquisition - a time when language can be acquired much more easily that when the critical period has passed (Marinova-Todd, Marshall, & Snow, 2000; Newport, 1990). Regardless of one's view on the usefulness or otherwise of the concept of a critical period for language acquisition, it is undoubtedly true that major neurological changes occur in the brain of the growing child during the period when early vocabulary is being learned, changes which may be linked in a variety of ways to the process of native language acquisition (Bates, Thai, & Janowsky, 1992).

It is conceivable that the age of acquisition effects revealed in adult language users operating in their native languages reveal differences in the quality of lexical representations acquired during or after the period when those developmental neural processes are occurring. One hint that this may not be the case, and that age of acquisition effects might be observed for representations acquired after the period of early childhood, comes from the study of Japanese kanji naming by Yamazaki, Ellis, Morrison and Lambon Ralph (1997). They identified two different forms of age of acquisition that exerted significant influences on kanji naming speed. One was the age of acquisition of the spoken words represented by the characters; the other was the age of acquisition of the characters themselves. Japanese children start learning to read at the age of 7 years and follow a well-structured programme which is common to all Japanese schoolchildren and which dictates the year of schooling in which different kanji characters will be introduced. Hence, a language researcher knows with some certainty when different characters will have been learned. In the Yamazaki et al. (1997) study the age of acquisition of the Japanese characters exerted a significant influence on naming speed over and above that of the age of acquisition of the words in spoken language. That effect of written age of acquisition involved differences in chronological age that began at 7 years and extended into the early teens. The effect of written age of acquisition was therefore based on differences in age that were more or less beyond any critical period for first language acquisition.

Another way to investigate the origins and nature of age of acquisition effects is to look to see if such effects can be found in second languages acquired in late childhood or adulthood. Spanish children are first introduced to the English language in school at around the age of 8-10 years and continue to learn English until they leave school. A working knowledge of English is increasingly important for students in higher education because of the amount of relevant material only in English and because of the current dominance of the English language on Internet. We report here a series of

experiments in which participants were all native speakers of Spanish who had spent their childhood in Spain. None of them had been introduced to English before the age of 7 years, and in most cases their first introduction to English had been at around the age of 10. In terms of the standard nomenclature for characterising different types of bilingual they would all be termed 'dominant' Spanish-English bilinguals. At the time of testing, the participants were resident in York, England, mostly undertaking advanced courses at the University of York.

It is possible to investigate age of acquisition effects in the second as well as the first languages of such people because there are some words that Spanish students learning English tend to be taught early and other words whose introduction is delayed until later (just as there are words which native speakers of Spanish or English typically learn early in childhood and other words whose acquisition is generally later). When a group of dominant Spanish-English bilinguals were asked to estimate at what point in their acquisition of English various words were learned, their ratings showed good agreement with each other and good agreement with normative data derived from books used to teach English in Spanish schools.

In Experiment 1, dominant Spanish-English bilinguals named pictures of familiar objects whose names were early or late acquired in both Spanish as a first language and English as a second language. The word sets were matched for frequency of occurrence in both Spanish and English; also on name agreement, object familiarity and word length. Word frequency has been demonstrated to be an influential variable in word recognition and production (Barry et al., 1997; Ellis & Morrison, 1998; Gerhand & Barry, 1998; 1999; Morrison & Ellis, 2000).

The investigation of its effect in the first and second language is outside the scope of this paper. However, word frequency was taken into account when designing the experiments presented here.

Experiment 2 was similar in conception to Experiment 1, but this time participants carried out lexical decision tasks in which they were required to distinguish words that are early and late acquired in both English and Spanish from stimuli that are nonwords in both languages. If age of acquisition effects could be observed in second language naming (Expt 1) and lexical decision (Expt 2) it would established that those effects were not dependent on having acquired the early vocabulary during the first years of life and might favour instead an approach to age of acquisition effects that placed more emphasis on order of acquisition rather than the chronological age at which words are learned.

The discovery of age of acquisition effects in second languages could have other theoretical implications in an area where good theoretical explanations have been scarce. Brown and Watson (1987) suggested that the age of acquisition effect is due to differences in the quality of phonological representations that early and late acquired words enjoy. They proposed that words acquired earlier are represented in a complete phonological form whereas late acquired words are phonologically fragmented and therefore

slow to retrieve since they need a time for some type of phonological assembly process (the completeness hypothesis). Though regularly cited, evidence for this explanation has been lacking. Monaghan and Ellis (in press, a) failed to support the prediction that late acquired words should, by virtue of their more fragmented representations, be easier to segment in phonological awareness tasks. Like Brown and Watson (1987), a number of other authors have also located the age of acquisition effect at the level of the phonological output (Barry et al., 1997; 2001; Gilhooly & Watson, 1981; Morrison & Ellis, 1995).

Ellis and Lambon Ralph (2000) proposed an alternative explanation for the age of acquisition effect. They suggest that the connections between representations (e.g., links between meanings and phonological/ orthographic word form) are superior for early than for late acquired words. They showed that if connectionist networks are trained on some ("early") items before other ("late") items are introduced into training, then the early items seize the opportunity to shift the connection strengths in their preferred direction. Items introduced later can re-adjust those connections to some degree, but their attempts to do so are resisted by the early items which continue to be trained alongside them. After extensive additional training on both early and late items the performance of the network continues to favour the early set. On this account, age of acquisition effects would apply to the mappings between any sets of representations, not just those between semantics and phonology or orthography. The influence of age of acquisition would, however, be in the links between representations rather than being an intrinsic property of the representations themselves.

Brysbaert,Van Wijnendaele and De Deyne (2000) argued instead that age of acquisition might be an organising principle within the lexical output and semantic systems, with the strength or quality of the representations themselves being a function of age of acquisition. This view has implications for the interpretation of possible second-language age of acquisition effects. It is generally agreed that the same semantic representations are involved in the processing of words in first and second languages (De Bot, 1992; Costa Miozzo, & Caramazza, 1999; Hell & de Groot, 1998; Kroll & Stewart, 1994). If this is true --if learning a word in a second language involves associating new orthographic and phonological forms with pre-existing semantic representations--, then age of acquisition effects that are inherent in the semantic representations should transfer to the second language vocabulary so that age of acquisition effects in a second language would reflect the order of acquisition of the corresponding meanings in the first language. If, in contrast, age of acquisition effects are a property of the phonological representations (Brown & Watson, 1987) or a property of the mappings (associations) between word-forms and meanings, (Ellis & Lambon Ralph, 2000; see also Monaghan & Ellis, in press b), then age of acquisition effects in a second language should reflect the order of acquisition of words in the second language rather than the order of acquisition of the word meanings in the first language. These contrasting predictions are tested in Experiments 3 and 4 of the present study.

EXPERIMENT 1

Dominant bilinguals are those who master two languages with different levels of proficiency in each. One of the two languages, often the mother tongue, is the dominant language whereas the other is their second language in which they are competent but not at a native speaker level. This type of bilingual offers the opportunity of testing if the age of acquisition effects observed in first languages are due to the age at which words are acquired (during an assumed critical period) or to the order of vocabulary acquisition.

In Experiment 1, dominant Spanish-English bilinguals completed a picture naming task in their dominant language, Spanish, and in their second language, English. The picture names were early or late acquired in both Spanish and English. If age of acquisition is an effect related to the order at which different words are acquired, the effect would have to be observed in both the first and the second language. However, if the age of acquisition effect is due to age constraints, with the effect being due to when within the critical period words are learned, then only the first language of these dominant bilinguals would be affected by the age of acquisition variable. Age of acquisition ratings in both languages were based on adult estimates of the age at which different words were first learned. Ratings for first language age of acquisition were taken from Cuetos et al., (1999). Several studies have shown such ratings to have good validity as estimates of the age and order of native vocabulary acquisition by children (e.g., Carroll & White, 1973; Gilhooly & Gilhooly, 1980; Morrison, Chappell, & Ellis, 1997). Ratings for second language acquisition were obtained by asking native Spanish speakers (who had acquired English as a second language in the same way as the participants in the experiment) to decide whether English words had been learned in the first year of studying English, in the second year, and so on. Those ratings were then validated against the vocabularies of two textbooks used in teaching English as a foreign language.

Words were selected that were early or late acquired both in Spanish as a first language and English as a second language. The sets were matched on object familiarity, visual complexity of the pictures, name agreement and word frequency in both Spanish and English. Early and late sets were matched on syllable length within languages. (It is difficult to match length across languages since Spanish object names are longer than English names.)

METHOD

Participants. The participants were 32 native speakers of Spanish (16 females and 16 males) with a mean age of 26 years (range 20-33) whose childhoods had been spent in Spain. The mean age at which they first began to learn English was 11 years old (range 8-20). At the time of testing, all the participants were studying at the University of York, England. They had been

resident in England, using English on a daily basis, for a mean time of 2 years (range 3 months to 5 years)[1].

Materials. The starting point for the experiment was 132 objects selected from Cuetos et al. (1999) on the basis that the items had single-word names in both Spanish and English and would be familiar to speakers in both countries and languages. Ratings for acquisition of the object names in Spanish as a first language were available from Cuetos et al. (1999). Word frequencies in Spanish were available from the Alameda and Cuetos (1995) frequency count, which is based on a corpus of two million words of written Spanish, while word frequencies in English were taken from the Celex Lexical Database (Baayen, Piepenbrock, & Van Rijn, 1993) using the combined written and spoken frequency measure of the word forms. Because of concerns as to whether the frequencies of different words in English as a foreign language reflected the frequencies of the same words in native language samples, ratings of the frequency of use of the English words were obtained from other native speakers of Spanish resident in England.

