Age of acquisition interactions in bilingual lexical access: A study of the weaker language of L2 learners and heritage speakers

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Abstract

Global age of acquisition of L1 and L2 in individual speakers has been investigated as a deterministic factor in nativelikeness of grammatical knowledge and lexical processing. The age of acquisition of individual words has also been shown to affect both native and nonnative lexical access. Given the centrality of the lexicon to language acquisition and use, this study investigated which of these variables is most relevant and how these two variables may potentially interact during lexical access of the less dominant language in bilinguals. A group of English-speaking late L2 learners of Spanish and a group of early bilingual speakers who were exposed to Spanish as an L1 at home and learned English in childhood (heritage speakers) completed a lexical decision task in Spanish and an English–Spanish translation decision task. The performance of the two groups, which vary on global age of acquisition of Spanish, but not on language dominance, was compared. The results indicated no differences in the overall accuracy of lexical access according to global age of acquisition of L1 and L2, though the L2 learners responded more quickly than the heritage speakers in both tasks. The results differed within each participant group depending on word age of acquisition, with heritage speakers showing a speed and accuracy advantage for words learned early in L1 Spanish and L2 learners showing an advantage for words learned early in L2 Spanish. Based on these findings, it is argued that it is the language experience along with word age of acquisition that determines lexical processing of the weaker language, whether in L1 or L2.

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Introduction

In second language (L2) acquisition and bilingualism, age of acquisition (AoA) has figured prominently as a deterministic factor in explaining potential nonnative outcomes in language learning (Abrahamsson & Hyltenstam, 2009; DeKeyser, 2000; Hyltenstam & Abrahamsson, 2003; Johnson & Newport, 1989; Long, 1990, 2007). Many studies of L2 ultimate attainment have demonstrated that AoA is correlated with bilingual outcomes: the earlier the AoA the more nativelike a bilingual is likely to become in the L2. Yet, the impact of age effects in L2 acquisition has been almost exclusively examined in the learning of phonology and morphosyntax. Because vocabulary feeds the grammar, building a lexicon is also central to language learning. Nevertheless, AoA in general has not received as much attention as an experimental variable in the study of L2 vocabulary acquisition and representation, probably because the ability to learn and remember words seems to rest heavily on experience and may be largely spared from a critical period (Curtiss, 1977; Long, 2007).

Most recently, age effects have also been implicated in the L1 attrition, or loss, of phonology, morphosyntax, and lexical semantics, with the observation that the earlier the AoA of L2 acquisition the less nativelike the bilingual is likely to become in the L1 (Bylund, 2009; Montrul, 2008; Schmid, 2011). Studies of lexical access and retention in L1 attrition research suggest that lexical access is one of the aspects of language most susceptible to loss (de Bot, 1998; Weltens & Grendel, 1993). After a certain degree of disuse, L1 speakers immersed in an L2 environment encounter lexical retrieval difficulties in the L1 due to low levels of activation (and reduced proficiency). Although the issue of age effects and vocabulary retention has not been investigated in L1 attrition, existing research suggests that very young children whose L1 acquisition has not been completed upon immigration, and prepuberty children, lose their L1 productive vocabulary faster and to a much greater extent than adults, whose language is fully developed upon immigration (Ammerlaan, 1996; Hulsen, 2000; Polinsky, 2005). Underscoring the importance of lexical learning and retention, Polinsky (1997, 2006) showed that degree of lexical retrieval is highly correlated with degree of morphosyntactic attrition in incomplete L1 learners of Russian.

In psycholinguistics, there have been some studies investigating AoA in monolingual and bilingual lexical access (Bonin, Barry, Méot, & Chalard, 2004; Izura & Ellis, 2002, 2004), except that in these studies AoA is defined differently. While in L2 acquisition and L1 attrition AoA is typically operationalized as the age at which the individual is first exposed to the second language or global AoA, AoA in these psycholinguistic studies refers instead to the age at which words are first learned in either their spoken or written form, or onset of word learning. That is, word AoA is a learning property that depends on the order, and not the age, at which words are learnt. AoA effects, in turn, refer to the observation that words acquired early in life are processed faster and more accurately than those acquired later. And not only does word AoA affect L1 lexical processing, but it also affects L2 lexical processing. Izura and Ellis (2004) found that how long it took to decide whether a string of letters was a word in Spanish (the L1 of the Spanish–English bilinguals tested) was predicted by AoA of words in Spanish, whereas the time it took to do the same in English (the bilinguals' L2) was predicted by AoA of words in English.

The purpose of our study is to investigate whether global AoA (i.e. the age at which the individual learned the L2 or became bilingual) and the AoA of individual words affect lexical retrieval and access in the less dominant language of bilinguals. Although lexical access and age effects have been independently examined in L2 acquisition and to a lesser extent in L1 attrition, the uniqueness of our study lies in the investigation of how global AoA of L1 and L2 interacts with the variable AoA of words in both L2 acquisition and L1 loss (or incomplete L1 acquisition). The present study examines the effect of word AoA in two groups of bilinguals: adult

English-speaking L2 learners of Spanish and adult English-dominant Spanish heritage speakers, whose L1 is Spanish (Valdés, 2000). In the context of the USA, heritage speakers are bilingual speakers whose family language is an ethnic minority language. In the two groups, the stronger language is English and the weaker language is Spanish, as shown by independent measures of proficiency and responses to a linguistic background questionnaire. However, for the L2 learners, Spanish is the L2, but for the heritage speakers, Spanish may be considered an incompletely acquired L1 (Montrul, 2002, 2008; Polinsky, 1997), a specific case of attrition in childhood.[1] L2 learners who acquire an L2 around or after puberty are also characterized as late bilinguals. The heritage speakers, who were exposed to Spanish and English in childhood, are early bilinguals. Hence, while the two groups were exposed to English in childhood, they differ on their AoA of Spanish (early for the heritage speakers and late for the L2 learners) as well as on the type of language-learning experience. After all, acquisition of vocabulary is heavily dependent on the context of learning and on when in life words are learned. Heritage speakers are exposed to the heritage language at home since early childhood while L2 learners are exposed to the L2 around or after puberty and primarily in the classroom. Thus, L2 adult learners typically do not know many L2 words acquired in early childhood by monolingual children and heritage speakers may not know words that are acquired later in life, when their use of the language becomes much less frequent.

A series of recent studies have investigated the role of AoA in aspects of morphosyntax and phonology and have compared the linguistic abilities of L2 learners and heritage speakers, who differ on their age and mode of acquisition of the majority language (Au, Knightly, Jun, & Oh, 2002; Montrul, 2009; Montrul, Foote, & Perpiñán, 2008). But to our knowledge, no published study to date has compared similar groups on their knowledge and retrieval of lexical items, and the present study aims to fill this gap. Investigating lexical knowledge and retrieval of words for these two groups can contribute to understanding lexical access as a function of experience and can also have implications for proficiency testing and language program development that seeks to understand linguistic differences between these two types of language learners (Fairclough & Ramírez, 2009).

AoA of language and AoA of words are tightly related, since the global AoA of L1 and L2 directly affects the AoA of specific words in L1 and L2. Furthermore, because the global AoA of L1 and L2 has been shown to play a deterministic role in how acquisition and loss proceed and in the ultimate outcomes of bilingualism, it is crucial to examine whether word AoA has the same effect on lexical access regardless of when a particular language was learned. In the present study, we therefore ask the following specific questions: (a) Does global age of language acquisition affect speed and/or accuracy of lexical access, irrespective of language dominance? In other words, do heritage speakers, who have been shown to have advantages over L2 learners in some aspects of phonology (Au et al., 2002) and in some aspects of lexical semantics (Montrul, 2005), access words more quickly and more accurately than L2 learners? (b) Does the AoA of words in L1 and/or L2 affect speed and/or accuracy of lexical access? Specifically, do both heritage speakers and L2 learners access words in Spanish more quickly and accurately based on Spanish word AoA? Before presenting the methodology and results of our study, we first address in more detail the issue of AoA in bilingual lexical access with a specific focus on L2 acquisition, lexical retention, and access under L1 attrition.

AoA in bilingual lexical access

The study of bilingual lexical representation and access has a long tradition in psycholinguistics (see Altarriba, 2000; Kroll & Dijkstra, 2002; Kroll & Sunderman, 2003; Libben, 2000; as well as

Kroll & De Groot, 2005). The relationship between words and concepts in the bilingual lexicon, the autonomous or interdependent connections between the L1 and the L2 lexicons, and the specific cognitive factors affecting accuracy and speed in lexical access during word recognition and production (as evidence of fluent language use) are among the central issues in this field. Although there are many word-related variables that contribute to how quickly and accurately words are identified and produced in a first or second language (e.g. concreteness, imageability, frequency, length, morphological complexity, semantic relatedness, phonological relatedness, and cognate status), in this study we are concerned with the effects of AoA: the age at which words are first learned.

