

Associative networks from L2 words in early and late Vietnamese-English bilinguals

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This study investigates whether highly-proficient Vietnamese-English bilinguals can activate associations in a native-like way from studying L2 words, whether these L2 associations interact with L1 words, and whether this depends on when they started learning L2 English. The results suggest that early bilinguals have native-like L2 English associative networks and these networks are interconnected with L1 Vietnamese words. Late bilinguals, in contrast, seem to indicate that their L2 English associative networks might be activated less automatically, and they are not so strongly connected with L1 words. This pattern of results are discussed in terms of how age of L2 exposure might affect the development of L2 associative networks.

Keywords: masked priming, DRM lists, speeded old-new task, early and late bilinguals

Many bilingual models, thus far, have proposed mechanisms as to how meanings of L2 words are activated, as well as how there might be differences in the qualities of these meanings. Such notable models that discuss semantic activation of L2 words include the Revised Hierarchical Model (henceforth, the RHM, Kroll & Stewart, 1994), the Distributed Feature Model (the DFM, de Groot, 1992), and the Sense Model (Finkbeiner, Forster, Nicol, & Nakamura, 2004; Wang & Forster, 2010). These models assume that the semantic system is shared between the two languages. This is mainly because many of these models are based on studies that examine whether L1 translations are activated when processing L2 words. However, there have been some suggestions that words in a bilingual's two languages that are translations of one another might not fully map onto the same lexical concept (Altarriba & Basnight-Brown, 2009; Francis, 2005; Paradis, 1997). Another semantic component that might also diverge between the two languages of a bilingual is lexical associations. Associations are assumed to develop through

co-occurrence of words (Fodor, 1983; McNamara, 1992; Thompson-Schill, Kurtz, & Gabrieli, 1998). For instance, one word that is associated with *ham* is *egg*. However, this association is only true in languages that have ham and eggs together for breakfast. If such is the case, then we suspect that L2 and L1 words would have different associative networks. Thus, an important question in bilingual lexical processing literature is whether bilinguals develop associations in their L2 in a native-like manner, and whether these associations are interconnected with L1 words. This study specifically examines the associative networks of L2 words in highly-proficient Vietnamese-English bilinguals. In particular, this study tests whether these bilinguals can form native-like associations in their L2, whether these L2 associations interact with L1 words, and whether this depends on at what age these bilinguals started learning their L2 English.

As mentioned, many bilingual processing models have discussed how semantic activation of L2 words takes place. Griffiths, Steyvers, and Tennenbaum (2007) posit that there can be several types of semantic knowledge – *word-concept* relations, in which the word *dog* refers to the concept “dog”; *concept-concept* relations, which refers to knowledge that dogs are animals that have tails and bark; *concept-percept* or *concept-action* relations, which is knowledge about dogs in terms of how they look, how they are different from other animals, and how to treat them; and finally, *word-word* relations, which is knowledge of words that are associated with or co-occur with *dog*. In psycholinguistic literature, traditionally, there have been two lines of research on semantic activation – one on the relations among concepts (or pure semantic relations) that cover word-concept, concept-concept, and concept-percept/concept-action relations, and the other on associative relations that entail word-word relations (Griffiths et al., 2007; Hutchison, 2003; Lucas, 2000; Neely, 1991; Perea & Rosa, 2002; Williams, 1996). Although the literature is mixed in terms of whether automatic priming can be obtained for semantic relations without association (Lucas, 2000; Thompson-Schill et al., 1998), and/or for associations without semantic overlap (McNamara, 1992; Moss, Ostrin, Tyler, & Marslen-Wilson, 1995; Williams, 1996), as Hutchison (2003) demonstrates in his review paper, both relation types seem to be crucial for meaning (see also, Neely, 1991; Perea & Gotor, 1997; Perea & Rosa, 2002; Williams, 1996). Bilingual processing models that deal with semantic activation of L2 words are, however, predominantly based on evidence of translations activating one another (translation production task, e.g., Kroll & Stewart, 1994; translation recognition task, e.g., Ferré, Sánchez-Casas, & Guasch, 2006; Sunderman & Kroll, 2006; Talamas, Kroll, & Dufour, 1999; translation priming, e.g., de Groot & Nas, 1991; Dimitropoulou, Duñabeitia, & Carreiras, 2011; Gollan, Forster, & Frost, 1997; Jiang, 1999; Kim & Davis, 2003). The DFM and the Sense Model consider translations to be connected through pure semantic relations (for the DFM, de Groot, 1992; van Hell &

de Groot, 1998; 2008; for the Sense Model, Finkbeiner et al., 2004; Wang & Forster, 2010). In contrast, the RHM posits that at least for the L2 to L1 translation direction, the translations are connected through lexical associative links. Thus, using translations as the main source of understanding bilinguals' semantic system does not provide a full picture of how this system works. Examining whether L2 words have associations to other L2 words and to L1 words makes it possible to determine which semantic components are shared and which are separate in bilingual semantic organization. This will also inform us as to whether this semantic system works in terms of spreading activation (e.g., Collins & Loftus, 1975; Neely, 1991) and/or in terms of distributed features, in which meaning is represented as a collection of interconnected features (Masson, 1995; Moss, Hare, Day, & Tyler, 1994; for further discussion on the differences between spreading activation and distributed features, see Hutchison, 2003; Lucas, 2000). In order to better understand the quality of the semantic system of L2 words, it is therefore necessary to examine whether L2 words are associated to each other, as well as how they are associated to L1 words.