Age of acquisition in English as a second language. Age of acquisition ratings for English as a second language were obtained for the 132 words selected from Cuetos et al. (1999). Twenty-eight Spanish native speakers with a mean age of 25 years (range 20 – 33 years) generated the ratings. None had experienced a bilingual environment during childhood. The mean age at which raters started to learn English was 11 years (range 7–14 years). They had been learning English for a mean period of 10 years (range 6–17 years) and had been living in England a mean time of one year (range 4 months – 3 years). None of the raters participated in Experiment 1. They were asked to rate the 132 English object names according to when they believed they first learned those words in English as a second language. The words were rated on a seven-point scale running from 1 = learned in the first year as an English language learner, through 2 = learned in the second year as an English language learner, to 7+ = learned in the seventh year as an English language learner or later. An additional option on the rating scale titled N.A. was created to allow raters to indicate that they had not yet learned that word in English. The ratings of 5 raters who were unfamiliar with more than 15 of the English words were discarded, so the final ratings were based on 23 raters. The ratings on the 1 to 7 scale were converted into months from the point at which the raters started learning English. Most words obtained a value between 12 months and 84 months.

One hundred and two of the words were found in the vocabulary lists of two textbook series used in Spain to teach English as a second language (Beaven, Soars, & Soars 1984; Walker, 1983). For each series, words listed as to be taught within the first year of learning English were assigned a value

[1] Some subjects participated in more than one experiment. However, the length of time between experiments was a minimum of six weeks.

of 12 months, words listed as to be taught in the second year were assigned a value of 24 months, and so on up to values of 48 months. For each word the values for the two book series were then averaged to create an objective age of acquisition measure for English as a second language. That objective measure correlated .62 with the ratings for acquisition in English as a second language. This is similar to the correlations reported for objective and rated measures of age of acquisition for native speakers (Morrison et al., 1997).

Word frequency in English as a second language. Another group of 24 Spanish native speakers rated 132 object names for the frequency in which they encountered or used. The mean age of the raters was 26 years (range 20 – 33 years). The mean age at which they had begun to learn English was 10 years old (range 7 – 14 years) and they had been learning English for a mean period of 16 years (range 9 – 24 years). At the time of the ratings, the participants had been living in England for a mean time of 2 years and one month (range 4 months – 4 years). Raters were asked to estimate how often they used or encountered each word in conversation or print on a 7-point scale ranging from 1 = about once a year through 2 = every few months to 7 = more than 5 times a day. An additional box was created for those words with which raters were unfamiliar in English. Thirteen words were removed because fewer than 75% of participants knew the word, leaving 119 words. The correlations obtained between rated frequency in English as a second language and objective frequency in English language samples was 0.51 for the comparison with the Celex frequency count and 0.57 for Hofland and Johansson (1988) frequency count. Those correlations are in the same range as the correlations obtained by Morrison et al. (1997) between frequency rated by native speakers of English and the same objective measure (0.48 and 0.55 respectively). The ratings for frequency in English as a second language correlated 0.89 with the ratings reported by Morrison et al. (1997) for native speakers of English, suggesting that the language experiences of the two groups are similar and that objective frequency counts of English are adequate for use with second language speakers of English resident in England.

Experimental items. Two sets of 32 items were created that were early or late acquired in both Spanish as a first language and English as a second language. Early acquired in Spanish as a first language equated to an estimated learning age of less than 5 years 8 months while late acquired in Spanish as a first language equated to an estimated learning age of 5 years 9 months or more. Early acquired in English as a second language meant that the word was learned within the first two years of studying English whereas late acquired in English as a second language meant that the word was learned in the third year of studying English, or later. The early and late sets were matched on the visual complexity of the pictures (from Morrison et al., 1997), the familiarity of the objects and their name agreement in both Spanish (Cuetos et al., 1999) and English (Morrison et al., 1997), the frequency of the object names in Spanish (Alameda & Cuetos, 1995) and English (Celex

Lexical Database: Baayen et al., 1993). The items and their characteristics are shown in Appendix 1.

Procedure. The stimuli were presented as black and white line drawings from Snodgrass and Vanderwart (1980) and Morrison et al. (1997). Participants were divided into two groups, with half of the participants naming the pictures in English and half naming the pictures in Spanish. Twenty pictures were presented for practice naming in English and in Spanish at the beginning of the experiment. The stimuli were presented using a Macintosh Centris 660 AV computer. Subjects sat facing the computer screen, which was about 60 cm in front of them. A fixation dot appeared in the centre of the screen for 1000 ms before each picture was presented. Pictures remained on the screen until the participant made a response. Response timing began at the onset of the stimulus. Verbal responses triggered a voice key linked to a high-sensitivity microphone attached to headphones worn by each participant. There was then an inter-trial interval of 500 ms before the presentation of the next fixation dot. Participants were asked to name the items as quickly and as accurately as possible. Presentation of items and recording of reaction times was done using the SuperLab experiment generator package (Abboud, 1991). Any naming errors, hesitations, misfirings of the voice key etc. were noted by the experimenter. There was no pre-exposure to the items before the experiment.

RESULTS

Only naming times for correct responses that fell within 3.5 standard deviations of the mean for that language were analysed. Eleven responses (2.15%) fell outside 3.5 SDs, four responses (0.78%) in the Spanish language condition and seven (1.38%) in the English language condition. A further 31 responses (6.05%) were removed from the Spanish language condition because of naming errors, hesitations and voice key failures, and 58 responses (11.33%) from the English language condition. Table 1 shows the mean naming RT and error percent in each condition.

Reaction times. An analysis of variance was carried out, with age of acquisition as a within subjects factor and language as a between subjects factor in the analysis by subjects and with language as a within subjects factor and age of acquisition as a between subjects factor in the analysis by items. The main effect of language was significant, $\underline{F}_1(1, 32) = 41.11$, $\underline{MSe} = 1291194.7$, $\underline{p}<.001$; $\underline{F}_2(1, 32) = 93.69$, $\underline{MSe} = 1200837.9$, $\underline{p} < .001$, with naming responses being faster in Spanish than in English. The main effect of age of acquisition was also significant, $\underline{F}_1(1, 32) = 37.68$, $\underline{MSe} = 304886.19$, $\underline{p} < .001$; $\underline{F}_2 (1, 32) = 19.77$, $\underline{MSe} = 315122.24$, $\underline{p} < .001$, with early acquired items being named faster than late acquired items. The interaction between language and age of acquisition was significant, $F_1 (1, 32) = 6.45$, $MSe = 52206.54$, $\underline{p} < 0.05$; $\underline{F}_2(1, 32) = 3.52$, $\underline{MSe} = 45149.88$, $\underline{p} < .05$, with the

difference in RTs between early and late items being numerically smaller for Spanish (81 ms) than English (195 ms). T-test analyses revealed that these RTs differences were significant for Spanish naming t (15) = -4.89, $p < .001$, and for English naming t (15) = -4.66, $p < .001$.

Errors. The low number of errors precluded the use of analysis of variance. Analysis of the mispronunciation rates using the Wilcoxon matched-pairs signed-ranks test revealed a significantly higher rate of errors to late than to early acquired words in English as a second language, $Z = -2.86$, $p < .01$. The difference in error rates for early and late acquired words in the native Spanish language condition approached significance, $Z = -1.93$, $p = .053$.

Table 1. Mean RTs in milliseconds (M), standard deviations (SD) and percent errors (% error) by subjects, for early and late acquired items in Spanish as a first language and English as a second language in Experiment 1 (picture naming).

		Early acquired	Late acquired
Spanish			
RT	M	780	867
	SD	75	116
% error		2.15	3.91
English			
RT	M	1001	1195
	SD	110	163
% error		3.32	8.01

DISCUSSION

Age of acquisition effects were found for the production of Spanish object names that were learned as part of the participants' acquisition of their native language vocabulary. This replicates previous reports of native language age of acquisition effects in picture naming for Spanish (Cuetos et al., 1999) as well as for French (Kremin et al., 2000) and English (e.g., Barry et al., 1997; 2001; Carroll & White, 1973; Ellis & Morrison, 1998).

An effect of age of acquisition was also found when participants named the same pictures in English. None of the participants had known any English before the age of 8 years, and the age of acquisition effect was based on a distinction between English words learned within the first two years tuition in English and words learned in or after the third year of studying English. This is the first report of age of acquisition effects in a second language. It is not really possible to compare ages of acquisition in first and second languages directly, but we note that there was no indication of the effect of age of acquisition on naming RT being weaker for a second than for a first language. If anything, the effect was stronger for the second than for the first language. This might be due to the differences in proficiency between the two languages. The first and better-established language shows an age of acquisition effect that is smaller than the less well established second language in which the differences between early and late acquired words are larger. This result is in accordance with some of the simulations presented by Ellis and Lambon Ralph (2000). They successfully simulated the age of acquisition effect in a back-propagation network. One of the simulations involved four different sets of patterns trained into the network at different times; very early, early, medium and, late. It is possible to observe that the differences between early and late entered patterns are greater at the initial stages of the training. Once the performance of the network has stabilised, earlier entered patterns show a smaller but constant advantage over late entered patterns.

Overall, the age of acquisition effect found in English as a second and late learned language suggests that the origins of the effect lie in the order of word learning rather than the age of the speaker when the words were learned.

EXPERIMENT 2

Robust effects of age of acquisition in first languages have also been observed in the visual lexical decision task, where participants must decide as quickly as possible if a string of letters on the screen constitutes a real word or an invented nonword (e.g., Butler & Hains, 1979; Gerhand & Barry, 1999; Morrison & Ellis, 1995; 2000). Experiment 2 applied the same logic as Experiment 1 in an effort to discover whether age of acquisition effects could be detected in English as a second language as well as in Spanish as a first language, not only in a word production task, such as picture naming, but also in a word recognition task, such a lexical decision.