Carroll and White (1973a, 1973b), according to Ellis and Morrison (1998), were the first to propose, on the basis of naming latencies for objects, that earlier learned words are retrieved faster than later learned words in monolingual lexical access and that the effect of word AoA is independent of other frequency effects. Because this early work relied on subjective measures of AoA of words as reported by participants participating in these experiments, the validity of AoA as a variable was seriously questioned. But a study by Ellis and Morrison (1998), which used real AoA norms with children, also found word AoA effects in two object-naming experiments. Even though words acquired earlier in life tend to be more concrete and shorter and occur more frequently in adulthood, Bonin et al.'s (2004) critical appraisal of AoA effects reported in several psycholinguistic tasks confirmed that AoA effects are independent of word frequency in the adult input. Three main theoretical explanations for why early acquired words are easier to process and retrieve than later acquired words have been proposed (Izura & Ellis, 2004). The first explanation relates AoA effects to phonological representations. Specifically, it may be the case that AoA affects the speed of retrieval of the phonological forms of words (Gilhooly & Watson, 1981; Levelt, Roelofs, & Meyer, 1999), though since AoA effects have been found in tasks that do not require word form retrieval (Moore & Valentine, 1999; Vitkovitch & Tyrrell, 1995), this explanation may be inadequate. The second explanation of AoA effects is that they are related to when a particular concept is acquired. However, Izura and Ellis's (2002, 2004) finding of AoA effects in an L2 (see below) creates problems for this explanation, since L2 learners do not learn new concepts as they learn an L2, but rather new word forms to go with the concepts that they already know. The third explanation of AoA effects that has been proposed is that they are found in the mapping between different levels of the representation of words. Links between semantic, phonological, and orthographic (for written forms of words) representations that were formed early in life are stronger than those that are formed later. This "Mapping Hypothesis" is based on simulations of word learning in a connectionist network that were conducted by Ellis and Lambon Ralph (2000). According to these simulations, AoA effects come about due to the nature of the lexical network, which becomes less plastic as word learning progresses (Ellis & Lambon Ralph, 2000, p. 1119). This explanation of AoA effects has the advantage over the other two proposals, in that it can account for effects that go beyond language (i.e. effects on object and face recognition), as pointed out by Izura and Ellis (2004, p. 167).

It appears, then, that AoA effects are relevant in the lexical processing of not only a first language, but also a second language. Izura and Ellis (2002) investigated AoA of L1 and L2 words in Spanish L1 speakers born and raised in Spain who started learning English as L2 or foreign language after the age of 10 years. Results of an experiment involving object naming and lexical decision found AoA effects in both L1 and L2; in English, the L2, participants were faster at recognizing/producing words that were acquired early than those that were acquired late in English. Some early acquired words in the L1 coincide with early acquired words in the L2, such as nouns for food or clothing, but this is not always the case. For example, adult L2 learners learn abstract vocabulary

related to school activities earlier than L1-acquiring children (e.g. *correo* "mail," *universidad* "university").

Izura and Ellis (2004) conducted a follow-up study with similar participants (20 Spanish learners of English in Spain with global AoA of the L2 ranging from 6 to 24 years, well before and well after puberty). They used a visual translation decision task, in which a decision is made as to whether two words are translation equivalents, (Experiments 1 and 3) and a lexical decision task (Experiment 2). Translation pairs used in the first experiment consisted of an L1 word followed by an L2 word (*camisa–shirt*), and there were four conditions: (a) early acquired words in both Spanish (L1) and English (L2), (b) words acquired early in Spanish (L1) but late in English (L2), (c) words acquired late in Spanish (L1) and early in English (L2), and (d) words acquired late in Spanish (L1) and in English (L2). Eighty percent of the words in the two lists were nouns, and the remaining 20% were verbs and adjectives. AoA of L2 words was decided by asking a group of participants when they thought they had learned certain words in English as a second language; AoA of L1 words was also based on ratings made by native Spanish speakers. In another experiment, the same participants completed the same translation decision task but with the presentation of the English words preceding the presentation of the Spanish words by 400 ms, as in *shirt–camisa*. The combined results of the three experiments showed that early acquired words in Spanish (the L1) were processed faster than late acquired words in Spanish and early acquired words in English (the L2) were also processed faster than late acquired words in English as a second language. Although important subject variables typically controlled in L2 acquisition studies such as global AoA (before and after puberty) and L2 proficiency level were not considered by Izura and Ellis, this study still suggests that AoA of words is an important factor in speed and accuracy of L2 lexical processing.

In terms of the overall or global AoA of the language (early in life or later in life), few psycholinguistic studies have focused on this issue in bilingual lexical access except for a study by Silverberg and Samuel (2004). Silverberg and Samuel investigated the effects of proficiency and AoA of Spanish as a second language in Spanish–English bilinguals (L2 learners) in the architecture of the mental lexicon. There were three groups: Early L2 learners, Late proficient L2 learners, and Late less proficient L2 learners. Using lexical priming experiments in which the effects of the presentation of one word (the prime) on a related word (the target) were investigated, the goal of this study was to determine whether AoA and proficiency mattered for the conceptual links to L1 and L2 acquired words. According to their results, there were priming effects for words related in meaning (semantic priming) and in orthographic form for the Early L2 learners, only form-related priming effects for the proficient Late L2 learners, and no priming effects of any sort for the less proficient Late L2 learners. Not only did this study show that AoA and proficiency in the L2 play a role in bilingual lexical access but also that both factors contribute to the organization of the developing mental lexicon. Specifically, Silverberg and Samuel argue that early learners have a shared conceptual level for both L1 and L2 concepts, but separate lexical stores for each language. In contrast, late proficient learners have separate concept stores for L1 and L2, but a shared lexical level. In conclusion, there is evidence that both AoA of words and global AoA of language play a role in bilingual lexical access.

Lexical access in L1 attrition: The case of heritage speakers

Under normal circumstances, L1 attrition refers to the loss of linguistic skills in a bilingual environment. Attrition may occur during the first generation of immigration, affecting structural aspects of the L1 due to language shift, or a change in the relative use of the L1 and the L2. Seliger (1996, p. 616) defines attrition as "the temporary or permanent loss of language ability

as reflected in a speaker's performance or in his or her inability to make grammaticality judgments that would be consistent with native speaker (NS) monolinguals of the same age and stage of language development." Recent research suggests that the extent of attrition is inversely related to age of onset of bilingualism (Bylund, 2009; Montrul, 2008; Pallier, 2007). Very young children whose L1 acquisition has not been completed entirely upon migration, and prepuberty children, tend to lose their L1 productive skills more quickly and to a greater extent than people who moved as adults and whose L1 was fully developed upon migration (Ammerlaan, 1996; Hulsen, 2000). That is, the extent of attrition and severe language loss is more likely in children younger than 10 or 12 years old than in individuals who immigrated after puberty. And within childhood, language attrition, most typically referred to as incomplete L1 acquisition (Montrul, 2008; Polinsky, 1997, 2006), also tends to be more extensive in younger children than in older children (Montrul, 2008).[2]

While L1 attrition may affect several linguistic components, lexical access, which heavily rests on experience and use, is most susceptible to language loss (de Bot, 1998; Weltens & Grendel, 1993). Due to less frequent use of their L1, low levels of activation, or reduced proficiency, speakers under attrition encounter lexical access and retrieval difficulties manifested in high error rates and slowed processing with lower frequency words. An example of a psycholinguistic study of lexical attrition confirming these effects is Hulsen (2000), who tested three generations of Dutch immigrants in New Zealand in their two languages, Dutch and English. The study also included a control group of Dutch speakers in The Netherlands. Hulsen used an oral picture-naming task (with objects) and a picture–word matching task to test both accuracy and speed of lexical access in production and comprehension.

Results of both the Dutch and the English experiments showed main effects for generation, cognate status of words, and frequency. The first-generation speakers were less accurate and slower in Dutch than the controls from The Netherlands, but only in production. The second-generation speakers were significantly slower and less accurate in Dutch than in English in both measures, although they were much slower and more inaccurate in production than in comprehension. The third-generation immigrants showed the highest level of attrition. In fact, the picture-naming task proved too difficult for these speakers, and the results had to be discarded. The performance on the picture-matching task was better than on the picture-naming task, suggesting that production is affected more by attrition and/or incomplete acquisition than comprehension. Thus, at least for lexical retrieval and access, Hulsen found that, in fact, Dutch is the weaker language both in terms of use and speed of access in incomplete learners of Dutch. Incomplete acquisition, as demonstrated from the second and third-generation speakers, affects lexical retrieval and production more dramatically than L1 attrition in first-generation speakers.

The present study

As the previous review shows, AoA of words has been investigated in L2 acquisition by Izura and Ellis (2002, 2004). However, Izura and Ellis did not control for, or directly manipulate, at what age L2 was learned or proficiency in the L2. In fact, some of the participants in their experiments were child L2 learners (exposed to the L2 between ages 6 and 12) and the rest were late L2 learners (13–24), but this crucial variable was not taken into account in their results. By contrast, Silverberg and Samuel (2004) did manipulate global AoA of L2 in their study of lexical access, but they did not look at word AoA as a factor in their study. Given that both AoA variables have been shown to play a role in bilingual lexical access independently, the purpose of this study is to expand this line of research to two different bilingual populations by investigating the potential interaction between

Table 1. Variables and groups manipulated in the present study.

Group	AoA of Spanish	AoA of words (with examples)		
		pañal "diaper"	*perro* "dog"	*correo* "mail"
Heritage speakers	Early (as L1)	Early	Early	Late
L2 learners	Late (as L2)	Late	Early	Early

AoA: age of acquisition.

the two types of AoA. Specifically, our study examines whether and how global AoA of L1 and L2 interacts with AoA of words in heritage speakers (a case of incomplete L1 acquisition) and late L2 learners of Spanish matched for proficiency in Spanish. Table 1 illustrates how AoA of Spanish as L1 or as L2 interacts with the assumed onset of word learning or AoA of words in the two participant groups.

Neither Izura and Ellis nor Silverberg and Samuel examined bilinguals whose dominant language was their L2, as we do in the current study. The inclusion of this population allows for an examination of how language experience in addition to age may interact with the effects of when particular words are acquired. By experience we mean the timing, type, modality, frequency, and amount of exposure to relevant input and use of the language, which differ in these two groups of language learners compared in the present study. L2 learners typically acquire the language in an instructed setting through visual and aural input, while Spanish heritage speakers are exposed to the language since early childhood at home, through aural input and interactions with caregivers.