Although associations have not made much of an impact on bilingual lexical processing models, there have been quite a few studies that have tested associations of words in bilinguals. One line of this research has employed the priming procedure. The purpose of these tasks is to examine whether responses to targets are faster if they are preceded by an associative prime. The current literature is inconclusive as to whether associative priming can be obtained within-L2 and cross-language conditions. When the stimulus-onset-asynchrony (henceforth, SOA) was long between the prime and the target (250 ms to 2000 ms), bilinguals showed significant associative priming for both within- (de Groot & Nas, 1991; Kotz & Elston-Güttler, 2004) and cross-language conditions (for both L1-L2 and L2-L1 direction, de Groot & Nas, 1991; Schoonbaert, Duyck, Brysbaert, & Hartsuiker, 2009; for L2-L1 direction, Grainger & Beauvillian, 1988; for L1-L2 but not L2-L1 direction, Keatley, Spinks, & van Gelder, 1994). At shorter SOAs, the findings are more mixed. Perea, Duñabeitia, and Carreiras (2008) showed that masked associative priming can be obtained both within- and cross-language conditions in simultaneous and in highly-proficient bilinguals. De Groot and Nas (1991) were able to observe masked associative priming in within-language condition, but not in cross-language condition. Basnight-Brown and Altarriba (2007) found associative priming only in the L2-L1 direction when the prime was not masked (see also, Frenck-Mestre & Prince, 1997; Schoonbaert et al., 2009), but did not find any cross-language associative priming when the 100-ms prime was preceded by a forward mask. Grainger and Beauvillian (1988) also failed to obtain cross-language associative priming even when the SOA was at 150-ms.

Another way to test associations in bilinguals is to employ false memory tasks. These tasks use the Deese-Roediger-McDermott (DRM) lists, which include sets of words that are all associated with one another (e.g., *bed, rest, awake*) by a non-present topic word – the critical lure (*sleep*) (Roediger & McDermott, 1995). The assumption behind the DRM lists is that upon being presented with the list of words, these words will activate associative networks, and this activation will in turn activate the critical lure. Thus, in many of the recognition and recall tasks, participants will falsely recognize or even recall the critical lure as being on the list (see e.g., Roediger & McDermott, 1995). Studies using this DRM lists with bilingual participants have generally revealed that the number of false recalls/recognition are higher in the more dominant language than in the less-dominant language (Anastasi, Rhodes, Marquez, & Velino, 2005; Howe, Gagnon, & Thouas, 2008; Kawasaki-Miyaji, Inoue, & Yama, 2003; Marmolejo, Diliberto-Macaluso, & Altarriba, 2009; Sunderman, 2011), suggesting that L1 words have richer associations than L2 words. Furthermore, false recalls/recognition were observed in both within-language condition (in which the test language is the same as the study language) and cross-language condition (in which the test language is different from the study language) (Cabeza & Lennartson, 2005; Howe et al., 2008; Kawasaki-Miyaji et al., 2003; Marmolejo et al., 2009; Sahlin, Harding, & Seamon, 2005). It is difficult to interpret what these studies show in light of how L1 and L2 words are associated with one another, given that these studies had different designs – i.e., some studies had bilingual participants study in one language and test in another (Howe et al., 2008; Marmolejo et al., 2009), while others had these participants study a mixed-language list and test in a mixed-language condition (Cabeza & Lennartson, 2005; Kawasaki-Miyaji et al., 2003; Sahlin et al., 2005). All in all, however, the collection of these studies suggest that L2 words seem to have associations with other L2 words and to L1 words, and that this false memory task is a reliable way to test associations of words in a bilingual.

Both of these methods have their advantages and disadvantages. The masked priming technique, in particular, is well known for eliminating any type of strategic effects because the masked prime cannot be consciously perceived (Forster, 1998; Forster & Davis, 1984; Forster, Mohan, & Hector, 2003; for strategic effects using priming procedure, see Neely, 1991). This has been supported by neuroimaging evidence demonstrating that there was reduced activation in the pre-frontal and parietal areas, suggesting that the primes were processed below consciousness (Dehaene et al., 2001). However, although masked priming is tested in various conditions, such as repetition, form, morphological, and translation (Forster et al., 2003), it is known to be notoriously difficult to observe masked semantic/associative priming even in native speakers (de Wit & Kinoshita, 2015;

Gomez, Perea, & Ratcliff, 2013). Even when there is an effect, this effect is usually small (Perea & Gotor, 1997; Perea & Rosa, 2002; but see Sereno, 1991).

The false memory task is particularly ideal to test whether associative networks in L2 users mirror that of native speaker counterparts. This is because these DRM lists were normed in English, and thus, are culturally biased. As Sahlin et al. (2005) note, one of the words associated with the critical lure *needle* is *haystack*. In order to associate *haystack* back to *needle*, it is necessary to have the knowledge of the English idiom, “a needle in a haystack” (see also Graves & Altarriba, 2014; Lee, Chiang, & Hung, 2008). In other words, it is not sufficient to process *haystack* semantically in order to activate *needle*, it requires the knowledge of this specific idiom to form this association. Other culturally-based associations may include *mouse* for the critical lure *man*. This specifically requires the knowledge of an American fiction, *Of Mice and Men*. As mentioned, associations are considered to develop through language use rather than word meaning (Thompson-Schill et al., 1998). One concern with this task, however, is that even if the bilingual participants activated the critical lure, the common recognition or recall tasks may not allow us to test this activation because bilingual speakers might be aware that the critical lure was not on the list. Indeed, several studies have found that bilinguals were more accurate in memorizing the exact words on the study list in their L2 than in their L1 (Francis & Gutiérrez, 2012; Francis & Strobach, 2013).