METHOD

Participants. The participants were 22 native speakers of Spanish (11 females and 11 males) with a mean age of 26 years (range 20-33) whose childhoods had been spent in Spain. The mean age at which they first began to learn English was 10 years (range 7-14). At the time of testing, all the participants were studying at the University of York, England. They had been

resident in England, using English on a daily basis, for a mean time of 2 years and 4 months (range 4 months to 8 years).

Materials. The stimulus words were 38 Spanish object names taken from Cuetos et al. (1999) and 38 English object names taken from Morrison et al. (1997). An effort was made to avoid the use of cognates and unlike Experiment 1 the Spanish and English words were not translation equivalents (i.e., they were the names of different objects). Each set of 38 words was divided into two sets of 19 early and 19 late acquired words. For the Spanish words this was done using the Cuetos et al. (1999) age of acquisition ratings for Spanish as a first language. The English words were divided into early and late acquired in English as a second language on the basis of the ratings obtained for Experiment 1. The word sets were matched on word frequency in English using the Celex database (Baayen et al., 1993) and the Hofland and Johansson (1988) frequency count, and on word frequency in Spanish from Alameda and Cuetos (1995). Early and late sets were matched within languages on number of letters and phonemes. The items and their characteristics are shown in Appendix 2.

Nonwords for use in the Spanish and English parts of the experiment were created from real words in those languages by changing one or two letters in such way that they remained orthographically legal and pronounceable. The number of nonwords used was the same than the number of words for each language condition; 38 nonwords for the Spanish lexical decision and 38 nonwords for the English lexical decision. Examples of Spanish nonwords are *jomo* and *rela* . Examples of English nonwords are *therry* and *brean*.

Procedure. The experiment was carried out using a Macintosh centris 660-AV computer. Participants sat facing the computer screen, which was approximately 60 cm in front of them. The stimuli were presented on the computer screen in lowercase 48 point New York font. Each trial began with a fixation dot in the centre of the screen for 1000 ms, followed by the word or nonword which remained on the screen until a response was made. Participants pressed the P key on a standard Qwerty keyboard if the item was a word, and the Q key if it was a nonword.

The experiment consisted of two parts, and English language part in which English words were distinguished from nonwords and a Spanish language part in which Spanish words were distinguished from nonwords. Participants were divided into two groups. One group of 11 participants received the English version and then in Spanish, while the order of the two languages was reversed for the other group. Each part of the experiment began with 10 practice items in the appropriate language (5 words and 5 nonwords). Presentation of items and recording of reaction times was done using the SuperLab experiment generator package.

RESULTS

Only correct responses that fell within 3.5 standard deviations of the mean for that language were analysed. Eight responses (0.48%) to Spanish words and 19 responses (1.14%) to English words fell outside 3.5 SDs for words in that language and were removed from the analysis. An additional 6 responses (0.36%) to Spanish words and 16 responses (0.96%) to English words were errors that involved pressing the wrong response key. Table 2 shows the mean RTs, standard deviations and error rates collapsed across the two task orders.

Reaction times. An analysis of variance was carried out on the reaction times to real words, with language and task order as between-groups factors and age of acquisition as a within-subjects factor. The main effect of language was significant only in the analysis by items, $F_2(1,76) = 10.21$, $MSe = 91199.29$, $p < .01$, with lexical decision responses tending to be faster to Spanish words than to English words. The main effect of age of acquisition was significant in both analysis by subjects and by items, $F_1(1, 44) = 36.05$, $MSe = 78229.79$, $p < .001$; $F_2(1,76) = 14.04$, $MSe = 125444.95$, $p < .001$, with early acquired items being correctly classified as real words faster than late acquired items. The effect of task order was significant only in the analysis by items, $F_2(1,76) = 23.82$, $MSe = 108936.23$, $p < .001$, with words being classified faster in the second part of the experiment than in the first, suggesting a general practice effect. No significant interactions were found, though as in Experiment 1, there was a numerically larger effect in English (69 ms) than in Spanish (43 ms).

The mean RTs for correctly rejecting nonwords in the Spanish and English language conditions were 923ms and 1059 ms respectively. The difference in reaction times was not significant, $t(21) = -1.68$, $p = .11$.

Errors. The low number of errors precluded the use of analysis of variance. Analysis of the error rates using the Wilcoxon matched-pairs signed-ranks test revealed a significantly higher rate of errors to early than to late acquired words in English as a second language, $Z = -2.06$, $p < .05$, but no significant difference was found for the native Spanish language condition, $Z = -.74$, $p = .46$, where few errors were made.

Nonwords were correctly rejected with an accuracy of the 98% for the Spanish nonwords and 96% for the English nonwords. This difference in error rates was not significant, $t(21) = -1.27$, $p = .22$

DISCUSSION

The age of acquisition effect in Spanish in Experiment 2 is the first demonstration of such an effect in lexical decision for Spanish but echoes the similar results found with native speakers of English (Butler & Hains, 1979; Gerhand & Barry, 1999; Morrison & Ellis, 1995; 2000). An effect of age of

acquisition was also found in the English language version of the experiment. Taken together, the results of Experiments 1 and 2 clearly establish the presence of age of acquisition in the production and recognition of words acquired in a second language after the stage of early childhood that may be considered to constitute the critical period for language acquisition. As Davis and Kelly (1997) argued, it might be the case that the lexicon is an aspect of language less vulnerable to critical period effects. Once again, it is the order and not the age at which words are acquired that is responsible for the age of acquisition effect.

Table 2. Mean RTs in milliseconds (M), standard deviations (SD) and percent errors (% error) for early and late acquired words in Spanish as a first language and English as a second language in Experiment 2 (lexical decision).

		Early acquired	Late acquired
Spanish			
RT	M	649	692
	SD	45	63
% error		0.24	0.12
English			
RT	M	684	755
	SD	88	64
% error		0.18	0.78

EXPERIMENT 3

The early stimulus sets in Experiments 1 and 2 were acquired early both in Spanish as a first language and English as a second language, while the late acquired sets were acquired late both in Spanish as a first language and English as a second language. One possible account of the results of Experiments 1 and 2 would be that age of acquisition effects in both first and second languages depend on the age at which the meanings of the words are acquired in the first language. If, as most theorists assume (De Bot, 1992; Costa et al., 1999; Hell & de Groot, 1998; Kroll & Stewart, 1994), first and second language share common semantic representations, then second

language vocabulary could inherit the age of acquisition characteristics of the corresponding words in the first language. For example, the word *caja* is learned early in the acquisition of Spanish as a native language, and its translation equivalent, *box*, is learned early in the acquisition of English as a second language. The word *cometa* is learned somewhat later in the acquisition of Spanish as a native language, and its translation equivalent, *kite*, is likewise learned relatively late in the acquisition of English as a second language. The second language age of acquisition effect revealed in the faster naming or lexical decision responses to the English word *box* than to *kite* by native speakers of Spanish may simply reflect the differences in age of acquisition of *caja* and *cometa* in Spanish.

A dependence of second language age of acquisition effects on the age at which words are learned in the first language could arise if the source of age of acquisition effects lies in the semantic representations (cf. Brysbaert, Van Wijnendaele, & De Deyne, 2000). If the semantic representations of early acquired words were in some way easier to activate than the semantic representations of later acquired words, then any task that involved semantic representations would be expected to show age of acquisition effects. Most theoretical accounts of object naming propose that the conversion of a perceptual description of an object or picture to a phonological code for speech output is mediated by an intervening stage at which semantic knowledge of the depicted object is activated (e.g., Humphreys, Price, & Riddoch, 1999; Levelt, Roelofs, & Meyer, 1999). Hence, age of acquisition effects would be expected in first language object naming, which they are. If it was the case that acquiring the name of an object in a second language involved associating a new word-form with a pre-existing semantic representation created when the object was first encountered and talked about, and if age of acquisition was reflected in those semantic representations, then the naming of an object in a second language would inherit the influence of age of acquisition generated during childhood and the acquisition of the first language vocabulary. That could account for the second language age of acquisition effect seen in Experiment 1.

Similarly, at least some theoretical accounts of lexical decision propose that one of the ways that participants distinguish words from nonwords is on the basis that familiar words cause much stronger semantic activation than nonwords do (e.g., Plaut, 1997). Support for this view may be sought in demonstrations that lexical decision is faster for words with concrete meanings than for words with abstract meanings (Hell & de Groot, 1998) and faster for words with several meanings than for words with a single meaning (Hino & Lupker, 1996), both of which findings implicate semantic representations in lexical decision. Once again, if acquiring a word in a second language involved forming an association between the new word-form and an old semantic representation which was consulted in the course of making a lexical decision response, then lexical decision to second language words would inherit the childhood age of acquisition effect residing in the semantic system.

This possibility –that age of acquisition is an inherent characteristic of semantic representations– would predict that word recognition and production in the second language would show age of acquisition effects that reflect the order of acquisition of the corresponding meanings or word-forms in the first language. The results of Experiments 1 and 2 do not speak to this possibility because the items selected were early or late acquired in both Spanish as a first language and English as a second language.

The order of acquisition of second language vocabulary echoes to an extent the order of acquisition of native language vocabulary, so that words learned early in the native language tend also to be learned early in the second language. But the two orders of acquisition do not mirror one another exactly. Second language learners tend to be introduced early on to vocabulary that has to do with surviving in a foreign country – vocabulary to do with renting accommodation, buying food and other items in shops, handling money, and so on. Young children are protected from such concerns, so tend to acquire the corresponding native vocabulary later. In contrast, children acquire early on a vocabulary that has to do with the world of stories and the imagination –words to do with giants and castles, fairies and dragons. Second language learners have less use for such words which tend to be acquired relatively late in a non-native language. Therefore, there are some words that are deemed useful to learn early in a second language whose translation equivalents are not acquired until late in the first language and, conversely, there are some words acquired early in the first language that are considered low priorities for second language acquisition and so tend to be learned late.