According to the Mapping Hypothesis (Ellis & Lambon Ralph, 2000; Izura & Ellis, 2004), early acquired words have superior links between semantic, phonological, and orthographic representations in the mental lexicon in comparison to late acquired words of comparable frequency because early words were acquired and used gradually and cumulatively. The mappings between phonology, semantics, and orthography tend to be less reliable for late acquired words. The advantage for early acquired over late acquired words is maintained even when these words are less frequently encountered later in life, according to the connectionist model simulations of AoA effects conducted by Ellis and Lambon Ralph (simulation 12). For words to lose the advantage that early acquisition confers, they must be completely replaced with a different set of words (e.g. as in the case of the Korean adoptees described by Pallier et al., 2003), or no longer be encountered at all (Ellis and Lambon Ralph, simulations 1 and 2). A unique feature of our study is that we verify this aspect of Ellis and Lambon Ralph's simulations with human participants. Their computer simulations would imply that although the weaker language investigated in heritage speakers is their L1, heritage speakers should not lose the advantage of early acquired words even when their L1 is no longer the stronger language, unless they completely stopped using the L1 when they learned the L2. For late L2 learners of Spanish, all Spanish words in general, whether learned early or late during the course of L2 acquisition, are at a disadvantage in terms of the strength of the links between semantic, phonological, and orthographic representations in the mental lexicon in comparison to L1 English words (i.e. words in their native language). However, learning a second language vocabulary require that new links be formed between orthographic, semantic, and phonological representations. Based on Izura and Ellis' (2004) results, stronger links are formed for early acquired words in the L2 than for later acquired L2 words as well; that is, AoA effects not only apply to L1 words but also to words learned as an adolescent or an adult in a second language.

A total of 28 heritage speakers and 28 late L2 learners of Spanish matched for proficiency completed a lexical decision task in Spanish and an English–Spanish translation decision task to words acquired at different ages in L1 and L2 in order to answer the questions outlined above and repeated here for convenience: (a) Does global age of language acquisition affect speed and/or accuracy of lexical access, irrespective of language dominance? In other words, do heritage speakers who were exposed to Spanish in childhood access Spanish words more quickly and more accurately than L2 learners who acquired those Spanish words later in life in their second language? (b) Does the AoA of words in L1 and/or L2 affect speed and/or accuracy of lexical access? Specifically, do both heritage speakers and L2 learners access words in Spanish more quickly and accurately based on Spanish word AoA?

The purpose of the tasks was to see how heritage speakers and L2 learners access words in their less dominant language, in this case Spanish, as a function of AoA. Word AoA effects have been reported in a number of tasks, most notably object naming, word naming, and visual lexical decision and translation decision. Several studies comparing L2 learners and heritage speakers have shown that heritage speakers outperform L2 learners in oral tasks, whereas L2 learners outperform heritage speakers in written tasks (Alarcón, 2011; Montrul, 2011; Montrul et al., 2008), so ideally we should have a task with oral and a task with visual stimulus presentation. We followed Izura and Ellis (2002) and chose to start with a visual lexical decision task and a visual translation decision task because visual tasks have been used as proficiency measures and placement tests for L2 learners and heritage speakers (Fairclough & Ramírez, 2009). The following hypotheses were formulated based on the assumption of effects of global AoA of both L1 and L2 (e.g. Silverberg & Samuel, 2004) and of individual words (e.g. Izura & Ellis, 2002, 2004):

1. If acquiring a language early in childhood confers an advantage over staring acquisition late, after puberty, then the heritage speakers may show an advantage over the L2 learners in both accuracy and reaction times (RTs) with Spanish words acquired early in L1 acquisition, but late in L2 acquisition (Early L1–Late L2; e.g. *pañal–diaper*) and with words acquired early in L1 acquisition and early in L2 acquisition (Early L1–Early L2; e.g. *perro–dog*), since the heritage speakers will have acquired all of these early words at a much younger age than the late L2 learners. The heritage speakers may also show an advantage over the late L2 learners with words acquired late in L1 acquisition but early in L2 acquisition (Late L1–Early L2; e.g. *correo–mail*), or the two groups may show similar results, depending on when each group acquired these words. These findings would suggest that global AoA affects lexical access.

2. We also hypothesize differences in the two tasks with the three sets of words within each group due to effects of word AoA as a function of experience. For example, the heritage speakers will be faster and more accurate in their responses to Early L1–Late L2 and Early L1–Early L2 words in comparison to Late L1–Early L2 words. The L2 learners will pattern in the opposite direction, with an accuracy and RT advantage for the Late L1–Early L2 and the Early L1–Early L2 words over the Early L1–Late L2 words.

Participants

A total of 56 participants, with intermediate to advanced proficiency in Spanish, completed the experiment. They were all enrolled in Spanish language classes at a major research university in the USA. For half of the participants, Spanish was the L2, and for the other half the L1. Twenty-eight adult native speakers of English who were L2 learners of Spanish (age: *M* = 22.4, range

Table 2. Information about participants in this study.

Group	N	L1	L2	AoA Spanish	Age at testing	Spanish proficiency score (maximum = 50)
				Mean (range)	Mean (range)	Mean (SD)
Heritage speakers	28	Spanish	English	Birth	21.2 (18–45)	39.22 (4.96)
L2 learners	28	English	Spanish	14.13 (12–25)	22.4 (18–39)	39.36 (6.86)

AoA: age of acquisition; SD: standard deviation.

18–39) and started their L2 acquisition after puberty (AoA Spanish: $M = 14.13$, range 12–25) were the participants in the L2 learner group. The heritage speaker group consisted of 28 Spanish adult heritage speakers from Mexican background exposed to English (their L2) before age 5, but with stronger command of English than of Spanish at time of testing. Their AoA of Spanish (the L1) was birth, and their age at the time of testing ranged from 18 to 45, mean 21.18. Twenty were born in the USA and the other eight were born in Mexico but immigrated to the USA in early childhood (range: 2–4 years old, age of immigration). Although all participants completed a language background questionnaire that included questions about self-assessments of their proficiency in Spanish, unlike Izura and Ellis (2004) who only used self-ratings, we used an independent measure of proficiency to assess their level of Spanish.[3] The measure consisted of the vocabulary part of a Modern Language Association test (30 items) and cloze part of the advanced *Diplomas de Español como Lengua Extranjera* (DELE; 20 items), the same test used in several other studies of L2 learners and heritage speakers (McCarthy, 2007; Montrul, 2005; White, Valenzuela, Kozlowska-Macgregor, & Leung, 2004). The maximum number of points on this test was 50. The two groups scored around 80% accuracy and did not differ statistically from each other: L2 learners: $M = 39.36$; standard deviation (SD) = 6.86; range, 30–50 and heritage speakers: $M = 39.22$; SD = 4.96; range, 30–48; $t(57) = 0.91$; $p = 0.34$. Reliability statistics, computed using Cronbach's alpha, were found to be high ($r = 0.87$) for both the heritage speakers and the L2 learners. Table 2 presents information about the two groups.

Materials—lexical decision task

The stimuli for the lexical decision task consisted of 108 (noncognate) Spanish words, 36 nouns, 36 verbs, and 36 adjectives.[4] In each word class, 12 words were classified as acquired early in L1 Spanish but late in L2 Spanish (Early L1–Late L2). Twelve others were classified as acquired late in L1 Spanish but early L2 Spanish (Late L1–Early L2), and the control condition, Early L1–Early L2, consisted of 12 words assumed to be acquired early in both L1 Spanish and L2 Spanish acquisition. Unlike Izura and Ellis (2004), who used native speaker judgment ratings on when they thought they had acquired some words, AoA in our study was decided by consulting the Mexican Spanish and English versions of the MacArthur–Bates Communicative Development Inventory (CDI) for L1 acquisition; if a word appeared in the inventory of the corresponding language, it was considered to be early acquired in the L1 (see also Kittredge, Dell, Verkuilen, & Schwartz, 2008, for use of the CDI to determine AoA).[5] A word was considered to be early acquired in the L2 if it appeared in the glossary of the first-year Spanish textbook used at the university where participants were tested. If a word appeared in both the inventory and the Spanish textbook, it was classified as "Early L1–Early L2." If it appeared only in the inventory, it was classified as "Early L1–Late L2." If it appeared only in the textbook, it was classified as "Late L1–Early L2." Examples of each word

Table 3. Example words for each word AoA category—lexical decision task.

	Early L1–Early L2	Early L1–Late L2	Late L1–Early L2
Noun	*lápiz* (pencil)	*pañal* (diaper)	*correo* (mail)
Verb	*besar* (to kiss)	*barrer* (to sweep)	*resumir* (to summarize)
Adjective	*cansado* (tired)	*travieso* (naughty)	*soltero* (unmarried)

AoA: age of acquisition.