Given this, the current study exploited the false memory paradigm with the masked priming procedure. Specifically, our bilingual participants studied DRM lists in their L2 to see whether their L2 associations are developed like native speakers such that the critical lure is activated in the process. After study, participants later performed speeded old-new tasks with the masked priming paradigm in which the words from the lists were the targets and the critical lure was the masked prime. If bilingual speakers have developed associations in their L2, then the critical lure should be activated from studying the false memory lists in their L2, and thus, the critical lure should prime the words on the list when participants are making speeded old-new decisions (“*Did you just study this word?*”) using the masked priming paradigm. If, on the other hand, L2 words have not developed associations, then the critical lure would not prime the words on the list. We believe that this new method would allow us to test whether L2 words can activate associations automatically, by giving participants a chance to pre-activate them through studying the DRM lists, and relying on response times rather than the accuracy of bilingual speakers’ memory.

In addition to our key question as to whether highly-proficient bilinguals have associations from L2 words, this study also tests whether the development of associations of L2 words is affected by the age at which a bilingual began acquiring the L2. Many studies have shown that the age of acquisition (AoA) is an influ-

ential factor in L2 performance (see e.g., Birdsong & Molis, 2001; Flege, Yeni-Komshian, & Liu, 1999; Johnson & Newport, 1989; Sabourin, Brien, & Burkholder, 2014). There are several reasons as to why it is of particular interest for our study to test how AoA might affect the quality of associative networks of L2 words. First, the RHM assumes that at early stages of acquiring an L2, L2 words are first translated into L1 in order to access the meaning, hence the lexical associations. Given this, we suspect that L2 words in late bilinguals may have stronger associations to L1 words than to L2 words. This is because, even though both our early and late bilinguals may be highly-proficient in their L2 at the time of this study, late bilinguals have originally established the meanings of L2 words through L1 translations. Early bilinguals, on the other hand, may have acquired their L2 more like a native language, and thus their L2 words might have more associations with other L2 words than with L1 words. Indeed, in masked translation priming literature, Sabourin et al. (2014) have demonstrated that only simultaneous and early bilinguals (those who were exposed to their L2 before the age of 5) show masked translation priming in the L2-L1 direction, and not late bilinguals or language learners (those who were exposed to their L2 after the age of 9). This study suggests that semantic activation of words may be dependent on AoA. It would be interesting to know if this affects automatic activation of L2 associations as well.

There is another reason to suspect that AoA might play a role in the quality of associations from L2 words. In memory literature, there have been studies comparing false recalls/recognition of critical lures between children and adults. Interestingly, these studies have shown that adults are more likely to falsely recall/recognize critical lures than children (in their L1) (see e.g., Howe, 2011; Howe et al., 2008). This has been taken to indicate that children have not fully developed their associative networks such that these networks are activated automatically, while adults have. Therefore, these adults are able to automatically activate them when presented with a list of semantically-associated words (Howe, 2007, 2011; Howe et al., 2008). Given this, we predict that early bilinguals would have richer associative networks in their L2 given that they have generally more experience in L2 than late bilinguals, and thus might show stronger associative priming. Moreover, Howe et al. (2008) report an interesting contrast between bilingual children and adults. They found that the youngest group of bilingual children seemed to associate words in the two languages more separately, since this group had more false recalls in the within-language condition than in the cross-language condition. In contrast, adult bilinguals seemed to have more uniform associative networks entailing both L1 and L2, since they had more false recalls in cross-language condition than within-language condition. Because of their limited development of L2 associative networks, late bilinguals may activate associative networks of L2 words independently of L1, such that L1 primes would not show priming in

these bilinguals. Early bilinguals, however, may have developed their associative networks in L2 such that these networks may include more L1 words, and/or may have interconnected with their L1 associative networks. (For more on this, see Graves & Altarriba, 2014.) Following Sabourin et al. (2014), this study defines early bilinguals as those who were exposed to L2 English before the age of 5, and late bilinguals as those who were exposed to L2 English after the age of 9.

In order to further examine the quality of associative networks of L2 words, two experiments were conducted. In both experiments, participants took part in an episodic recognition task. In this task, participants studied four DRM lists in English. They later then took a speeded old-new task, in which the words on the DRM lists were presented as targets, and the critical lure was presented as the masked prime. Experiment 1 examined whether early and late Vietnamese-English bilinguals can form native-like associations in their L2. Thus, in Experiment 1, the critical lures which were presented as masked primes were all in L2 English. Experiment 2 investigated whether these early and late bilinguals have formed associations from their L2 English to their L1 Vietnamese. As such, in Experiment 2, the critical lures were presented in L1 Vietnamese. In both experiments, we anticipated that if these bilinguals have formed associations within- and cross-languages, there would be associative priming for studied old words. In contrast, since the unstudied new words were not activated during study, we expected to find no priming for these words.