The account of second language age of acquisition effects that we have just outlined would predict that processing speed in the second language would reflect first language age of acquisition, irrespective of the order in which the equivalent words were learned in the second language. This prediction was tested in Experiments 3 which employed the lexical decision task, and asked whether lexical decision RT in a second language was better predicted by second language age of acquisition or by the age of acquisition of the corresponding words (translation equivalents) in the first language. A regression analysis approach was chosen as a technique that permits the observation of the relative contributions of several predictor variables over latencies times. The main variables of interest were age of acquisition of the English word as a second language item and age of acquisition of the corresponding word in Spanish as a first language. Other predictors were imageability, word frequency in English, number of orthographic neighbours of the English word, and word length in letters.

METHOD

Participants. Twenty-two native Spanish speakers (9 males and 13 females) with a mean age of 26 (range 18-33) who had learned English as a second language took part in the experiment. As in the previous experiments,

all the participants had spent their childhoods in Spain. The mean age at which they started learning English was 14 years (range 8-22 years) and they had been learning English for a mean time of 11 years (range 5-20 years). They were all students of the University of York, England and had been resident in England for a mean time of 2 years (range 6 months – 5 years).

Materials. The experimental stimuli were 199 words and an equal number of non-words. One hundred and two of the words were taken from the set previously rated on age of acquisition in Spanish as a first language (Cuetos et al., 1999) and English as a second language (Experiment 1). The remaining 97 items came from a set of 160 words that were mostly selected on the basis that their ages of acquisition might be rather different in first and second languages; for example, words related to children's games or stories (e.g. cradle, marble, fairy) which might be early in the first language but late in the second, or words related to adult daily life (e.g. expensive, rent, welcome) which might be late in the first language but early in the second. The new set included 40 words which also occurred in the previous ratings studies. New ratings of age of acquisition in Spanish as a first language were collected from 20 native speakers of Spanish using the same scale as employed by Cuetos et al. (1999). The correlation between the new and old ratings for those 40 items was $\underline{r} = 0.89$.

Age of acquisition in English as a second language. New ratings were also obtained for the 160 new items for age of acquisition in English as a second language. Twenty native speakers of Spanish with English as a second language, resident in England, estimated the point at which they had acquired 160 English words in their learning of English. They used the same scale as described in Experment 1 (from 1= learnt in the first year of English learning to 7+ = learnt in the seventh year of English learning or later, with an additional box labelled N.A. (Not Applicable) for those words not yet acquired). Forty of the words had been previously rated for Experiment 1. The correlation between the ratings for those items was $\underline{r} = 0.92$. The 97 new items added to the 102 for which ratings already existed were all known by at least 80% of the raters.

Imageability. Twenty English native speakers were asked to rate 138 words as to how easy or difficult these words conjure a mental image, from 1 = hard to form an image to 7 = very easy to form an image. Imageability ratings for 61 additional words were taken from Morrison et al. (1997).

Word frequency. The word frequency measure used was the combined written and spoken count from the CELEX database, which is based on a large corpus of contemporary British English (Baayen et al., 1993).

Number of orthographic neighbours (N). This was defined as the number of English words that differ from the target word by a single letter.

Word length. The number of letters in the English word was taken as the measure of length.

The full set of items with their values on the predictor variables and their RTs is shown in Appendix 3. One hundred and ninety-nine legal, pronounceable nonwords were created by changing single letters in a new set of English words. The English nonwords were not words in Spanish.

Procedure. The stimuli were presented in the centre of an Apple Mac Centris 660-AV computer screen in black 72 lowercase print using New York font. The screen was approximately 60 cm away from the participant. The order of presentation was randomised (words and non-words) separately for each participant. A 1-second fixation dot was followed immediately by the stimulus word or nonword which remained on the screen until the participant made a response, whereupon the fixation dot reappeared. Participants were instructed to decide as quickly and as accurately as possible if the stimulus item was a word or a non-word. They pressed the Bb key for words and the Qq key for nonwords. Presentation of the items and recording of the reaction times was controlled by the SuperLab experiment generator package. Twenty practice items (10 words and 10 nonwords) were presented at the start of the experiment.

RESULTS

Only correct responses that fell within 3.5 standard deviations of the mean for that language were analysed. Fifty-three responses (1.2%) to English words fell outside 3.5 standard deviations and were removed from the analysis. An additional 209 responses (4.8%) to words were errors that involved pressing the wrong response key. Mean accuracy of nonword rejection was 93%. Overall, the mean RT for correct responses to words was 723 ms while the mean RT for correct rejections of nonwords was 911 ms.

Word frequency and number of orthographic neighbours were subjected to a log (1+x) transform while the other predictors were square root transformed to reduce skew. Table 3 shows the intercorrelations of the predictor variables and their correlations with mean lexical decision RT. Age of acquisition in the second language showed the highest correlation with RT, followed by word frequency, word length and number of orthographic neighbours. Imageability and age of acquisition of the corresponding words in Spanish as a first language did not correlate significantly with lexical decision RT in English.

The six predictor variables were entered into a simultaneous multiple regression analysis with each item's mean lexical decision RT as the dependent variable. The results are shown in Table 4. Taken together, the independent variables were able to predict English lexical decision RT to a

significant degree, F(6, 192) = 23.60, MSe=127008.17, p < .001, accounting for 43% of the variance in RT. The factors exerting significant independent effects on lexical decision speed were age of acquisition in English as a second language, English word frequency and word length. The age of acquisition of the equivalent words in Spanish as a first language did not make an independent contribution to predicting RT, neither did the imageability of the words or their number of orthographic neighbours (N).

Table 3. Correlation matrix among all the independent variables and English lexical decision RT (Experiment 3).

		1	2	3	4	5	6	7
1	RT	1.00	.066	.545*	.102	-.464*	-.203*	.340*
2	Spanish AOA		1.00	.277*	-.466*	.054	-.261*	.228*
3	English AOA			1.00	-.002	-.495*	-.046	.115
4	Imageability				1.00	-.398*	.228*	-.096
5	Word frequency					1.00	.045	-.142
6	N						1.00	-.778*
7	No. letters							1.00

*p < .01

DISCUSSION

Inspection of Table 3 shows that for the 199 words used in Experiment 3 the correlation between age of acquisition in Spanish as a first language and age of acquisition in English as a second language was .277. But although the two age of acquisition measures were themselves intercorrelated, only age of acquisition in English as a second language correlated significantly (.545) with lexical decision RT for English words from participants who had acquired English as a second language. The correlation between lexical decision RT in English and the age of acquisition of the corresponding Spanish words was just .066.

In the regression analysis, age of acquisition in English as a second language made a significant contribution to predicting lexical decision RT in English but age of acquisition of the corresponding words in Spanish did not. The other variable that significantly predicted RT was the frequency of words

in English: faster RTs were associated with words learned early in the second language and encountered with higher frequencies. This observation of independent contributions of frequency and age of acquisition to lexical decision speed is in line with previous findings in the monolingual domain (e.g., Butler & Hains, 1979; Gerhand & Barry, 1999; Morrison & Ellis, 1995; 2000).

Table 4. Results of the simultaneous multiple regression analysis of English lexical decision RTs (Experiment 3).

	B	Standard Error	Beta coefficient	t value	Significance
Spanish AOA (1st lang)	-35.61	21.61	-.108	-1.65	.101
English AOA (2nd lang)	35.56	5.47	.442	6.50	.001
Imageability	-1.97	18.26	-.008	-0.11	.914
Word frequency	-29.95	10.86	-.199	-2.76	.006
N	11.25	19.35	.052	0.58	.562
No. letters	87.34	23.91	.325	3.65	.001

Table 3 shows that the age at which words are acquired in Spanish as a first language correlates significantly (.466) with their imageability - words with more concrete, imageable meanings are learned earlier in a first language than words with more abstract meanings. We note, though, that imageability has a correlation with age of acquisition of words in the second language that is virtually zero (-.002). Second language learners must learn the vocabulary of the adult world if they are to get by in another country: abstract words to do with finding accommodation, organising money and so on are aspects of adult life from which young children are mercifully protected.

EXPERIMENT 4

Experiment 3 indicated that the age at which words are acquired in the second language is a more important predictor of word recognition speed in the second language than is the age of acquisition of the corresponding words and their meanings in the first language. This suggestion was tested further in Experiment 4. Using the ratings obtained for Experiment 3 it was possible to

select two sets of items. The first were words whose Spanish equivalents are learned early in Spanish as a first language but whose English forms are learned relatively late in the acquisition of English as a second language. Examples are *hada/fairy* and *muñeca/doll*. The second set were words with the opposite characteristics, words whose Spanish equivalents are learned relatively late in Spanish as a first language but whose English forms are learned early in the acquisition of English as a second language. Examples are *barato/cheap* and *viaje/travel*.

As before, the participants were native speakers of Spanish who were born and raised in Spain, who learned English as a second language, and who were resident in England (mostly as visiting students) at the time of testing. Half the participants performed lexical decision in Spanish to the Spanish versions of the words (*hada, muñeca, barato, viaje,* etc.) while the other participants performed lexical decision in English to the English versions of the words (*fairy, doll, cheap, travel,* etc.). If the indications of Experiment 3 are correct, then the group presented with Spanish words to recognise should be faster to the early Spanish / late English items than to the late Spanish / early English items while the group presented with English words to recognise should be faster to the late Spanish / early English items than to the early Spanish / late English items.

METHOD

Participants. Forty-four native Spanish speakers (21 males and 23 females) with a mean age of 26 (range 19-46) who had learned English as a second language took part in the experiment. All the participants had spent their childhoods in Spain. The mean age at which they started learning English was 12 years (range 8-26 years) and they had been learning English for a mean time of 10 years (range 2-24 years). They were mostly students of the University of York, England and had been resident in England for a mean time of 1 year (range 2 months - 5 years).