AoA category along with their English translations are shown in Table 3, with the full list of critical stimuli available in Appendix 1. (Although this could be another control condition, we chose not to include the other possible variable Late L1–Late L2 to simplify the design.)[6]

All words were matched for frequency (*Léxico informatizado del español*, Sebastián Gallés, Cuetos, Carreiras, & Martí, 2000) and syllable and character length as much as possible across the three word AoA conditions. The majority of the nouns were concrete (and thus highly imageable) across the three word AoA conditions. One-way analysis of variances (ANOVAs) confirmed that frequency ($F(2, 105) = 0.21$, $p = 0.811$) did not differ across the word AoA conditions; however, length in syllables did differ ($F(2, 105) = 3.61$, $p < 0.05$), with a Tukey's post hoc test indicating marginal differences between syllable length for the Late L1–Early L2 words and the other two categories ($p = 0.056$). Similarly, length in characters differed across the three word AoA conditions ($F(2, 105) = 4.09$, $p < 0.05$), with a Tukey's post hoc test showing differences between the Late L1–Early L2 words and the other two categories ($p < 0.05$).[7]

In addition to the words used in the task, there were also 108 nonword items (36 nouns, 36 verbs, 36 adjectives), constructed from the original stimuli by changing a letter to produce an orthographically legal and pronounceable nonword (e.g. real word *pañal* "diaper," nonword *pañel*).

Materials—translation decision task

The 108 translation pairs used in the translation decision task consisted of a Spanish word and an English word; another list of 108 pairs was nontranslations. (One-third of the words were the same words used in the lexical decision task.) For the translation pairs, only noncognate words were used. As in the lexical decision task, there were three types of translation equivalent pairs: pairs classified as "Early L1–Early L2," pairs classified as "Early L1–Late L2," and pairs classified as "Late L1–Early L2." The pairs were classified based on the AoA of the Spanish word since the AoA of English words was similar in both participant groups. Each condition consisted of 36 words (12 nouns, 12 verbs, and 12 adjectives); one-third of the words within each condition were repeated from the lexical decision task. All words were matched for frequency (in Spanish), and syllable and character length across the three word AoA categories as much as possible. The majority of the nouns were concrete and highly imageable. According to one-way ANOVAs, frequency did not differ across the word AoA conditions ($F(2, 105) = 0.24$, $p = 0.784$). Syllable length differed marginally in Spanish ($F(2, 105) = 3.03$, $p = 0.053$) and significantly in English ($F(2, 105) = 3.87$, $p < 0.05$), with a Tukey's post hoc test indicating that Late L1–Early L2 words were longer than Early L1–Early L2 words ($p < 0.05$). The length in characters did not differ across the word AoA conditions in Spanish ($F(2, 105) = 2.49$, $p = 0.088$), but it did in English ($F(2, 105) = 3.66$, $p < 0.05$). A Tukey's post hoc test showed that the Late L1–Early L2 words were longer than Early

Table 4. Translation decision task (Experiment 2): example word pairs for each word AoA category in Spanish.

	Early L1–Early L2	Early L1–Late L2	Late L1–Early L2
Noun	*lapis*–pencil	*cuna*–crib	*correo*–mail
Verb	*besar*–kiss	*barrer*–sweep	*resumir*–summarize
Adjective	*cansado*–tired	*travieso*–naughty	*soltero*–unmarried

AoA: age of acquisition.

L1–Early L2 words (*p* < 0.05). See Table 4 for an example of translation pairs and Appendix 1 for a list of critical stimuli pairs.

Procedure

The 56 participants met individually with a research assistant and completed first the lexical decision task in Spanish and then the English–Spanish translation decision task, in addition to other oral and written tasks not related to this study. The words, nonwords, translation, and nontranslation pairs were presented in lower case letters in 40-point Courier New font in the center of a computer screen. In the lexical decision task, each trial began with a 1000-ms fixation point that was followed by a word or nonword. The word or nonword remained on the screen until the participant pressed the YES- or NO-designated key on the keyboard to indicate whether the string of letters on the screen was a word or not in Spanish. The screen went blank for 250 ms after the response was made and the fixation point for the next trial appeared. To familiarize the participants with the task, 10 words and 10 nonwords were presented as practice items. In the translation decision task, after the 1000-ms fixation point appeared, the Spanish word was presented for 400 ms and was then replaced with the English word. Participants had to decide as quickly as possible whether the English word was a correct translation of the Spanish word, by pressing a YES- or NO-designated key on the keyboard. Presentation of the items and analyses were done with E-prime (Psychology Software Tools; Pittsburgh, PA). The presentation of the items was randomized for each participant. Both accuracy and RTs were measured.

Results—lexical decision task

Analyses of accuracy and RT data are presented separately. The analyses of accuracy included correct and incorrect responses, while RT analyses only included correct responses. Before conducting the analyses of RT data, responses with times greater than 2000 ms or less than 100 ms were removed from the data set. In addition, responses that were greater or less than 2.5 SDs from each participant's mean were trimmed to the corresponding upper or lower limit. This affected 7.2% of the data. Table 5 lists mean accuracy rates and RTs in milliseconds for each stimuli condition in each participant group (SDs are given in parentheses).

Accuracy. According to Table 5, overall accuracy rates in the two participant groups were similar. Though slight, the heritage speakers showed the predicted accuracy advantage over the L2 learners for Early L1–Late L2 words. Both groups were most accurate with Early L1–Early L2 words (mean accuracy = 98% for both groups). The heritage speakers were equally accurate with Early L1–Late L2 and Late L1–Early L2 words (mean = 95%), but the L2 learners were less accurate

Table 5. Accuracy rates and RTs for each stimuli condition by group in the lexical decision task.

	Heritage speakers (*n* = 28)		L2 learners (*n* = 28)	
	Accuracy	RT	Accuracy	RT
Early L1–Early L2	98 (3)	836 (167)	98 (4)	740 (102)
Early L1–Late L2	95 (4)	876 (153)	91 (9)	783 (117)
Late L1–Early L2	95 (4)	895 (155)	96 (5)	768 (91)

RT: reaction time.

with Early L1–Late L2 words (mean = 91%) than with Late L1–Early L2 words (mean = 96%). Mixed ANOVAs were conducted on the accuracy rates.[8] In the by-participants analysis, group was a between-participants factor with two levels (heritage speakers vs. L2 learners) and word AoA was a within-participants factor with three levels (Early L1–Early L2 vs. Early L1–Late L2 vs. Late L1–Early L2). In the by-items analysis, word AoA was a between-items factor and group was a within-items factor. The analysis yielded a main effect of word AoA (F_1(2, 108) = 21.06, $p < 0.001$, mean squared error (MSE) = 0.002, $\eta_p^2 = 0.281$; F_2(2, 105) = 4.64, $p < 0.05$, MSE = 0.010, $\eta_p^2 = 0.081$). There was no main effect of group (F_1(1, 54) = 0.97, $p = 0.330$, MSE = 0.004, $\eta_p^2 = 0.018$; F_2(1, 105) = 1.82, $p = 0.180$, MSE = 0.003, $\eta_p^2 = 0.017$), but there was an interaction effect between word AoA and group (F_1(2, 108) = 5.68, $p < 0.01$, MSE = 0.002, $\eta_p^2 = 0.095$; F_2(2, 105) = 4.53, $p < 0.05$, MSE = 0.003, $\eta_p^2 = 0.079$), indicating that the two groups were different in terms of accuracy rates depending on word AoA, as predicted. That is, the L2 learners were the least accurate on Early L1–Late L2 words, but the heritage speakers were as accurate with these words as with Late L1–Early L2 words. This interaction is depicted in Figure 1

Repeated measures (by-participants) and one-way (by-items) ANOVAs conducted separately for each participant group with word AoA as a within-participants factor of three levels in the
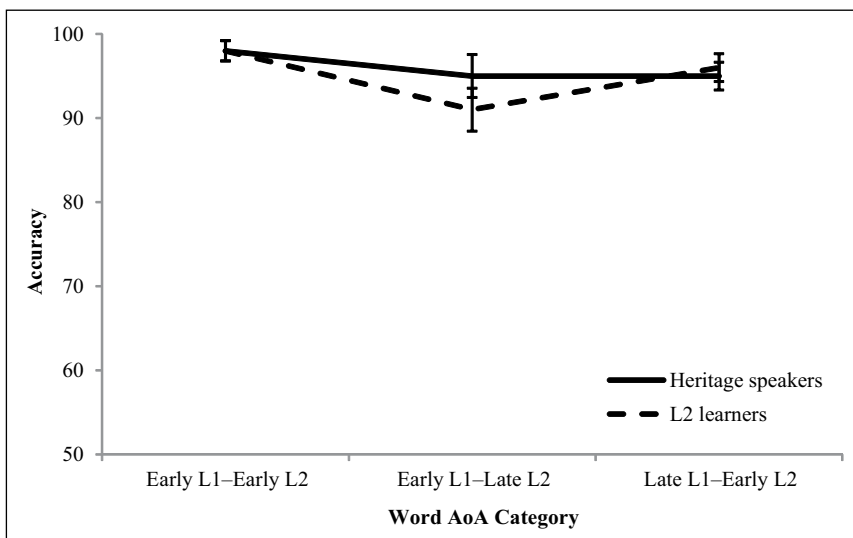

Figure 1. Lexical decision task: accuracy rates by word AoA category and participant group.

by-participants analyses, and a between-items factor of three levels in the by-items analyses yielded a main effect for word AoA for heritage speakers in the by-participants analysis ($F_1(2, 54) = 6.40$, $p < 0.01$, MSE = 0.001, $\eta_p^2 = 0.192$), but not in the by-items analysis ($F_2(2, 105) = 1.92$, $p = 0.152$, MSE = 0.004, $\eta_p^2 = 0.035$). Both by-participants and by-items analyses yielded a main effect for word AoA for the L2 learners ($F_1(2, 54) = 16.34$, $p < 0.001$, MSE = 0.001, $\eta_p^2 = 0.377$; $F_2(2, 105) = 6.03$, $p < 0.01$, MSE = 0.008, $\eta_p^2 = 0.103$). Pairwise comparisons confirmed that the heritage speakers were significantly more accurate with Early L1–Early L2 words than with Early L1–Late L2 ($p < 0.01$) and Late L1–Early L2 words ($p < 0.05$) and that L2 learners were more accurate with Early L1–Early L2 words than with Early L1–Late L2 words ($p < 0.01$) and more accurate with Late L1–Early L2 words than with Early L1–Late L2 words ($p < 0.001$).