Experiment 1 – L2 primes

Experiment 1a

Methods

Participants

A total of 94 participants participated in Experiment 1a. The first group consisted of 39 native speakers of English, who were undergraduate students from the University of Texas at Arlington (UTA) and participated for course credit. The second group involved a total of 27 highly-proficient early Vietnamese-English bilinguals, while the third group had a total of 28 highly-proficient late Vietnamese-English bilinguals. These Vietnamese-English bilinguals were all Vietnamese-Americans living in the Dallas-Fort Worth area in Texas. They were recruited at a Vietnamese-speaking Catholic church. The two bilingual groups participated voluntarily. The language background of the bilingual participants for all experiments are presented in Table 1. This information was collected through a language back-

ground questionnaire, which all participants filled out prior to the experiment. (Note that the numbers that are reported on this table are based on participants that were ultimately included in the analyses.) The participants were considered as early bilinguals if they were exposed to L2 English (or AoA) at or before the age of 5, and as late bilinguals if they were first exposed to L2 English at the age of 9 or older. Early Vietnamese-English bilingual participants had begun acquiring English on average at 3.92 years, with the earliest since birth and the latest at age 5. These participants were either born in the U.S. or have lived in this country (that is, length of residence, or LoR) on average of 31.67 years, with the shortest amount of time in the U.S. being 24 and the longest being 40 years. Late Vietnamese-English bilingual participants, on the other hand, had begun acquiring English on average at 12.83 years, with the earliest at age 10 and the latest at age 20. These participants all had been living in the U.S. for an average of 24.46 years, with the shortest amount of time being 7 years and the longest being 40 years. In order to consider these bilinguals as highly-proficient in their L2 English, we made sure that all bilingual participants held high school diplomas from the U.S., and/or had at least some college experience from U.S. schools.

In addition to AoA, LoR, and education information, bilingual participants were asked to rate themselves on their L2 English and L1 Vietnamese proficiency on a 10-point scale, with 1 being the lowest and 10 being the highest. In order to determine whether there was a difference in English proficiency, a 3x3 ANOVA was conducted looking at the effect of speaker group and language skills on mean self-rated English proficiency. The results showed that there was a significant main effect of speaker group, $F(2, 77) = 7.07$, $p < .01$. Subsequent pairwise comparisons indicated that native speakers (mean overall self-rating 9.67) and early bilinguals (mean overall self-rating 9.65) rated themselves on English proficiency similarly, $F < 1$. However, the mean self-ratings were different between native English speakers and late bilinguals (mean overall self-rating 8.93), $F(1, 54) = 10.03$, $p < .01$, and crucially, different between early and late bilinguals as well, $F(1, 46) = 9.50$, $p < .01$. Although we attempted to find late bilinguals who were just as proficient as early bilinguals by making sure that they had at least received high school diplomas from the U.S., it seems that this .7 point difference on a 10-point scale between early and late bilinguals in mean self-ratings of their L2 English proficiency was significantly different. A 2x3 ANOVA was also conducted in order to look at the effect of speaker group and language skills on mean self-rated L1 Vietnamese proficiency. The results showed a main effect of speaker group, $F(1, 46) = 17.92$, $p < .001$, suggesting that late bilinguals (mean overall self-rating 9.18) rated themselves as more proficient in L1 Vietnamese than early bilinguals (mean overall self-rating 7.43).

Table 1. Information of bilingual participants. Mean self-rating scores out of a 10-point scale for speaking, understanding, and reading and in both L1 Vietnamese (V) and L2 English (E), with ten being the highest and one being the lowest, as well as mean age of acquisition (AoA) and mean length of residence in the US (LoR)

Language	Experiment 1a				Experiment 1b				Experiment 2			
	Early		Late		Late		Early		Early		Late	
	Vietnamese	English	Vietnamese	English	Vietnamese	English	Vietnamese	English	Vietnamese	English	Vietnamese	English
Speaking	7.38	9.58	9.08	8.88	9.38	8.38	7.59	9.52	9.14	8.57		
Understanding	8.25	9.67	9.13	9.08	9.33	8.50	7.75	9.41	9.43	8.86		
Reading	6.67	9.71	9.33	8.83	9.33	8.71	5.93	9.38	9.39	8.93		
AoA		3.92		12.83		13.25		4.07		13.25		
LoR		31.67		24.46		25.25		32.8		26.41		

Materials and design

Eight DRM false memory lists were selected. Five lists were from Roediger and McDermott (1995) and three were from Stadler, Roediger, and McDermott (1999). The five lists from Roediger and McDermott (1995) were *foot*, *king*, *music*, *needle*, and *sleep*. The three from Stadler et al. (1999) were *cup*, *pen*, and *shirt*. These particular lists were chosen because most of the words on these lists were judged by the first author (who is a Vietnamese-English bilingual) to be familiar to the bilingual group. For example, one of the lists that was selected was the critical lure *foot*, which included the words like *shoe* and *hand*. On the other hand, a list that was not chosen was the critical lure *spider*, which had words such as *arachnid* and *feelers*. Each of these lists contains 15 words that are associated with the critical lure (e.g., *foot*). These words are ordered from most strongly associated to the critical lure to the least associated (Roediger & McDermott, 1995). The first 13 words from each list were used in this study. Thus, a total of 104 words were chosen in addition to the critical lures. These 8 lists were then randomly divided into two groups, which were counterbalanced such that one group of these lists served as *old* items (i.e., studied), while the other served as *new* (i.e., unstudied), and vice versa. All 13 words from each of the 4 old lists were presented during the study session, but only the first 12 words in each list were used as targets in the later test session. The 13th word served as a practice item for the test session. These 48 items (4 lists of 12 words) were presented in the test session as old items, while the other 48 items that were not presented during the study session were presented as new items in the test session. In the test session, these 96 target items were preceded by a masked prime. For the related condition, the masked primes were the critical lures that are associated with these target words. For the unrelated condition, the masked primes were critical lures from other lists (thus, they were not associated with these target words). These unrelated control primes were the critical lures from other old lists if they were in the old condition, and from other new lists if they were in the new condition. This way, we were able to test the associative relatedness between the prime and the target, and not the congruence between old and new items. In sum, each critical lure was presented as masked primes 12 times during the test session – 6 times as related primes and other 6 times as unrelated control primes.