Materials. Stimuli consisted of one set of 36 items whose age of acquisition ratings indicated that they were learned relatively early in Spanish as a first language and relatively late in English as a second language and a second set of 36 items whose age of acquisition ratings indicated that they were learned relatively late in Spanish as a first language and relatively early in English as a second language. The items had different forms in the two languages (i.e. they were not cognates). The sets were matched on English word frequency (Celex combined) and on Spanish word frequency (Alameda & Cuetos, 1995); also on imageability and letter length in the two languages. The items are shown in Appendix 4. Thirty-six nonwords with English orthographic characteristics and 36 nonwords with Spanish orthographic characteristics were selected from the sets used in Experiment 3.

Procedure. The conditions of presentation and mode of response were the same as in Experiment 3. Participants were given 20 practice trials (10 words and 10 nonwords) at the start of the session.

RESULTS

Only correct responses that fell within 3.5 standard deviations of the mean for that language were analysed. Nine responses (0.6%) to Spanish words and 12 responses (0.8%) to English words fell outside 3.5 SDs for words in that language and were removed from the analysis. An additional 26 responses (1.6%) to Spanish words and 37 responses (2.3%) to English words were errors that involved pressing the wrong response key. Table 5 shows the mean RTs, standard deviations and error rates in the two conditions (English and Spanish).

Reaction times. By-subjects and by-items analysis of variance was carried out, with language of presentation and stimulus set (early Spanish / late English vs late Spanish / early English) as factors. The main effect of language was significant, $F_1(1, 44) = 16.57$, MSe = 633254.25, $p < .001$; $F_2(1, 36) = 47.61$, MSe = 530903.29, $p < .001$, with lexical decision responses being faster overall in Spanish (mean = 658 ms) than in English (mean = 828 ms). The main effect of stimulus set was also significant, F_1 (1, 44) = 21.99, MSe = 53750.68, $p < .001$; F_2 (1, 36) = 4.99, MSe = 47525.47, $p < .05$, with overall RTs being faster to the late Spanish / early English set (mean = 718 ms) than to the early Spanish / late English set (mean = 767 ms). Importantly, the interaction between language and stimulus set was significant, F_1 (1, 44) = 43.99, MSe = 107511.09 $p < .001$; F_2 (1, 36) = 9.96, MSe = 94843.19, $p < .01$. Separate analyses of RTs in Spanish and English showed that for the group responding to words presented in Spanish, RTs were faster to early Spanish / late English items than to late Spanish / early English items, $t(21) = -2.21$, $p = .03$ while for the group responding to words presented in English, RTs were faster to late Spanish / early English items than to early Spanish / late English items, $t(21) = -6.37$, $p < .001$. In other words, age of acquisition effects in the two languages reflected the age (or order) of acquisition of the different word-forms in those two languages.

The mean RTs for correctly rejecting nonwords in the Spanish and English language conditions were 770 ms and 1129 ms respectively. The difference in reaction time was significant, $t(21) = -3.80$, $p < .001$.

Errors. The low number of errors precluded the use of analysis of variance. Analysis of the error rates using the Wilcoxon matched-pairs signed-ranks test showed that the group responding to English words made more errors to early Spanish / late English words than to late Spanish / early English words, $Z = -3.22$, $p < .05$. Error rates were low to both word sets in

the group responding to Spanish words and the difference was not significant, $Z = -1.05$, $p = .294$.

Nonwords were correctly rejected with an accuracy of the 94% for the Spanish nonwords and 92% for the English nonwords. This difference in error rates was not significant (Mann-Whitney U test: $Z = -.85$, $p = .396$).

Table 5. Mean (M), standard deviation (SD) and percent error (% error) in Experiment 4 (lexical decision).

			Early Spanish / Late English	Late Spanish / Early English
Spanish				
	RT	M	648	669
		SD	41	91
	% error		0.63	1.01
English				
	RT	M	892	768
		SD	154	87
	% error		2.02	0.31

DISCUSSION

The results of Experiment 4 support those of Experiments 2 and 3. Age of acquisition effects were found when native Spanish speakers responded to Spanish words. Those effects reflected the order of acquisition of the words in Spanish as a first language, so RTs were faster to early than late acquired Spanish words irrespective of the fact that the English versions of the early Spanish words are late acquired in English as a second language while the English versions of the late Spanish words are early acquired in English as a second language. Conversely, age of acquisition effects were found when native Spanish speakers responded to English words that reflected the order of acquisition of the words in English as a second language. Thus, RTs were faster to early than late acquired English words, irrespective of the fact that the Spanish versions of the early English words are late acquired in Spanish as a

first language while the Spanish versions of the late English words are early acquired in Spanish as a first language. Taken together, the results of Experiments 3 and 4 confirm the presence of age of acquisition effects for second language vocabularies and show that those effects reflect the order in which the second language words are acquired rather than the order in which the equivalent first language words are acquired. The fact that first language age of acquisition did not affect lexical decision latencies in Experiments 3 or 4 suggests that the origin of the age of acquisition effect is lexical or in the mappings between semantics and lexical representations, but not in the semantic system itself.

GENERAL DISCUSSION

The results of the four experiments presented here are relatively clear, and are relatively clear in their implications. In Experiment 1, native speakers of Spanish who started learning English at an average of 11 years of age named pictures of familiar objects in either Spanish or English. The objects had names that are either early acquired in both languages or late acquired in both languages. Objects were named faster in the participants' native language of Spanish than in their second language of English, and naming RTs were faster to early than late items in both languages.

Experiments 2, 3 and 4 all employed the lexical decision task, with participants responding to English or Spanish words in the context of nonwords that looked either English or Spanish. In Experiment 2, sets of words were used that were again early or late acquired in both Spanish and English. Lexical decision responses were marginally faster for first language Spanish words than for second language English words (a pattern repeated in Experiment 4), but age of acquisition effects were found in both languages. Experiments 3 and 4 employed different methodologies to address the question of whether age of acquisition effects in a second language reflect the order of acquisition of words in the second language or the order of acquisition of the equivalent words (and their meanings) in the first language. In Experiment 3, participants responded to English words whose age of acquisition in English as a second language was known, as was the age of acquisition of the translation equivalents in Spanish. In a regression analysis, lexical decision RTs were found to be affected by the age of acquisition of the words in the second language of English but not by the age of acquisition of the first language Spanish equivalents. That is, the effect of age of acquisition seemed to be tied to the age at which the English word-forms had been learned, not the age at which the verbal-semantic representations had been acquired in the native Spanish language.

The indication in Experiment 3 that second language age of acquisition effects reflect the age of acquisition of those words in the second language was supported in Experiment 4. Participants performed a lexical decision task in either Spanish (first language) or English (second language). Half the items were ones whose Spanish forms were early acquired in Spanish as a first language but whose English forms were late acquired in English as a second

language. The other half had the opposite characteristics: their Spanish forms were late acquired in Spanish as a first language but their English forms were early acquired in English as a second language. The group responding in Spanish classified the early Spanish set faster than the late Spanish set, irrespective of the fact that the early Spanish items were late acquired in English while the late Spanish items were early acquired in English. More importantly perhaps, the group responding in English classified the early English set faster than the late English set, irrespective of the fact that the early English items were late acquired in Spanish as a first language while the late English items were early acquired in Spanish.

The combined results of the four experiments rule out some possible explanations of how and why age of acquisition effects emerge. First, age of acquisition effects do not appear to depend on a contrast between words learned in early childhood during a possible 'critical period' for language acquisition and words learned later. If they did, then the participants in the present experiments, who only started learning English in late childhood or later, would have been expected to show age of acquisition effects in their native Spanish but not in English. Yet age of acquisition affected the processing of English words in both object naming (Experiment 1) and lexical decision (Experiments 2, 3 and 4).

Second, age of acquisition effects in a second language do not reflect the order of acquisition of the corresponding word meanings in the first language. Both Experiment 3 and Experiment 4 found that the age of acquisition effect for lexical decision in English as a second language was determined by the age of acquisition of the various English word-forms, not the age of acquisition of the corresponding words in Spanish. From this we conclude that while age of acquisition might affect tasks that require accessing meanings (Brysbaert et al., in press b), the origins of those effects do not lie within the semantic representations themselves.

The results of the present experiments remain compatible with a number of theoretical positions. One is that age of acquisition is a property of orthographic or phonological representations themselves (cf. Brown & Watson, 1987; Gerhand & Barry, 1998; Morrison & Ellis, 1995). If orthographic and phonological representations are separate for two languages (cf. De Bot, 1992; Costa et al., 1999; Hell & de Groot, 1998; Kroll & Stewart, 1994), then the quality of the representations of early vocabulary could differ from the quality of the representations of later vocabulary in such a way as to generate faster processing of the early items in both languages. For example, Brown and Watson (1987) proposed that as more and more words are learned (in a first language), lexical representations progress from being relatively wholistic to being segmented into syllables and phonemes (or letters). Brown and Watson (1987) suggested that the extra processing time required to assemble a late acquired and therefore highly segmented word might account for the slower processing of those words. If this pattern was repeated for words learned in a second language, then the same processing differences could hold for second as for first language vocabulary.