To summarize, there were no reliable across-the-board group differences in accuracy, though heritage speakers showed an accuracy advantage over the L2 learners with Early L1–Late L2 words but not with Early L1–Early L2 words or Late L1–Early L2 words. Accuracy varied according to word AoA within groups, with the L2 learners in particular responding least accurately to Early L1–Late L2 words, as predicted. However, in contrast to what we hypothesized, the heritage speakers were less accurate with Early L1–Late L2 words than with Early L1–Early L2 words (in the by-participants analysis only), suggesting some sort of difference beyond the manipulated factors between these two types of words for these participants, in spite of the fact that both categories of words were early acquired in Spanish.

RTs. As shown in Table 5, the L2 learners were faster than the heritage speakers in all three word AoA conditions; the predicted speed advantage for the heritage speakers over the L2 learners did not occur. Within groups, the heritage speakers were fastest to respond to Early L1–Early L2 words (mean RT = 836). They were next fastest to respond to Early L1–Late L2 words (mean RT = 876) and slowest to respond to Late L1–Early L2 words (mean RT = 895), as predicted. The L2 learners were also fastest to respond to Early L1–Early L2 words (mean RT = 740), but patterned differently with the other word AoA categories, responding next fastest to Late L1–Early L2 words (mean RT = 768) and slowest to Early L1–Late L2 words (mean RT = 783), as predicted. A mixed ANOVA was conducted on RTs with group as a between-participants factor with two levels (heritage speakers vs. L2 learners) and with word AoA as a within-participants factor with three levels (Early L1–Early L2 vs. Early L1–Late L2 vs. Late L1–Early L2) in the by-participants analysis; group was a within-items factor and AoA was a between-items factor in the by-items analysis. These analyses yielded a main effect of word AoA ($F_1(2, 108) = 17.47$, $p < 0.001$, MSE = 1968, = 0.244; $F_2(2, 105) = 4.41$, $p < 0.05$, MSE = 12,416, $\eta_p^2 = 0.077$), with pairwise comparisons indicating that the Early L1–Early L2 words were responded to the most quickly. There was also a main effect of group ($F_1(1, 54) = 9.28$, $p < 0.01$, MSE = 50,104, $\eta_p^2 = 0.147$; $F_2(1, 105) = 173.87$, $p < 0.001$, MSE = 2753, $\eta_p^2 = 0.623$), with the L2 learners responding overall more quickly than the heritage speakers. There was no interaction between word AoA and group in the by-participants analysis ($F_1(2, 108) = 2.34$, $p = 0.101$, MSE = 1968, $\eta_p^2 = 0.041$), but there was an interaction between word AoA and group in the by-items analysis ($F_2(2, 105) = 3.38$, $p < 0.05$, MSE = 2753, $\eta_p^2 = 0.060$), suggesting that there were differences between the two groups in how word AoA affected response times. These differences are illustrated in Figure 2

Repeated measures (by-participants) and one-way (by-items) ANOVAs conducted separately for each participant group confirmed these patterns statistically, with a main effect for word AoA for heritage speakers ($F_1(2, 54) = 12.26$, $p < 0.001$, MSE = 2073, $\eta_p^2 = 0.312$; $F_2(2, 105) = 3.90$, $p < 0.05$, MSE = 9371, $\eta_p^2 = 0.069$) and for L2 learners ($F_1(2, 54) = 7.28$, $p < 0.01$, MSE = 1863, $\eta_p^2 = 0.212$; $F_2(2, 105) = 4.75$, $p < 0.05$, MSE = 5798, $\eta_p^2 = 0.083$). According to pairwise
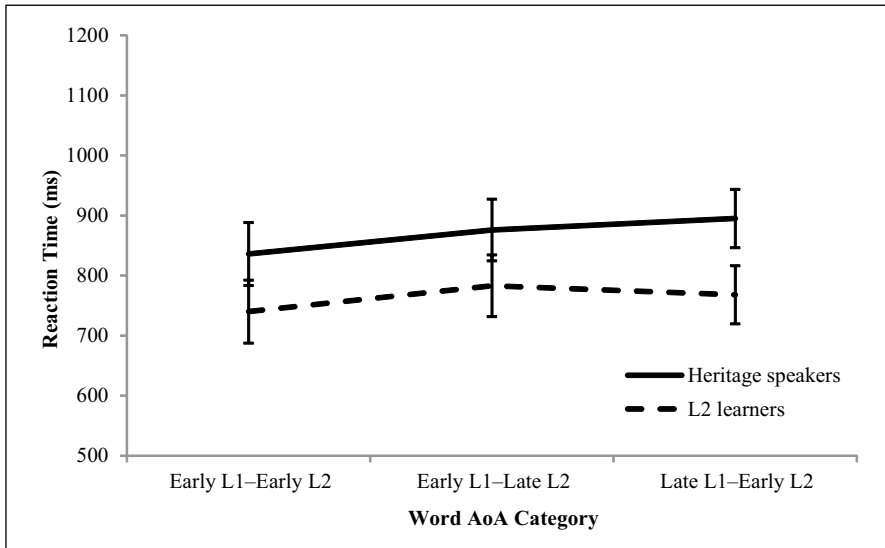
Figure 2. Lexical decision task: RTs in milliseconds by word AoA category and participant group.

comparisons, heritage speakers responded significantly faster to Early L1–Early L2 words than to Early L1–Late L2 words ($p < 0.01$) and to Late L1–Early L2 words ($p < 0.001$). L2 learners were faster with Early L1–Early L2 words than with Early L1–Late L2 words ($p < 0.01$). In summary, although the L2 learners were actually faster than the heritage speakers in all three word AoA conditions, in contrast to the between-group predictions we made, there were effects of word AoA within each group as hypothesized. The heritage speakers showed an advantage for the Early L1–Early L2 words (and a nonsignificant numerical advantage for the Early L1–Late L2 words) over the Late L1–Early L2 words, and the L2 learners demonstrated an advantage for the Early L1–Early L2 words (and a nonsignificant numerical advantage for the Late L1–Early L2 words) over the Early L1–Late L2 words.

To sum up, the heritage speakers showed an accuracy advantage over the L2 learners for the Early L1–Late L2 words but the L2 learners were faster than the heritage speakers in all three word AoA conditions, even when they learned these words in Spanish later in life than the heritage speakers. However, the predicted within-group differences according to word AoA were confirmed statistically. Both groups were fastest and most accurate with Early L1–Early L2 words. The heritage speakers were slowest with Late L1–Early L2 words and the L2 learners were slowest and least accurate with Early L1–Late L2 words. One difference that surfaced in the results that was not predicted was the heritage speakers' difference in accuracy and in RTs between the Early L1–Early L2 words and the Early L1–Late L2 words. Though both of these groups of words were acquired early in these participants' L1 (Spanish), the heritage speakers were not as accurate or as fast in their responses to the Early L1–Late L2 words. We will return to this point in the discussion. First, we turn to the results for the translation decision task.

Results—translation decision task

As with the lexical decision task, analyses of accuracy and RT data are presented separately for the translation decision task. The analyses of accuracy included correct and incorrect responses, while

Table 6. Accuracy rates and RTs for each stimuli condition by group in the translation decision task.

	Heritage speakers ($n = 28$)		L2 learners ($n = 28$)	
	Accuracy	RT	Accuracy	RT
Early L1–Early L2	97 (3)	665 (138)	98 (3)	613 (128)
Early L1–Late L2	94 (4)	726 (138)	90 (7)	679 (128)
Late L1–Early L2	94 (4)	761 (134)	95 (6)	661 (127)

RT: reaction time.

RT analyses only included correct responses. The same methods of data trimming were applied to this task as were applied to the lexical decision task. This affected 9.4% of the data. Table 6 lists mean accuracy rates and RTs in milliseconds (ms) for each stimuli condition in each participant group (SDs are given in parentheses).

Accuracy. As in the lexical decision task, the results of the translation decision task shown in Table 6 shows that accuracy rates were similar in both groups, with the heritage speakers again showing a slight accuracy advantage over the L2 learners for Early L1–Late L2 words. The two groups were most accurate with Early L1–Early L2 words (mean accuracy [M] = 97% for the heritage speakers and 98% for the L2 learners). As in the previous task, the heritage speakers were equally accurate with Early L1–Late L2 and Late L1–Early L2 words ($M = 94\%$) and the L2 learners were less accurate with Early L1–Late L2 words ($M = 90\%$) than with Late L1–Early L2 words ($M = 95\%$). Mixed ANOVAs were again conducted on accuracy rates, with the same design as in the lexical decision task analyses.[9] These ANOVAs yielded a main effect of word AoA ($F_1(2, 108) = 23.42$, $p < 0.001$, MSE $= 0.002$, $\eta_p^2 = 0.302$; $F_2(2, 105) = 5.20$, $p < 0.01$, MSE $= 0.010$, $\eta_p^2 = 0.090$), with participants responding more accurately to Early L1–Early L2 words than to Early L1–Late L2 and Late L1–Early L2 words and more accurately to Late L1–Early L2 words than to Early L1–Late L2 words. There was no main effect of group ($F_1(1, 54) = 0.434$, $p = 0.513$, MSE $= 0.003$, $\eta_p^2 = 0.008$; $F_2(1, 105) = 0.312$, $p = 0.578$, MSE $= 0.006$, $= 0.003$), but there was an interaction between word AoA and group that was only significant in the by-participants analysis ($F_1(2, 108) = 6.03$, $p < 0.01$, MSE $= 0.002$, $\eta_p^2 = 0.100$; $F_2(2, 105) = 2.29$; $p = 0.107$, MSE $= 0.006$, $\eta_p^2 = 0.042$). This interaction suggests that, as in the lexical decision task, the two groups were different in terms of accuracy rates depending on word AoA. The interaction is presented in Figure 3