Four counterbalanced lists were developed with a $2 \times 2 \times 4$ design, with study status (old, new), priming (related, unrelated), and lists / item group as factors. Study status and priming were repeated for both subject and item analyses, while lists were non-repeated for subject analysis, and item groups were non-repeated for item analysis.

Procedure

Each participant was given a language background questionnaire to complete before beginning the study to identify which participant group they belonged to. Participants took the experiment individually on a computer. The experiment presentation and data collection were done using the DMDX software (Forster & Forster, 2003). All native speakers of English and some Vietnamese-English bilingual participants took the experiment in the Psycholinguistics Lab at UTA, while other Vietnamese-English bilingual participants took it in a quiet room at the aforementioned Vietnamese Catholic church in the Dallas-Fort Worth area in Texas. All the computers used to collect data for this study had a refresh rate of 60 Hz. Thus, the primes were presented for 3 refresh intervals of approximately 16.67 ms, which would amount to 50 ms. The experiment had two parts – the study session and the test session. In the study session, the participants studied four of the eight DRM lists. A total of 52 words were presented during study. These words were presented in the DRM lists in descending order, with the first word being most associated with the critical lure and last word being the least associated. Note that the critical lures were not presented during study. These words from the DRM lists were presented three times in lowercase letters. During the first presentation, a fixation point (“+”) was presented for 500 ms. This was followed by the first word in the list which automatically appeared in the center of the screen for 3000 ms (3 seconds). The next 12 words followed in the same procedure automatically. Once all 13 words were presented in the one list, then the next set of words followed until all 4 lists were presented. The second presentation of these words was the same as the first presentation, except that each word was presented only for 2500 ms (2.5 seconds). In the third presentation, all the words in each list appeared all at once on the computer screen, and the participants were instructed to memorize the words at their own pace and to move on to the following list once they felt ready.

After the study session, the test session immediately followed. During testing, participants performed a speeded old-new task, in which they made judgments of whether the word on the screen was one of the words from the lists that they had just studied. These stimuli were presented in a regular three-phase masked priming paradigm – a forward mask consisting of ten hashmarks (#####) for 500 ms, prime in lowercase letters (*sleep*) for 50 ms, followed by the target word in uppercase letters (*DREAM*) for 500 ms. The participants were expected to make a response within 4 seconds after the target stimulus was presented on the screen. After 4 seconds elapsed without a response, the following stimulus was automatically presented on the screen. Stimuli from all eight lists were presented in a random order. The participants were asked to decide whether the word on the screen is one of the words from the list of words they had just learned. They were asked to

press the right bumper button on the gamepad if the word was from the study list and to press the left bumper button if the word was not from the study list. There were eight practice trials before the task began, which again, consisted of the 13th word on each DRM list as targets. Reaction times and error rates were recorded for analysis. All items and critical lures in the study session and the test session were presented in bold 12 point Courier New, a monospaced font type.

Results

Any participants that had higher than a 20% error rate were excluded, resulting in the elimination of 14 participants in total. Thus, there were 32 native English speaker participants, 24 early bilinguals, and 24 late bilinguals included in the analysis. Furthermore, reaction times shorter than 300 ms and longer than 1500 ms were excluded from the analysis. Outliers were also adjusted to 2 standard deviations (SD) above or below the mean. This trimming procedure affected approximately 5.45% of the native English speaker data, 5.63% of the early Vietnamese-English bilingual data, and 6.9% of the late Vietnamese-English bilingual data. Subject- and item- analyses of variance (ANOVAs) were conducted separately on correct response latencies and on error rates with study status (old/new) and priming (related/control) as repeated-measures and list (for subject analysis) and item group (for item analysis) as non-repeated measures. (Note that study status was confounded with the use of different buttons on the gamepad – i.e., old items required pushing of the right bumper button, while new items required the use of the left bumper button.) The mean reaction times and error rates for all three groups of participants are presented in Table 2.

The $2 \times 2 \times 4$ ANOVA for reaction times with native English speakers revealed a marginally significant effect of study status, $F_1(1, 28) = .73$, $p = .40$, $F_2(1, 92) = 4.78$, $p = .031$, and nothing for priming, $F_1(1, 28) = 2.51$, $p = 0.12$, $F_2(1, 92) = 3.09$, $p = .082$. The interaction between study status and priming was marginally significant, $F_1(1, 28) = 3.18$, $p = .085$, $F_2(1, 92) = 1.89$, $p = .17$. Although the interaction was only marginally significant, since we had anticipated that only old items would show a priming effect and not new items, we proceeded to conduct planned comparisons. As anticipated, a significant effect of priming was found for the old items (15 ms), $F_1(1, 28) = 5.13$, $p < .05$, $F_2(1, 92) = 4.94$, $p < .05$, but there was no significant effect found in the new items (1 ms), both F 's < 1 . The omnibus ANOVA for error rate data for native English speakers showed a significant main effect of study status, $F_1(1, 28) = 15.7$, $p < .001$, $F_2(1, 92) = 18.88$, $p < .001$, with old items producing more errors than new. There was also a significant effect of priming, $F_1(1, 28) = 6.88$, $p < .05$, $F_2(1, 92) = 6.99$, $p < .01$, with related items having less errors than control items. The interaction between study status and priming was significant, $F_1(1, 28) = 5.76$, $p < .05$, $F_2(1, 92) = 6.29$, $p < .05$. Planned comparisons dis-

played a significant main effect of old items, $F(1, 28) = 7.46$, $p < .05$, $F(1, 92) = 10.37$, $p < .01$, with more errors in the unrelated condition than in the related condition. This difference was not found for new items, both F 's < 1 .