If the effects of age of acquisition are located at the level of individual representations and if, as assumed by the revised hierarchical model (Kroll & Stewart, 1994), the different vocabularies of a bilingual are stored in separate lexicons, then there should be two effects of age of acquisition; one for each language or vocabulary. The present results are compatible with this explanation. They are also compatible with the view that the origins of age of acquisition effects lie in the mappings between different representations of words (orthographic, phonological and semantic) that are forged during the acquisition of both first and second languages (Ellis & Lambon Ralph, 2000; Monaghan & Ellis, in press b). According to Kroll and Stewart's (1994) model, in the process of learning a second language connections of different strengths are created linking L2 words with L1 words and L2 words with their meanings. Thus, acquiring a second language vocabulary will involve a whole new process of strengthening and weakening connections between representations to create new associations between semantic, phonological and orthographic representations. As with first language acquisition, words encountered early in the learning of the second language will seize the opportunity to modify connection strengths in directions favourable to representing them. Words learned later in the second language will attempt to reconfigure the new associations, and will succeed to an extent, but because the early second language vocabulary continues to be experienced, used and therefore reinforced, the organisation of the network will forever favour those items learned early in the process of second language acquisition. Second language vocabulary will therefore show age of acquisition effects like first language vocabulary (Experiments 1 and 2), and those effects will be determined by the order of acquisition of words in the second language, rather than the order of acquisition of their first language counterparts (Experiments 3 and 4). What the present results to not support is the proposal that age of acquisition effects reside in semantic representations (Brysbaert et al., 2000), because that theory would predict that second-language vocabulary would inherit the age of acquisition characteristics of the corresponding first language vocabulary, which is not what was found in the present Experiments 3 and 4.

What is clear is that models of bilingual lexical representation will have to take age of acquisition into account as an important property of words that is a major predictor of the speed of processing of those words in both first and second languages.

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APPENDIX 1

Items used in Experiment 1 (picture naming) with their RTs.

A) Items named in Spanish (first language)

Spanish name	English translation	Spanish AoA	log (1 + freq)	Object familiarity	Visual Complexity	Name Agreement	No.of syllables	RT
Early acquired Spanish items								
Gato	Cat	3.33	1.85	3.67	2.71	100	2	703
Gallina	Chicken	3.43	1.30	2.46	3.41	95	3	827
Vaca	Cow	3.68	1.11	2.89	2.97	100	2	706
Pato	Duck	3.44	0.78	2.39	3.17	98	2	675
Pez	Fish	3.67	1.49	3.77	3.34	92	1	714
Gafas	Glasses	3.98	1.59	3.83	2.20	100	2	792
Cuchillo	Knife	3.12	1.40	4.60	1.49	94	3	709
Luna	Moon	3.90	1.91	4.12	1.14	100	2	811
Pera	Pear	3.65	1.04	3.66	1.19	100	2	890
Lápiz	Pencil	3.48	1.04	4.65	1.68	84	2	837
Cerdo	Pig	3.77	1.26	2.38	3.17	92	2	718
Conejo	Rabbit	3.67	1.00	2.31	3.31	100	3	924
Zapato	Shoe	3.20	1.26	4.46	3.17	100	3	840
Calcetín	Sock	3.28	0.60	4.69	1.61	100	3	775
Cuchara	Spoon	3.16	0.70	4.72	1.86	90	3	733
Estrella	Star	4.04	1.69	3.49	1.19	100	3	834
M		3.55	1.25	3.63	2.35	96.56	2.38	780
SD		0.29	0.39	0.90	0.88	4.90	0.62	75
Late acquired Spanish items								
Flecha	Arrow	4.90	0.95	3.03	1.08	92	2	780
Botón	Button	4.39	1.41	4.13	1.46	98	2	843
Gorra	Cap	4.79	1.15	2.28	1.76	90	2	1125
Cadena	Chain	5.06	1.08	2.04	2.31	95	3	915
Guante	Glove	4.38	1.11	3.76	2.44	92	2	833
Martillo	Hammer	4.65	0.95	2.31	2.36	97	3	815
Bolso	Handbag	4.72	1.30	3.88	2.61	95	2	769
Plancha	Iron	4.84	0.85	3.52	3.15	100	2	796
Jarra	Jug	4.26	0.95	3.88	1.81	89	2	772
Escalera	Ladder	4.24	1.82	2.71	2.08	95	4	795
Hoja	Leaf	4.12	1.57	3.54	2.42	94	2	871
Cebolla	Onion	5.06	1.28	3.68	2.36	95	3	869
Anillo	Ring	4.78	1.32	3.98	1.64	90	3	853
Regla	Ruler	4.80	1.57	3.51	2.61	97	2	836
Maleta	Suitcase	4.54	1.40	3.28	3.19	97	3	845
Corbata	Tie	5.10	1.43	2.11	2.32	100	3	1166
M		4.66	1.26	3.23	2.23	94.75	2.50	867
SD		0.31	0.27	0.72	0.57	3.42	0.63	116

B) Items named in English (second language)

English name	English AoA	log (1 + freq)	Object familiarity	Visual complexity	Name agreement	No. of syllables	RT
Early acquired English items							
Cat	12.00	1.62	4.00	2.60	100	1	1117
Chicken	13.80	1.49	3.20	2.90	70	2	999
Cow	21.00	1.36	3.18	3.85	100	1	971
Duck	23.40	0.70	2.59	3.05	82	1	906
Fish	13.20	1.91	3.09	2.95	100	1	1022
Glasses	22.80	1.30	3.82	2.60	86	2	906
Knife	19.20	1.56	4.82	1.95	96	1	1159
Moon	18.00	1.73	3.32	1.05	91	1	786
Pear	23.33	0.48	3.23	1.20	100	1	967
Pencil	13.20	1.20	4.00	2.05	100	2	1059
Pig	18.00	1.28	2.36	2.70	96	1	1199
Rabbit	19.20	1.08	2.81	2.65	95	2	1139
Shoe	17.40	1.18	4.68	3.20	100	1	909
Sock	24.00	0.60	4.73	1.80	100	1	950
Spoon	20.40	1.08	4.64	1.90	91	1	984
Star	16.80	1.73	3.09	1.00	96	1	941
M	18.48	1.27	3.60	2.34	93.94	1.25	1001
SD	3.93	0.41	0.80	0.82	8.43	0.45	110
Late acquired English items							
Arrow	41.68	0.95	3.27	1.60	100	2	1133
Button	29.40	1.20	4.09	2.02	100	2	874
Cap	40.42	1.45	2.91	2.18	91	1	1202
Chain	60.63	1.53	2.57	2.50	96	1	1349
Glove	31.58	0.78	2.91	2.70	91	1	1343
Hammer	29.65	1.00	2.82	2.55	100	2	987
Handbag	25.80	0.95	3.00	2.70	70	2	1142
Iron	32.40	1.84	3.05	3.25	100	2	1177
Jug	57.18	0.95	3.23	1.85	100	1	1100
Ladder	33.88	1.15	2.64	2.55	96	2	1532
Leaf	50.82	1.20	3.41	2.75	100	1	1043
Onion	36.00	1.00	3.95	2.85	100	2	1119
Ring	28.20	1.56	3.82	2.55	95	1	1259
Ruler	27.79	0.95	3.82	2.40	100	2	1179
Suitcase	36.60	1.11	2.50	3.30	77	2	1318
Tie	42.32	1.30	2.91	2.65	100	1	1358
M	37.77	1.18	3.18	2.53	94.75	1.56	1195
SD	10.55	0.29	0.51	0.45	8.97	0.51	163

APPENDIX 2

Words used in Experiment 2 (lexical decision) with their RTs.

A). Spanish words (first language)

Spanish word	English translation	Spanish AoA	log (1+ freq)	No of phonemes	No.of letters	RT
			Early acquired Spanish words			
árbol	tree	3.65	1.75	5	5	650
botella	bottle	3.67	1.77	6	7	593
caja	box	4.10	1.79	4	4	619
camión	truck	3.86	1.15	6	6	655
caracol	snail	3.88	1.08	7	7	659
escoba	broom	4.00	0.78	6	6	635
flor	flower	3.18	1.78	4	4	598
fresa	strawberry	4.08	0.70	5	5	559
gafas	glasses	3.98	1.59	5	5	637
gallina	chicken	3.43	1.30	6	7	630
globo	balloon	3.04	1.18	5	5	625
jarra	jug	4.26	0.95	4	5	603
jersey	jumper	3.83	1.04	6	6	734
pantalón	trousers	3.85	1.51	8	8	704
payaso	clown	3.44	0.85	6	6	673
rana	frog	3.91	0.78	4	4	680
sombrero	hat	4.15	1.65	8	8	695
tijeras	scissors	4.08	0.78	7	7	682
vela	candle	3.90	1.45	4	4	697
M		3.80	1.26	5.58	5.74	649
SD		0.33	0.39	1.30	1.33	45
			Late acquired Spanish words			
araña	spider	4.59	1.00	5	5	730
ardilla	squirrel	4.80	1.36	6	7	705
bolso	handbag	4.72	1.30	5	5	631
chaleco	vest	5.78	1.28	6	7	670
collar	necklace	4.44	1.18	5	6	669
cometa	kite	4.62	1.28	6	6	728
corazón	heart	4.27	2.28	7	7	621
flecha	arrow	4.90	0.95	5	6	713
foca	seal	5.34	0.78	4	4	663
guante	glove	4.38	1.11	6	6	699
hacha	axe	4.81	0.90	3	5	848
iglesia	church	4.62	2.04	7	7	669
jarron	vase	4.65	0.78	5	6	683
llave	key	4.53	1.65	4	5	579
percha	hanger	4.88	0.90	5	6	774
pincel	paintbrush	4.91	0.90	6	6	708
tren	train	4.37	1.75	4	4	598
vestido	dress	4.27	1.93	7	7	724
zanahoria	carrot	4.30	0.78	8	9	743
		4.69	1.27	5.47	6.00	692
		0.38	0.46	1.26	1.20	63

B). English words (second language)

English word	English AoA	log (1+ freq)	No of phonemes	No.of letters	RT
Early acquired English words					
cat	12.00	1.62	3	3	614
apple	12.60	1.28	4	5	604
pencil	13.20	1.20	6	6	599
ear	14.40	1.63	3	3	650
monkey	15.60	1.00	5	6	718
basket	17.40	1.28	6	6	680
shoe	17.40	1.18	2	4	734
moon	18.00	1.73	3	4	625
pig	18.00	1.28	3	3	627
rabbit	19.20	1.08	5	6	687
spoon	20.40	1.08	4	5	787
butterfly	22.20	0.78	7	9	778
knife	19.20	1.56	3	5	697
umbrella	18.00	1.08	7	8	668
duck	23.40	0.70	3	4	639
shirt	22.80	1.66	4	5	613
bear	24.60	0.85	3	4	654
sock	24.00	0.60	3	4	969
bell	25.20	0.11	3	4	651
M	18.82	1.14	4.05	4.95	684
SD	4.11	0.42	1.51	1.61	88
Late acquired English words					
skirt	27.00	1.32	4	5	688
ring	28.20	1.56	4	4	675
fork	30.00	1.11	4	4	792
sheep	38.40	1.32	3	5	787
onion	36.00	1.00	5	5	651
cigar	32.40	1.15	5	5	871
wheel	37.89	1.46	3	5	729
envelope	34.20	1.30	7	8	731
flag	35.40	1.00	4	4	648
suitcase	30.60	1.11	7	8	756
fox	37.80	1.04	3	3	771
crown	38.12	1.38	4	5	787
tie	42.32	1.30	2	3	719
hammer	29.65	1.00	5	6	750
brush	42.00	1.11	3	5	790
leaf	50.82	1.20	3	4	766
ladder	33.88	1.15	5	6	877
bow	51.00	1.18	3	3	825
chain	60.63	1.53	4	5	739
	37.70	1.22	4.11	4.89	755
	8.68	0.18	1.33	1.41	64

APPENDIX 3

Words used in Experiment 3 (lexical decision) with their RTs.