Repeated measures and one-way ANOVAs conducted separately for each participant group yielded a main effect for word AoA for heritage speakers in the by-participants analysis ($F_1(2, 54) = 7.69$, $p < 0.01$, MSE $= 0.001$, $\eta_p^2 = 0.222$) that did not reach significance in the by-items analysis ($F_2(2, 105) = 2.66$, $p = 0.074$, MSE $= 0.005$, $\eta_p^2 = 0.048$). As in the lexical decision task, both by-participants and by-items analyses yielded a main effect for word AoA for the L2 learners ($F_1(2, 54) = 18.86$, $p < 0.001$, MSE $= 0.002$, $\eta_p^2 = 0.411$; $F_2(2, 105) = 4.75$, $p < 0.05$, MSE $= 0.012$, $\eta_p^2 = 0.083$). Pairwise comparisons showed that the heritage speakers were again significantly more accurate with Early L1–Early L2 words than with Early L1–Late L2 words ($p < 0.05$) and Late L1–Early L2 words ($p < 0.01$) and that L2 learners were more accurate with Early L1–Early L2 words than with Early L1–Late L2 words ($p < 0.001$) and more accurate with Late L1–Early L2 words than with Early L1–Late L2 words ($p < 0.01$). In summary, the accuracy results in the translation decision task reflect the very same patterns that occurred in the lexical decision task.
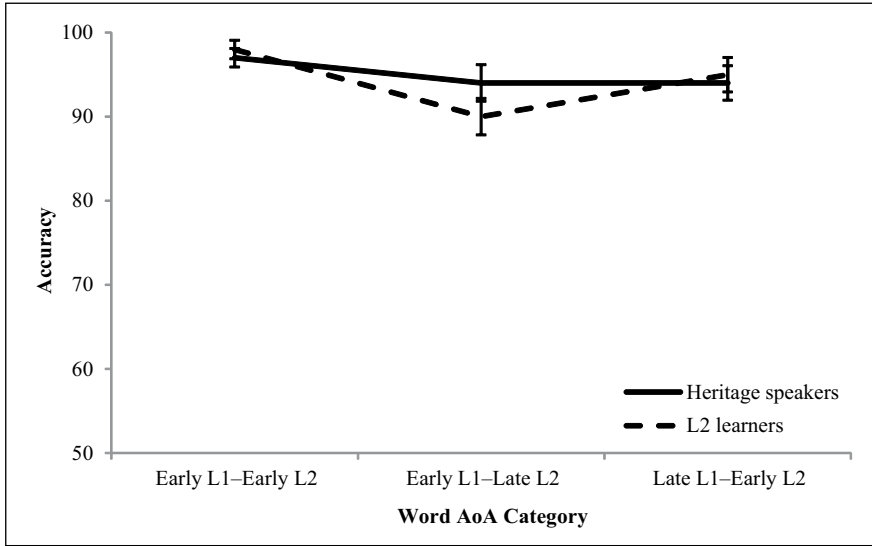
Figure 3. Translation decision task: accuracy rates by word AoA category and participant group.

RTs. As Table 6 indicates, the L2 learners were once again faster than heritage speakers in all three word AoA conditions. Within groups, the patterns were also the same as in the lexical decision task; the heritage speakers were fastest to respond to Early L1–Early L2 words (mean [*M*] RT: = 665), next fastest to respond to Early L1–Late L2 words (*M* = 726), and the slowest to respond to Late L1–Early L2 words (*M* = 761). The L2 learners were fastest to respond to Early L1–Early L2 words (*M* = 613), next fastest to respond to Late L1–Early L2 words (*M* = 661), and slowest to respond to Early L1–Late L2 words (*M* = 679). Mixed ANOVAs conducted on RTs with the same design as in the previous task yielded a main effect of word AoA (F_1(2, 108) = 41.60, *p* < 0.001, MSE = 2099, η_p^2 = 0.435; F_2(2, 105) = 7.43, *p* < 0.01, MSE = 15,768, η_p^2 = 0.124), with pairwise comparisons showing that the Early L1–Early L2 words were responded to more quickly than the Early L1–Late L2 and the Late L1–Early L2 words. There was a main effect of group that approached significance in the by-participants analysis (F_1(1, 54) = 3.88, *p* = 0.054, MSE = 48,273, η_p^2 = 0.067) but reached significance in the by-items analysis (F_2(1, 105) = 48.95, *p* < 0.001, MSE = 4549, η_p^2 = 0.318), confirming that the L2 learners responded more quickly than the heritage speakers. In addition to the main effects, there was an interaction between word AoA and group that reached significance in both the by-participants and the by-items analysis (F_1(2, 108) = 5.87, *p* < 0.01, MSE = 2099, η_p^2 = 0.098; F_2(2, 105) = 4.32, *p* < 0.05, MSE = 4549, η_p^2 = 0.076), again confirming differences between the heritage speakers and the L2 learners in how word AoA affected response times. This interaction is depicted in Figure 4

Repeated measures and one-way ANOVAs conducted separately for each group yielded a main effect of word AoA for the heritage speakers (F_1(2, 54) = 34.27, *p* < 0.001, MSE = 1961, η_p^2 = 0.559; F_2(2, 105) = 9.31, *p* < 0.001, MSE = 9885, = 0.151) and for the L2 learners (F_1(2, 54) = 14.50, *p* < 0.001, MSE = 2237, η_p^2 = 0.349; F_2(2, 105) = 4.30, *p* < 0.05, MSE = 10,432, η_p^2 = 0.076). Pairwise comparisons revealed that heritage speakers were faster with Early L1–Early L2 words than Early L1–Late L2 (*p* < 0.01) and Late L1–Early L2 words (*p* < 0.001) and faster with Early L1–Late L2 words than Late L1–Early L2 words (*p* < 0.01). L2 learners were faster with
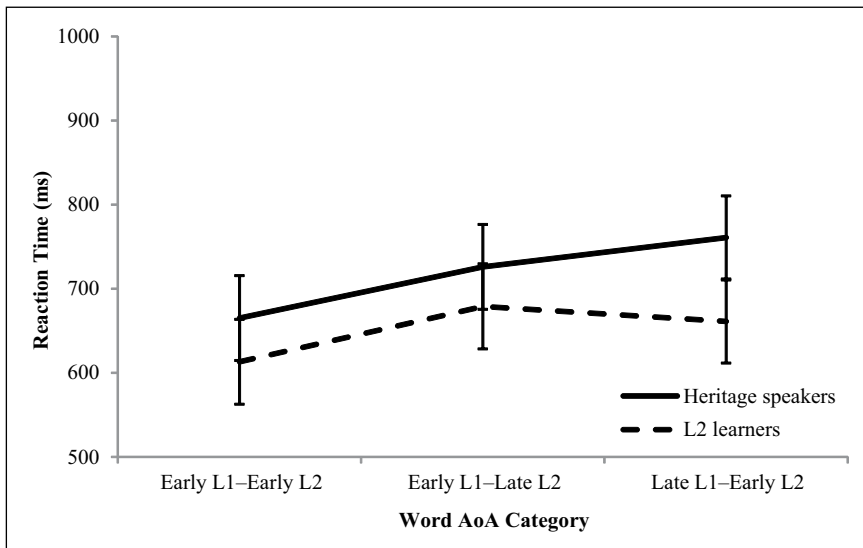
Figure 4. Translation decision task: RTs in milliseconds by word AoA category and participant group.

Early L1–Early L2 words than with Early L1–Late L2 words ($p < 0.001$) and Late L1–Early L2 words ($p < 0.01$). To sum up, as in the lexical decision task, in the translation decision task, L2 learners were faster than heritage speakers overall, contrary to our predictions. However, in accord with our within-group predictions, the heritage speakers showed a speed advantage for the Early L1–Early L2 words and the Early L1–Late L2 words over the Late L1–Early L2 words. The L2 learners showed an advantage for the Early L1–Early L2 words over the Late L1–Early L2 words, but although they were faster with Late L1–Early L2 words than with Early L1–Late L2 words, this difference was not significant.