Table 2. Mean reaction times (in milliseconds) and error rates in percentages (in parentheses) for native English speakers, early Vietnamese-English bilinguals, and late Vietnamese-English bilinguals in Experiment 1a

	Native speakers		Early bilinguals		Late bilinguals	
	Old	New	Old	New	Old	New
Related	683 (11.1)	697 (7.6)	645 (12.1)	665 (6.1)	733 (13.7)	772 (11.5)
Unrelated	698 (16.8)	698 (7.6)	669 (16.5)	665 (6.8)	728 (16.0)	766 (9.5)
Priming	15*	1	24**	0	-5	-6

* $p < .05$, ** $p < .01$, *** $p < .001$

The overall ANOVA for reaction times with early Vietnamese-English bilinguals revealed no main effect of study status, $F(1, 92) = 1.16$, $p = .28$. There was, however, a significant main effect of priming, $F(1, 20) = 6.75$, $p < .05$, $F(1, 92) = 7.91$, $p < .01$, with the related condition being responded to faster than the control condition. A significant interaction was also found between study status and priming, $F(1, 20) = 6.35$, $p < .05$, $F(1, 92) = 8.71$, $p < .01$. Planned comparisons showed a significant main effect of old items (24 ms), $F(1, 20) = 13.11$, $p < .01$, $F(1, 92) = 14.09$, $p < .001$, whereas there was no significant main effect for new items (0 ms), both F 's < 1 . The ANOVA for the error rates data revealed a significant main effect for study status, $F(1, 20) = 23.39$, $p < .001$, $F(1, 92) = 20.55$, $p < .001$, with old items yielding higher error rates than new items. However, the main effect for priming was marginal, $F(1, 20) = 4.01$, $p = .059$, $F(1, 92) = 4.74$, $p < .05$. No significant interaction was found between study status and priming, $F(1, 20) = 1.52$, $p = .23$, $F(1, 92) = 2.27$, $p = .14$. Planned comparisons revealed that the main effect for old items was marginal as well, $F(1, 20) = 3.26$, $p = .08$, $F(1, 92) = 4.73$, $p < .05$, while there was no main effect for new items, both F 's < 1 .

The omnibus ANOVA for reaction time data with late Vietnamese-English bilinguals revealed a main effect of study status, $F(1, 20) = 14.6$, $p < .01$, $F(1, 92) = 19.90$, $p < .001$, with old items being responded to faster than new. There was no effect, however, for priming, interaction, or in any of the planned comparisons (-5 ms for old and -6 ms for new items), all F 's < 1 . The ANOVA for error rates displayed a significant main effect of study status, $F(1, 20) = 6.03$, $p < .05$, $F(1, 92) = 4.65$, $p < .05$, again with old items producing higher error rates than new. However, there was not a significant main effect for priming, both F 's < 1 . There was no significant interaction between study status and priming, $F(1, 20) = 1.73$,

$p = .20$, $F(1, 92) = 2.16$, $p = .15$. Planned comparisons revealed that there was not a significant main effect for old items, $F(1, 92) = 1.19$, $p = .28$, or for new items, $F(1, 20) = 1.41$, $p = .25$, $F(1, 92) = 1.13$, $p = .29$.

In sum, planned comparisons revealed priming for old items in native English speakers and early bilinguals, but not in late bilinguals. Furthermore, as anticipated, there was no priming for new items in any of the speaker groups. In order to examine whether the priming effect for old items statistically differed among the three speaker groups, a $2 \times 3 \times 4$ ANOVA for old items was conducted, with priming and speaker groups as factors. This revealed a significant interaction, $F(2, 68) = 3.562$, $p < .05$; $F(2, 184) = 4.021$, $p < .05$. Further analyses revealed that priming for old items was not different between native speakers and early bilinguals, both F 's < 1 ; but was significantly different between early and late bilinguals, $F(1, 40) = 6.558$, $p < .05$, $F(1, 92) = 6.772$, $p < .05$. Interestingly, priming for old items was only marginally different between native speakers and late bilinguals, $F(1, 48) = 3.228$, $p = .0761$, $F(1, 92) = 3.624$, $p = .0601$. This suggests that early bilinguals behaved like native speakers for old items, while late bilinguals did not. A $2 \times 3 \times 4$ ANOVA was conducted for new items as well, but this did not reveal a significant interaction, both F 's < 1 , indicating that there was no priming for new items in all three speaker groups.