Words	English AOA	Spanish AOA	log (1+ freq)	Imag.	N	No. letters	RT
able	33.00	6.65	2.52	1.22	0.48	4	899
address	13.20	6.30	1.62	2.18	0.00	7	695
alone	20.40	4.30	2.29	1.96	0.60	5	631
although	39.00	6.30	2.48	1.07	0.00	8	758
always	19.80	5.45	2.82	1.24	0.30	6	596
anchor	47.29	5.61	0.78	2.56	0.00	6	852
answer	16.80	5.40	2.01	1.76	0.00	6	720
ant	39.60	3.25	0.70	2.43	1.08	3	785
apple	12.60	2.94	1.28	2.55	0.48	5	664
arrow	41.68	4.90	0.95	2.51	0.00	5	735
ashtray	54.32	4.86	0.00	2.36	0.00	7	947
axe	52.00	4.81	0.00	2.49	1.08	3	718
balloon	36.00	3.04	0.60	2.56	0.48	7	912
basket	17.40	4.49	1.28	2.57	0.95	6	720
bear	24.60	4.10	0.85	2.53	1.38	4	640
bed	12.60	2.49	2.39	2.56	1.28	3	651
bee	37.26	4.30	0.90	2.51	0.90	3	773
beer	27.00	5.25	1.67	2.63	0.85	4	716
bell	25.20	4.31	0.11	2.57	1.30	4	652
best	24.00	5.15	2.46	1.75	1.00	4	718
biscuit	23.40	2.75	0.78	2.47	0.00	7	700
boat	24.60	3.30	1.76	2.62	0.60	4	673
book	12.60	3.62	2.43	2.46	1.26	4	610
bottle	16.80	3.67	1.92	2.52	0.70	6	720
box	18.60	4.10	1.60	2.37	1.26	3	590
break	29.40	5.70	1.43	2.05	0.85	5	712
broom	43.64	4.00	0.85	2.51	0.78	5	1144
brush	42.00	4.06	1.11	2.49	0.78	5	643
bubble	46.20	4.60	0.70	2.58	0.85	6	868
business	39.00	6.90	2.37	2.05	0.30	8	842
butterfly	22.20	4.42	0.78	2.50	0.00	9	756
candle	36.60	3.90	0.95	2.64	0.85	6	723
cap	40.42	4.79	1.45	2.43	1.34	3	730
car	12.60	3.51	2.44	2.58	1.40	3	638
carpet	36.60	6.95	1.38	2.58	0.48	6	640
carrot	27.60	4.30	0.60	2.63	0.90	6	714
cat	12.00	3.33	1.62	2.53	1.48	3	553
century	36.60	7.05	2.26	1.69	0.00	7	666
chair	13.20	3.37	2.02	2.54	0.48	5	652
cheap	19.20	5.55	1.60	1.69	0.48	5	772
cheek	41.68	5.95	1.40	2.40	0.70	5	812
cherry	41.05	4.06	0.78	2.60	0.60	6	737
chicken	13.80	3.43	1.49	2.64	0.48	7	640
chilly	60.00	3.05	0.78	2.18	0.48	6	769
Christmas	15.00	3.45	1.78	2.40	0.00	9	707
church	16.20	4.62	2.20	2.57	0.00	6	596
city	12.60	4.25	2.30	2.52	0.48	4	615
cloud	23.40	3.15	1.49	2.57	0.60	5	768
clown	37.80	3.44	0.60	2.59	0.60	5	646
coin	21.00	4.50	0.90	2.59	0.95	4	665

comb	45.23	3.78	0.70	2.48	0.78	4	803
cough	42.00	3.45	1.08	2.06	0.90	5	828
council	52.80	7.00	2.01	1.83	0.00	7	697
country	16.80	5.35	2.53	2.25	0.00	7	661
cow	21.00	3.68	1.36	2.63	1.45	3	695
crown	38.12	4.88	1.38	2.57	0.95	5	730
cup	18.60	3.23	1.78	2.55	1.23	3	683
dead	21.00	5.05	2.17	1.75	1.11	4	706
deep	37.80	7.00	0.60	1.82	1.00	4	677
dog	12.00	3.00	1.85	2.58	1.38	3	577
doll	30.60	2.85	1.26	2.57	1.08	4	688
donkey	28.42	3.10	1.00	2.62	0.30	6	756
door	12.60	3.50	2.52	2.44	1.04	4	624
drawer	40.42	3.70	1.20	2.36	0.30	6	772
dress	18.60	4.27	1.88	2.47	0.85	5	635
drum	39.33	4.60	0.90	2.57	0.90	4	768
duck	23.40	3.44	0.70	2.52	1.20	4	768
ear	14.40	3.29	1.63	2.49	1.32	3	721
easy	14.40	3.85	1.00	1.36	0.48	4	640
empty	19.80	5.45	0.00	1.99	0.00	5	716
end	13.20	4.35	2.61	1.76	0.30	3	636
every	15.60	5.55	2.74	1.26	0.30	5	638
expensive	18.60	5.20	1.85	1.67	0.48	9	773
eye	13.20	3.02	2.11	2.60	1.04	3	723
fact	42.00	5.65	2.71	1.32	0.85	4	628
fairy	51.60	4.15	1.08	2.51	0.70	5	768
farm	22.80	4.20	1.82	2.57	0.90	4	651
fear	43.20	3.16	2.06	1.69	1.11	4	628
fish	13.20	3.67	1.91	2.63	1.04	4	622
flag	35.40	4.85	1.00	2.52	1.08	4	735
flower	15.60	3.18	1.45	2.59	0.70	6	744
forehead	42.95	4.40	1.40	2.57	0.30	8	954
fork	30.00	3.14	1.11	2.52	1.04	4	710
fox	37.80	4.66	1.04	2.63	1.00	3	648
freedom	34.20	6.60	2.00	1.86	0.00	7	625
frog	36.60	3.91	0.70	2.52	0.95	4	675
frost	43.20	5.85	0.95	2.32	0.48	5	790
gentleman	26.40	5.70	1.41	2.30	0.30	9	718
ghost	30.60	3.35	1.32	2.33	0.00	5	810
gift	37.20	3.55	1.51	2.29	0.90	4	644
glass	19.80	2.98	2.10	2.45	0.70	5	621
glasses	22.80	3.98	1.30	2.50	0.00	7	663
glove	31.58	4.38	0.78	2.44	0.90	5	737
great	27.60	2.45	2.81	1.52	0.48	5	699
grocer	39.16	6.40	0.70	2.36	0.30	6	879
hammer	29.65	4.65	1.00	2.47	0.90	6	743
hand	13.20	3.17	2.64	2.51	1.20	4	660
handbag	25.80	4.72	0.95	2.41	0.30	7	819
hanger	48.00	4.88	0.30	2.38	0.95	6	942
hat	14.40	4.15	1.73	2.57	1.48	3	659
health	34.20	5.95	2.12	1.66	0.48	6	676
heart	24.00	4.27	2.16	2.59	0.48	5	679
horse	14.40	3.64	1.93	2.59	1.18	5	617
hundred	16.20	5.45	2.30	2.02	0.00	7	743
hunger	32.84	3.05	1.40	1.90	0.70	6	710
hunter	43.33	4.95	1.08	2.36	0.78	6	764
iron	32.40	4.84	1.84	2.41	0.30	4	627