Discussion

The goal of the present study was to examine how the global AoA of L1 and L2 interacts with the AoA of specific lexical items in L1 and L2. Age of language acquisition has been shown to be a predictor of bilingual outcomes, both in L2 acquisition and in L1 attrition research. Moreover, the age at which individual lexical items are acquired has been found to affect speed of lexical access in both L1 and in L2, independent of frequency. This study combined these two AoA factors to ask whether speed and accuracy of lexical access is affected by the AoA of words in L1 and in L2 in a visual lexical decision task and in a translation decision task for groups varying on overall age of language acquisition, specifically, heritage speakers (early learners of Spanish and English) and late L2 learners of Spanish (whose L1 is English). Hypotheses of differences between these two participant groups based on overall AoA and a speed advantage for heritage speakers over L2 learners were generally not supported by the results. Although the heritage speakers were more accurate than the L2 learners with Early L1–Late L2 words, the L2 learners were faster than the heritage speakers in all word AoA conditions. Unlike the acquisition of aspects of morphosyntax and phonology, for which AoA has been claimed to play a significant role in ultimate attainment (Abrahamsson & Hyltenstam, 2009; DeKeyser, 2000; Hyltenstam & Abrahamsson, 2003; Johnson

& Newport, 1989; Long, 1990; Paradis, 2004, 2009), this study suggests that visual word recognition seems to be spared from similar generalized maturational effects. Lexical access rests almost exclusively on experience rather than on predetermined linguistic knowledge. However, Silverberg and Samuel (2004) found that age of L2 acquisition and proficiency affect the architecture of the bilingual mental lexicon and the specific links between lexical and conceptual representations in the two languages. Although we did not investigate specific issues related to the organization of the bilingual mental lexicon as manifested in tasks involving semantic or orthographic priming, it is still possible to extrapolate how Silverberg and Samuel's (2004) account could apply to our results. The fact that we did not find an AoA advantage for heritage speakers, for whom Spanish is their L1, could suggests that because the L1 of the heritage speakers is now functionally like an L2 analogous to the L2 and nondominant language in late proficient L2 learners, their mental lexicon may be organized like that of late proficient L2 learners and includes a separate conceptual level for L1 and L2 words but a shared lexical level. In short, heritage speakers and late proficient L2 learners would differ from early proficient L2 learners, who have a shared conceptual level for both L1 and L2 concepts, but separate lexical stores for each language, if we follow Silverberg and Samuel's (2004) reasoning. However, this explanation is unlikely because many of the participants in Silverberg and Samuel's early bilingual group seem to be heritage speakers, except that they self-rated their abilities in Spanish and English about the same. So, it is not clear that our results can speak directly to these issues. An interesting extension of this study to what Silverberg and Samuel looked at would be to use the same type of priming task that they did, but with stimuli that varied in word AoA. Our results may predict differences in lexical organization based on word AoA, so that early acquired words may show the "nativelike" early bilingual pattern of both meaning and mediated form priming, while late acquired words may show the form only priming (as in the late, highly proficient learners of Silverberg and Samuel).

Interestingly, word AoA was found to be significant within each group, confirming previous findings in the psycholinguistics literature for L1 and L2 (Carroll & White, 1973a, 1973b; Ellis & Lambon Ralph, 2000; Ellis & Morrison, 1998; Izura & Ellis, 2002, 2004), even when different methods were used to select words according to AoA. Within-group differences according to word AoA category did pattern generally as predicted, with the greater majority of participants in each group responding the fastest and most accurately to Early L1–Early L2 words, but patterning differently with the other groups of words. The majority of the heritage speakers were slowest to respond to Late L1–Early L2 words, while the majority of the L2 learners were slowest and least accurate with Early L1–Late L2 words.

One unexpected result was the difference in the accuracy of heritage speakers' responses to Early L1–Early L2 words and Early L1–Late L2 words. Because the words in these two AoA categories should have been acquired early in Spanish for these speakers, no differences in accuracy or in RT were predicted in principle. However, many heritage speakers were slightly more accurate and faster with Early L1–Early L2 words than with Early L1–Late L2 words.

One possible explanation for the differences in the heritage speakers' accuracy with the Early L1–Late L2 words in comparison to the Early L1–Early L2 words may lie in the fact that these participants were enrolled in Spanish classes along with the late L2 learners at the time of testing. Even though the heritage speakers learned these two groups of words early in Spanish, and therefore should not have performed differently on them in terms of speed or accuracy, it could be the case that since the Early L1–Early L2 words are presented and learned earlier in the L2 Spanish classroom context than the Early L1–Late L2 words, the heritage speakers may have experienced an additional advantage for Early L1–Early L2 words over and beyond the advantage that early acquisition of the Early L1–Late L2 words provided. This advantage could be attributable to a

more recent usage of the Early L1–Early L2 words than the Early L1–Late L2 words, or it may be the case that the Early L1–Early L2 words we included in the tasks (e.g. *pencil, dance, sick*) are simply more frequent in the classroom context than the Early L1–Late L2 words (e.g. *doll, jump, sticky*), and therefore more frequent for the particular participants tested; although the words in the present study were matched for frequency across the three word AoA categories, the frequency count used was based on L1 Spanish texts, not on L2 learner corpora. It is also likely that those early acquired L1 words are infrequently used by the heritage speakers in young adulthood, and because they are not being reinforced by English usage, they have lower levels of activation and are slower to retrieve than Early L1–Early L2 words. Thus, assuming the Mapping Hypothesis, the Early L1–Late L2 words may have lost some of their initial advantage, resulting in a weakened mapping between the conceptual, semantic, and orthographic levels.

On the whole, the results of our experiments suggest that early age of language acquisition does not confer an overall speed advantage in lexical access, though it may confer a slight accuracy advantage for words that are learned later in the course of L2 acquisition, but early in L1 acquisition. However, there were no significant group differences that indicated that having learned Spanish as an adolescent or adult led to slower or less accurate access of L2 words. This supports the idea that there may not be age effects for the acquisition of lexical items, though it must be kept in mind that we only investigated lexical access in an online visual comprehension task. Extending the theoretical model of the bilingual lexical architecture and research methodology (semantic priming) employed by Silverberg and Samuel (2004) with early and late L2 learners to heritage speakers and late L2 learners matched for proficiency would be an ideal way to pursue this issue further and understand how the lexical architecture may change with shifts in language dominance in heritage speakers.

The most significant finding of our study is the interaction between global AoA and word AoA that we were able to detect by focusing on bilingual participants matched for proficiency but who differed on whether their weaker language was an L1 (heritage speakers) or an L2 (late second language learners). According to our results, it appears that early learned words in L1 and in L2 are accessed more quickly and generally more accurately than are late learned words, regardless of overall AoA in the L1 or the L2. In accordance with Ellis and Lambon Ralph's (2000) assertion that the advantage for early learned words does not disappear unless those words fall into complete disuse, the heritage speakers of the present study were generally faster and slightly more accurate in their responses to words that they had acquired early in life in their L1 (Spanish), even though they were dominant in English (the L2) at the time of testing. This suggests that in spite of the fact that lexical access tends to be heavily affected under conditions of reduced input and use, if there is at least some use of early acquired words, knowledge of those words is preserved even when the language to which they belong is no longer the dominant one. The L2 learners of the present study also showed a consistent speed and accuracy advantage for early acquired L2 words in comparison to late acquired L2 words, similar to the L2 learners of Izura and Ellis (2004). This advantage held for both the lexical decision task and for the translation decision task, with learners responding more quickly and more accurately to early learned L2 words than to later learned L2 words. The fact that they were slowest at responding to words acquired early in the L1 but late in the L2 suggests that L1 and L2 words do not share the same conceptual links for this group, as the semantic hypothesis would predict. Thus, the combined results of the L2 learners and the heritage speakers are consistent with the Mapping Hypothesis, which states that it is the semantic, lexical, and phonological representations established early, gradually, and cumulatively that explain observed AoA effects of words in both L1 and L2 acquisition, especially when the mappings between concepts and words are arbitrary as in word learning in an L2.

In conclusion, according to our results, the age at which individual lexical items are acquired in the L1 or the L2 when these are the nondominant language of bilinguals matters for speed and accuracy of lexical access. The effect of AoA of words in heritage speakers and L2 learners suggests that their knowledge of words is profoundly shaped by their experience with the language and the context of acquisition. As stated earlier, unlike the acquisition of syntax, morphology, and phonology, which appear to have a maturational schedule and are less dependent on context (Abrahamsson & Hyltenstam, 2009), words are acquired through experience in specific situations and may be spared of critical period effects, at least in terms of their visual recognition.

Learning words for concepts relies on declarative memory—also called episodic memory, experiential memory (Penfield & Roberts, 1959), or semantic memory (Paradis, 2004)—and not so much on procedural memory. Procedural memory (Cohen, 1984) relates to internalized procedures that contribute to automatic performance and implicit knowledge of language (Paradis, 2004). Many researchers contend that grammatical linguistic rules (syntax, morphology, morphology) are handled by procedural memory (Pinker, 2000; Ullman, 2001). Paradis (2009) and DeKeyser (2000) independently argue that the critical period hypothesis applies to implicit knowledge handled by procedural memory. Although declarative memory and executive function decline with age in adulthood (Paradis, 2009), they are not subject to critical period effects like procedural memory. This distinction would explain why it is possible to find across the board age effects in phonology, syntax, and morphology as opposed to semantics and word learning.

There is another possible explanation related to experience for why the heritage speakers were slower in general than the L2 learners, even though Spanish is their L1 (the L2 learners were faster than the heritage speakers in all conditions in the two tasks). While heritage speakers have the advantage of having learned Spanish at a much younger age than L2 learners, they primarily learn the language via aural input. Of the four skills (listening, speaking, reading, and writing), reading and writing are their weakest in their heritage language. Generally, they have less experience with written Spanish until taking formal Spanish courses in high school or college. By comparison, late L2 learners are hyperliterate in Spanish and learn words in the L2 via both written and aural input from the beginning, but with a much heavier emphasis on the written modality due to the classroom context. This may mean that their visual word recognition skills can equal or even exceed those of heritage speakers, who have less experience with visual word recognition in their native language (though the heritage speakers of the present study were enrolled in Spanish courses, they typically had had less time in formal courses than the L2 learners).[10] Our findings are thus not surprising in light of several recent studies comparing the linguistic abilities of L2 learners and heritage speakers on a variety of oral, written, off-line, and online tasks (Alarcón, 2011; Bowles, 2011; Montrul et al., 2008; Potowski, Jegerski, & Morgan-Short, 2009). All these studies suggest important task effects by visual and oral modality and the explicitness of the tasks. It could be the case that our results would have differed had we tested participants with an aural lexical decision task or if the task had required word production rather than comprehension. Hulsen's (2000) results, which show a disparity in performance between comprehension and production tasks in the case of incomplete L1 acquisition, suggest that age may in fact affect comprehension and production to different degrees; further research with L2 learners will confirm whether this is also the case in the L2 acquisition of lexical items. Overall age of language acquisition may make a difference in speed and accuracy of lexical access, depending on modality or whether comprehension or production is involved. Since AoA of words has also been found in word naming and picture naming, we expect that the interaction between global AoA and AoA of words detected in the present study with L2 learners and heritage speakers will hold in those tasks modalities as well.