Discussion

The goal of Experiment 1a was to examine whether studying the DRM lists, a list of associated words in L2 English, would activate the unrepresented critical lures. Native English speakers as well as early and late Vietnamese-English bilinguals were tested. As anticipated, all three groups showed no priming for new items. This shows that the study phase allows for semantically activating an associated word (i.e., the critical lure) to each of the DRM lists. Furthermore, native English speakers showed priming for old items when the masked prime was the critical lure. Interestingly, early bilinguals also revealed priming for old items, indicating that these bilinguals were able to successfully activate the critical lure by studying the DRM lists. Late bilinguals, however, showed no priming for old items.

So, why did the late bilinguals not show any priming for old items? At first glance, this seems to suggest that the late bilinguals were not able to activate associative networks by studying the DRM lists in L2, such that they failed to show priming when the critical lure was presented as the masked prime. The obvious way to interpret this pattern of results is to assume that these late bilinguals have not developed native-like associations in their L2 English. Thus, although these bilinguals were able to perform the task (note that their error rates were not particularly different from early bilinguals or from native English speakers), the masked prime in L2 did not affect the processing of the target.

Another way to explain why late bilinguals did not show any priming may be because the associations for L2 words in these late bilinguals might look different from native speakers. Recall that these DRM lists were normed in English. Thus, these DRM lists are culturally biased. All of our bilingual participants were proficient in L2 English, have at least a high-school degree and/or have or will have some form of college from the U.S., and lived in the U.S. on average for 31.67 years if they were early bilinguals and for 24.46 years if they were late bilinguals. (For early bilinguals, some of them were born in the U.S.) Therefore, our bilingual participants presumably know all the words on the DRM lists. Even if these late bilinguals may have been able to semantically interpret these words on the lists, however, they may not have been able to make the connection between words on the DRM lists and the critical lure. Early bilinguals, on the other hand, may have the cultural proficiency to make these connections. This is an interesting point to note because many bilingual studies using DRM lists have translated the original English versions to bilinguals' other language, and yet were able to obtain false recalls/recognition of critical lures (see e.g., Anastasi et al., 2005; Cabeza & Lennartson, 2005; Howe et al., 2008; Marmolejo et al., 2009; see also Lee et al., 2008).

Before we conclude that early bilinguals can benefit from L2 critical lures as masked primes while late bilinguals cannot, it is necessary to check whether late bilinguals would show priming for old items if the masked primes in L2 were presented at a longer SOA. After all, these late bilinguals rated themselves lower in L2 English proficiency than the native English speakers and early bilinguals. As such, these late bilinguals may not have been able to process the masked L2 prime as efficiently as native speakers and early bilinguals. Indeed, in several studies that tested late bilinguals using episodic recognition tasks with masked priming, it seemed to be the case that a longer SOA was required to obtain a priming effect. Specifically, L2-L1 translation priming in episodic recognition was only observed when the SOA was longer, at 250 ms (Finkbeiner, 2005; Jiang & Forster, 2001; Witzel & Forster, 2012; see Jiang, 1999, for more discussion on processing masked L2 primes). Thus, it might be the case that late bilinguals were not able to process the masked L2 prime under the regular three-field masking procedure such that it would affect the processing of targets. With that being said, Experiment 1b tests whether late bilinguals show priming from masked L2 primes at a longer SOA.

Experiment 1b

Methods

Participants

A total of 28 highly-proficient late Vietnamese-English bilinguals were tested in Experiment 1b. Since late Vietnamese-English bilinguals may not have been able to process the masked L2 prime at an SOA of 50 ms in Experiment 1a, Experiment 1b tested this particular group again with a longer SOA. As in Experiment 1a, these late bilinguals were also Vietnamese-Americans who were living in the Dallas-Fort Worth area of Texas, and were again, members of a Catholic church in the area. These late bilinguals began acquiring L2 English on average at the age of 13.25, with the earliest at age 10 and the latest at age 20. These bilinguals had been living in the U.S. on average of 25.3 years, with the least amount being 5 years and the most being 41 years, at the time the experiment was conducted. Again, all of these participants had a high-school degree, and/or some college experience in the U.S. These late bilinguals rated their L2 English proficiency as 8.53, and their L1 Vietnamese proficiency as 9.35. Since the Vietnamese-American population is not that large, there were some late Vietnamese-English bilingual participants in this experiment who had also taken Experiment 1a. Unlike in Experiment 1a, the participants in this experiment were compensated monetarily for their participation (US\$5).

Materials and design

The materials and design of Experiment 1b were similar to Experiment 1a with the following exception: eight completely different sets of DRM word lists were selected. The eight sets of DRM lists were the following – *black, cold, doctor, man* (Roediger & McDermott, 1995), *car, city, trash*, and *lion* (Stadler et al., 1999). A new set of DRM lists were selected such that participants who have taken Experiment 1a could also participate in Experiment 1b. Similar to the reasons in Experiment 1a, these lists of words were chosen to ensure that the bilingual participants would recognize most of the words on the DRM lists.

Procedure

The procedure for Experiment 1b was similar to Experiment 1a in that the masked primes were presented in L2 English. The difference between Experiment 1a and this experiment was that during the speeded old-new judgment task, the SOA was extended by 200 ms. During this test session, instead of a standard three-phase masked priming procedure, participants were presented with a forward mask consisting of ten hashmarks (#####) for 500 ms, prime in lowercase letters (*black*) for 50 ms, a blank interval for 50 ms, a backward mask consisting of ten

hashmarks (#####) for 150 ms, followed by the target word in uppercase letters (*WHITE*) for 500 ms (see Figure 1).