jelly	54.75	6.45	1.04	2.45	0.90	5	848
journal	36.00	5.00	1.28	2.33	0.00	7	782
jug	57.18	4.26	0.95	2.51	1.26	3	874
jumper	35.40	3.83	0.30	2.49	0.70	6	694
kettle	41.33	6.50	1.08	2.50	0.90	6	739
key	18.00	4.53	1.85	2.50	1.20	3	607
kid	22.20	2.15	1.48	2.44	1.04	3	704
king	16.20	3.35	1.95	2.52	1.18	4	608
knife	19.20	3.12	1.56	2.57	0.30	5	676
ladder	33.88	4.24	1.15	2.59	0.95	6	792
leaf	50.82	4.12	1.20	2.54	1.11	4	764
learn	19.80	4.50	1.49	1.58	0.30	5	637
level	26.40	6.95	2.26	1.82	0.70	5	654
library	21.60	6.15	1.73	2.48	0.00	7	640
lorry	36.71	3.86	0.95	2.59	0.78	5	855
market	22.80	5.90	2.12	2.53	0.48	6	614
mister	22.11	4.10	0.70	1.88	0.78	6	645
monkey	15.60	4.40	1.00	2.54	0.48	6	638
moon	18.00	3.90	1.73	2.58	1.26	4	682
mushroom	40.80	5.25	0.78	2.48	0.00	8	740
necklace	48.67	4.44	0.48	2.51	0.00	8	945
needle	52.67	5.00	1.00	2.46	0.00	6	751
never	16.20	5.75	2.95	1.34	0.70	5	662
next	17.40	7.20	1.75	1.48	0.70	4	715
nose	15.60	3.32	1.87	2.41	1.15	4	713
nun	47.33	5.20	0.78	2.49	1.18	3	768
nut	55.80	5.00	0.90	2.39	1.20	3	752
onion	36.00	5.06	1.00	2.49	0.48	5	751
paintbrush	43.80	5.65	0.00	2.53	0.00	10	1021
pear	27.33	3.20	0.48	2.48	1.32	4	727
pearl	40.67	6.00	0.85	2.57	0.30	5	729
pencil	13.20	3.48	1.20	2.52	0.30	6	594
penny	27.16	7.85	1.18	2.54	0.48	5	644
pie	40.20	3.25	1.15	2.62	1.08	3	728
pig	18.00	3.77	1.28	2.60	1.15	3	613
pineapple	30.60	4.83	0.48	2.50	0.00	9	738
pleasure	39.60	7.30	1.92	1.95	0.00	8	686
pound	26.53	7.65	1.64	2.33	0.90	5	666
prize	29.40	4.55	1.28	2.22	0.60	5	628
pub	27.60	4.75	1.34	2.58	1.11	3	616
punishment	46.74	4.20	1.52	1.90	0.00	10	804
rabbit	19.20	3.67	1.08	2.57	0.60	6	666
rent	40.20	7.30	1.58	1.70	1.26	4	681
ring	28.20	4.78	1.56	2.44	1.08	4	619
rocket	45.88	5.35	0.95	2.56	1.04	6	793
rubber	24.60	4.60	1.41	2.25	0.48	6	844
ruler	27.79	4.80	0.95	2.40	0.00	5	737
sale	30.60	6.80	1.54	1.86	1.30	4	675
scissors	30.00	4.08	0.70	2.47	0.00	8	828
seed	49.33	5.50	1.46	2.46	1.32	4	745
sheep	38.40	3.88	1.32	2.53	1.00	5	665
shell	41.05	4.40	1.46	2.41	1.04	5	716
shirt	22.80	4.20	1.66	2.51	0.95	5	715
shoe	17.40	3.20	1.18	2.53	0.90	4	690
silly	22.80	2.45	1.65	1.63	0.90	5	647
skirt	27.00	4.10	1.32	2.46	0.70	5	742
slang	57.88	8.00	0.60	1.41	0.78	5	894

slippers	64.67	3.40	0.95	2.54	0.78	8	966
snail	36.00	3.88	0.60	2.50	0.60	5	847
sock	24.00	3.28	0.60	2.49	1.15	4	774
soul	38.40	6.85	1.62	1.67	0.70	4	656
speaker	28.80	7.85	1.26	2.19	0.30	7	741
spider	25.80	4.59	0.70	2.62	0.70	6	709
spoon	20.40	3.16	1.08	2.62	0.90	5	684
squirrel	50.00	4.80	0.70	2.61	0.00	8	951
star	16.80	4.04	1.73	2.61	1.04	4	616
strawberry	30.00	4.08	0.60	2.62	0.00	10	775
success	42.60	7.05	2.01	1.61	0.00	7	661
suitcase	30.60	4.54	1.11	2.64	0.00	8	683
sun	12.00	3.08	2.18	2.62	1.30	3	640
swan	53.33	5.11	0.78	2.64	1.00	4	911
swing	46.00	3.15	1.27	2.48	0.90	5	690
table	12.00	3.55	2.31	2.64	0.85	5	667
tap	50.82	4.80	1.20	2.58	1.41	3	774
tax	46.11	7.75	2.04	1.77	1.32	3	668
thirsty	24.60	6.70	0.78	1.84	0.30	7	699
thousand	16.80	7.50	2.06	1.90	0.00	8	724
tidy	32.67	5.85	0.95	1.94	0.48	4	729
tie	42.32	5.10	1.30	2.58	1.28	3	739
tortoise	39.53	3.85	0.70	2.62	0.00	8	917
travel	20.40	4.80	1.48	2.10	0.30	6	888
tree	12.60	3.65	1.86	2.63	1.08	4	650
trousers	16.20	3.85	1.46	2.59	0.30	8	1068
ugly	21.60	2.60	1.38	2.20	0.00	4	674
umbrella	18.00	4.18	1.08	2.63	0.00	8	696
village	26.40	4.20	2.13	2.49	0.48	7	656
wasp	56.25	4.50	0.48	2.58	0.90	4	787
welcome	16.20	6.65	0.78	1.77	0.00	7	617
wheel	37.89	3.82	1.46	2.63	0.30	5	688
window	13.20	3.88	2.12	2.63	0.30	6	634
witch	50.12	2.80	1.23	2.55	0.95	5	826
wizard	55.06	3.80	0.48	2.55	0.30	6	779

APPENDIX 4

Words used in Experiment 4 (lexical decision) with their RTs.

English word	Spanish word	Eng AoA	Span AoA	Eng freq (Celex)	Eng freq (K-F)	Span freq	Eng imag	Span imag	Eng L	Span L	Eng RT	Span RT
					Early Spanish / Late English							
brush	cepillo	42.00	4.06	1.11	1.65	0.95	6.20	6.83	5	7	695	621
cherry	cereza	41.05	4.06	0.78	0.85	0.78	6.75	6.96	6	6	752	649
chilly	frio	60.00	3.05	0.78	0.78	2.12	4.75	4.65	6	4	827	619
cough	tos	42.00	3.45	1.08	0.90	1.08	4.25	4.96	5	3	858	637
doll	muñeca	30.60	2.85	1.26	1.04	1.23	6.60	6.96	4	6	805	656
donkey	burro	28.42	3.10	1.00	0.30	1.28	6.85	6.87	6	5	992	605
drawer	cajón	40.42	3.70	1.20	0.95	1.43	5.55	6.74	6	5	1017	686
fairy	hada	51.60	4.15	1.08	0.70	0.81	6.30	5.83	5	4	1002	744
fear	miedo	43.20	3.16	2.06	2.11	2.23	2.85	5.09	4	5	725	594
ghost	fantasma	30.60	3.35	1.32	1.08	1.36	5.45	5.70	5	8	735	710
gift	regalo	37.20	3.55	1.32	1.53	1.62	5.25	5.87	4	6	831	615
hunger	hambre	32.84	3.05	1.40	1.26	1.82	3.60	4.87	6	6	848	643
lorry	camión	36.71	3.86	0.95	0.00	1.15	6.70	6.91	5	6	889	632
onion	cebolla	36.00	5.06	1.00	1.20	1.28	6.20	6.87	5	7	693	589
punishment	castigo	46.74	4.20	1.52	1.34	1.48	3.60	5.04	10	7	1073	689
tortoise	tortuga	39.53	3.85	0.70	0.60	1.00	6.85	6.91	8	7	1137	667
witch	bruja	50.12	2.80	1.23	0.78	1.18	6.50	6.52	5	5	1201	676
slippers	zapatillas	64.67	3.40	0.95	0.60	1.29	6.45	6.87	8	10	979	626
	M	41.87	3.55	1.15	0.98	1.34	5.59	6.14	5.72	5.94	892	648
	SD	9.84	0.48	0.32	0.50	0.40	1.28	0.87	1.56	1.63	154	41

						Late Spanish / Early English						
address	dirección	13.20	6.30	1.62	1.89	1.96	4.75	3.65	7	9	739	742
basket	cesta	17.40	4.49	1.28	1.26	0.90	6.60	6.91	6	5	637	626
bell	campana	25.20	4.31	0.11	1.28	1.26	6.60	6.91	4	7	669	839
butterfly	mariposa	22.20	4.52	0.78	0.48	0.95	6.25	6.96	9	8	873	600
carrot	zanahoria	27.60	4.30	0.60	0.30	0.78	6.90	6.91	6	9	793	819
cheap	barato	19.20	5.55	1.60	1.40	1.13	2.85	3.96	5	6	697	651
coin	moneda	21.00	4.50	0.90	1.04	1.29	6.70	6.83	4	6	705	606
empty	vacío	19.80	5.45	0.00	1.81	0.40	3.95	3.96	5	5	748	629
expensive	caro	18.60	5.20	1.85	1.65	1.34	2.80	4.30	9	4	756	762
gentleman	caballero	26.40	5.70	1.41	1.46	1.81	5.30	6.26	9	9	882	652
handbag	bolso	25.80	4.72	0.95	0.00	1.30	5.80	6.91	7	5	842	634
key	llave	18.00	4.53	1.85	1.95	1.65	6.25	6.83	3	5	679	590
penny	penique	27.16	7.85	1.18	1.41	0.00	6.45	5.57	5	7	901	853
pound	libra	26.53	7.65	1.64	1.46	0.70	5.45	4.48	5	5	801	637
pub	bar	27.60	4.75	1.34	0.30	1.92	6.65	6.91	3	3	734	582
rubber	goma	24.60	4.60	1.41	1.20	1.13	5.05	6.74	6	4	822	637
ruler	regla	27.79	4.80	0.95	0.60	1.57	5.75	6.70	5	5	899	596
travel	viaje	20.40	4.80	1.48	1.79	2.17	4.40	6.13	6	5	650	587
	M	22.69	5.22	1.16	1.18	1.24	5.47	5.94	5.78	5.94	768	669
	SD	4.39	1.06	0.54	0.60	0.57	1.28	1.25	1.86	1.83	87	91