In conclusion, we have shown that AoA of words interacts with global AoA in unbalanced bilinguals. Heritage speakers and L2 learners may have different vocabularies in their weaker language

and access some words differently due to their different language-learning experiences, which encompasses AoA, context of acquisition, and modality of acquisition, among others.

Notes

1. For more specific and detailed discussion about the differences between incomplete acquisition and attrition in childhood and adulthood, see Montrul (2008).
2. Attrition implies that something was acquired and subsequently lost. Incomplete acquisition means that something did not reach full development. Montrul (2008) explains that in heritage speakers, who experience incomplete acquisition and attrition in childhood depending on the input and particular grammatical properties investigated, the two processes are not necessarily mutually exclusive.
3. Self-ratings for Spanish ability ranged from 3 to 5 over a maximum of 5 for the two groups, but the mean for heritage speakers was 4.44 and the mean for the L2 learners was 3.89.
4. In a small-scale study with five native speakers and five heritage speakers, Polinsky (2005) found that Russian heritage speakers have selective control of lexical classes, retaining verbs more than nouns and adjectives in their incompletely acquired Russian. Because we also wanted to corroborate this hypothesis, we included an equal number of words per lexical class. However, we failed to replicate Polinsky's results and we did not find an advantage of verbs over nouns across the board, at least for the Spanish heritage speakers.
5. The MacArthur–Bates Communicative Development Inventory is a tool intended to assess language development in children from 8 to 30 months of age extensively used for clinical applications and research purposes. It includes lists of words that are part of a normally developing child's comprehensive and/or productive vocabularies, based on parental report. The inventory was normed with approximately 1800 English-speaking children (the English version) and 2000 Mexican Spanish-speaking children (the Spanish version). See the English *(Fenson, Dale, Reznick, Thal, Bates, Hartung, Pethick, & Reilly, 1992) and the Mexican Spanish (Jackson-Maldonado, Thal, Fenson, Marchman, Newton, & Conboy, 2003)* user's guide and technical manuals for more information.
6. A reviewer found problematic that we did not include the fourth category Late L1–Late L2 and requested that we perform an analysis of the nonword data to make up for this gap in our design. The analysis of the nonword data showed the same overall pattern of the word data in the two tasks, namely that the L2 learners were overall faster than the heritage speakers in their RTs.
7. Late L1–Early L2 words were marginally statistically longer in syllable and character length than the other two sets of words, but this difference should not have affected the overall pattern of between-group results, because length would affect the two participant groups equally. In terms of within-group results, as Table 5 shows, the L2 learners were faster and more accurate with Late L1–Early L2 words than with Early L1–Late L2 words, as we predicted based on word AoA; if length played a significant role, then they should have been slower and/or less accurate with the Late L1–Early L2 words than with any other word group, but this was not the case.
8. Because accuracy rates are binary data, we also analyzed accuracy via a model-comparison approach, using mixed logit models that allow for participants and items as crossed random effects. Based on the

best-fitting model, neither group ($p = 0.432$) nor word AoA ($p = 0.113$) reached significance, nor did the interaction between the two ($p = 0.423$). The results of this analysis suggest that, since accuracy is almost at ceiling, standard statistical analyses should be interpreted with caution.

9. We also analyzed accuracy data for this task using a model-comparison approach with mixed logit models. Based on the best-fitting model, group did not reach significance ($p = 0.435$), but word AoA did ($p < 0.05$), as did the interaction between the two ($p < 0.05$).

10. Had we tested late L2 learners who learned Spanish in a naturalistic rather than a classroom context, the finding that these learners were faster than the heritage speakers may not have surfaced. This would provide further support for the idea that the speed advantage experienced by the late learners of the present study was due to context of acquisition and type of L2 input received (heavily visual in a classroom context vs. mainly aural in a naturalistic setting), rather than the factor of age of language acquisition.

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Appendix 1

	Lexical decision task	
	Experimental item	English translation
	Spanish word	English word
Early L1–Early L2	*lápiz*	pencil
	jabón	soap
	vaca	cow
	queso	cheese
	helado	ice cream
	pelota	ball
	oreja	ear
	abrigo	coat
	avión	airplane
	leche	milk
	espejo	mirror
	pelo	hair
	besar	kiss
	lavar	clean
	almorzar	eat lunch
	quitar	take out

Appendix 1 (Continued)

	Lexical decision task	
	Experimental item	English translation
	Spanish word	English word
	gritar	shout
	bailar	dance
	ayudar	help
	tocar	touch
	abrir	open
	correr	run
	buscar	look for
	poner	put
	ruidoso	noisy
	despierto	awake
	pesado	heavy
	sucio	dirty
	feo	ugly
	bonito	pretty
	cansado	tired
	rubio	blond
	enfermo	sick
	malo	bad
	verde	green
	grande	big
Early L1–Late L2	pañal	diaper
	galleta	cookie
	panza	belly
	ombligo	navel
	globo	balloon
	cuna	crib
	muñeca	doll
	pierna	leg
	dedo	finger
	luna	moon
	brazo	arm
	fuego	fire
	peinar	comb
	barrer	sweep
	agarrar	crab
	apagar	turn off
	saludar	greet
	arreglar	fix
	saltar	jump
	parar	stop
	acabar	finish
	oír	hear

(Continued)

Appendix 1 (Continued)

	Lexical decision task	
	Experimental item	English translation
	Spanish word	English word
	perder	lose
	caer	fall
	pegajoso	sticky
	travieso	naughty
	chulo	cute
	lindo	pretty
	flaco	skinny
	eeco	dry
	lento	slow
	roto	broken
	oscuro	dark
	lleno	full
	vacío	empty
	fuerte	strong
Late L1–Early L2	*gemelo*	twin
	correo	mail
	cuñado	brother-in-law
	piscina	pool
	cuaderno	notebook
	corbata	tie
	ascensor	elevator
	basura	trash
	invierno	winter
	tarea	homework
	jefe	boss
	empresa	company
	resumir	summarize
	pescar	fish
	ahorrar	save
	rezar	pray
	asistir	attend
	preguntar	question
	crecer	grow
	fumar	smoke
	matar	kill
	empezar	begin
	pagar	pay
	seguir	follow
	junto	together
	soltero	single
	calvo	bald
	gracioso	funny

Appendix 1 (Continued)

	Lexical decision task	
	Experimental item	English translation
	Spanish word	English word
	barato	cheap
	caro	expensive
	casado	married
	temprano	early
	cerrado	closed
	loco	crazy
	abierto	open
	libre	free
	Translation decision task	
	Spanish word	English word
Early L1–Early L2	*tenedor*	fork
	jabón	soap
	manzana	apple
	queso	cheese
	pollo	chicken
	pelota	ball
	pájaro	bird
	abrigo	coat
	camisa	shirt
	leche	milk
	vestido	dress
	pelo	hair
	cocinar	cook
	lavar	wash
	nadar	swim
	quitar	take out
	enseñar	teach
	bailar	dance
	cantar	sing
	tocar	touch
	escuchar	listen
	correr	run
	jugar	play
	poner	put
	enojado	mad
	despierto	awake
	guapo	handsome
	sucio	dirty
	tonto	stupid
	bonito	pretty
	gordo	fat

(Continued)

Appendix 1 (Continued)

	Lexical decision task	
	Experimental item	English translation
	Spanish word	English word
	rubio	blond
	caliente	hot
	malo	bad
	triste	sad
	grande	big
Early L1–Late L2	*chupón*	pacifier
	galleta	cookie
	payaso	clown
	ombligo	navel
	rodilla	knee
	cuna	crib
	zapato	shoe
	pierna	leg
	hombro	shoulder
	luna	moon
	piedra	stone
	fuego	fire
	patear	kick
	barrer	sweep
	asustar	scare
	apagar	turn off
	quemar	burn
	arreglar	fix
	cargar	load
	parar	stop
	llorar	cry
	oír	hear
	sacar	take out
	caer	fall
	chaparro	short
	travieso	naughty
	morado	purple
	seco	dry
	limpio	clean
	roto	broken
	suave	soft
	lleno	full
	duro	hard
	fuerte	strong
Late L1–Early L2	*suegro*	father-in-law
	correo	mail
	sobrino	nephew
	piscina	pool

Appendix 1 (Continued)

	Lexical decision task	
	Experimental item	English translation
	Spanish word	English word
	chiste	joke
	corbata	tie
	maleta	suitcase
	basura	trash
	moda	fashion
	tarea	homework
	calor	heat
	empresa	company
	afeitar	shave
	pescar	fish
	faltar	lack
	rezar	pray
	exigir	demand
	preguntar	ask
	viajar	travel
	fumar	smoke
	parecer	seem
	empezar	start
	llamar	call
	seguir	follow
	perezoso	lazy
	soltero	single
	egoísta	selfish
	gracioso	funny
	orgulloso	proud
	caro	expensive
	sabio	wise
	temprano	early
	hermoso	beautiful
	loco	crazy
	extraño	strange
	libre	free

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