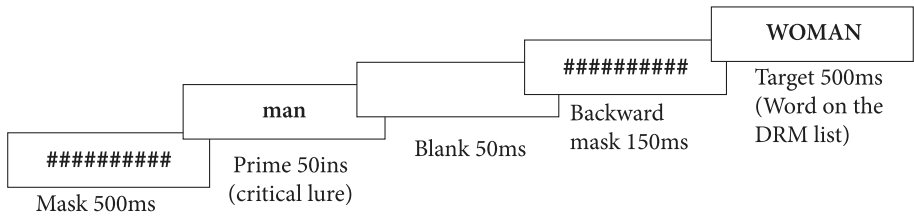


Figure 1. Priming procedure for Experiment 1b for the DRM list *man*.

Results

Participants with error rates of over 20% were excluded from the analysis, resulting in the removal of four participants. Thus, there were a total of 24 late Vietnamese-English bilingual participants included in the analyses. The trimming procedure employed in Experiment 1a was adopted in this experiment, which affected 5.23% of data from this late bilingual group. The data was analyzed in the same way as in Experiment 1a.

Table 3. Mean reaction times (in milliseconds) and error rates in percentages (in parentheses) for late Vietnamese-English bilinguals in Experiment 1b

	Late bilinguals	
	Old	New
Related	717 (10.1)	798 (7.6)
Unrelated	753 (10.4)	792 (7.1)
Priming	38 ^{***}	-6

* $p < .05$, ** $p < .01$, *** $p < .001$

The mean reaction times and error rates are presented in Table 3. The $2 \times 2 \times 4$ ANOVA for the reaction times of the group revealed a significant main effect of study status, $F_1(1, 20) = 25.80$, $p < .001$, $F_2(1, 92) = 83.39$, $p < .001$, and a significant main effect of priming, $F_1(1, 20) = 8.01$, $p < .05$, $F_2(1, 92) = 7.26$, $p < .01$. There was also a significant interaction between study status and priming, $F_1(1, 20) = 14.78$, $p < .005$, $F_2(1, 92) = 14.68$, $p < .001$. Planned comparisons revealed that there was a significant effect of old items (35 ms), $F_1(1, 20) = 19.08$, $p < .001$, $F_2(1, 92) = 17.73$, $p < .001$. However, there was no significant effect of priming for new items (-6 ms), both F 's < 1 . The omnibus ANOVA for error rates of the group did not reveal a significant main effect of study status, $F_1(1, 20) = 3.42$, $p = .08$, $F_2(1, 92) = 2.50$, $p = .11$, or of priming, both F 's < 1 . There was no significant interaction between study sta-

tus and priming, both $F_s < 1$. Planned comparisons did not show significant priming for either old or new items, all $F_s < 1$.

Discussion

Interestingly, the late bilinguals in Experiment 1b showed a robust priming effect for old items when the SOA for the masked L2 prime was longer. This suggests that the lack of priming for Experiment 1a with these bilinguals was not because these bilinguals have not developed associations in a native-like way. In fact, it seems like the reason why these late bilinguals did not show priming in Experiment 1a is because they were not capable of fully processing the masked L2 prime at 50 ms such that it affects the processing of the target. Witzel and Forster (2012) accounted for why this interpolated mask is necessary by appealing to the idea that the blank interval after the prime produces an iconic persistence effect (Coltheart, 1980; Sperling, 1960). That is, even though the prime is actually on the screen for 50 ms, the blank interval creates an illusion of the prime being on the computer screen for a longer time. They concluded that this additional time may be necessary for primes to be processed such that it can impact the processing of the target. This study shows that this extra processing time is only necessary for late Vietnamese-English bilinguals, and not for early bilinguals. Indeed, it is interesting to note that the bilinguals in Finkbeiner (2005), Jiang and Forster (2001), and Witzel and Forster (2012) were all late bilinguals as well, which suggests that the efficiency in processing L2 primes might depend on the AoA of an L2.

It is interesting to further note that despite the L2-L1 priming condition in episodic recognition tasks requiring this additional interval after the masked L2 prime, this interval was not necessary when Witzel and Forster (2012) tested the repetition priming condition in the same task with late bilinguals. They briefly mention that the additional interval might be necessary when the task requires an activation of semantic properties. That the early bilinguals not needing this additional interval between the masked prime and the target, but the late bilinguals did in our study seems to suggest that the associative networks of L2 words are not as automatically activated in late bilinguals as in early bilinguals. Howe et al. (2008) notes that the difference between bilingual adults and children may be the automaticity in which associations are activated. Given that the late bilinguals in our study seem to have developed native-like associations in L2, but require additional processing of the L2 prime seem to support this idea – that it is the automaticity of the activation that may still need to be developed in late bilinguals.

In sum, the combination of Experiments 1a and 1b demonstrates that (i) early bilinguals activate L2 associations and process masked primes just like native speakers, and (ii) late bilinguals activate L2 associations just like native speakers, but cannot process masked L2 primes like them. Now that we have confirmed that

both early and late bilinguals have developed associations within L2 words, Experiment 2 examines whether L2 words are interconnected with L1. In the following experiment, both early and late bilinguals study DRM lists in their L2 English. However, unlike in Experiment 1, during the study phase when they perform the speeded old-new task, the primes are in their L1 Vietnamese.

Experiment 2 – L1 primes

Methods

Participants

A total of 64 participants took part in Experiment 2. Since the masked primes were presented in L1 Vietnamese in this experiment, only the two bilingual speaker groups participated. There were 33 highly-proficient Vietnamese-English participants in the early bilingual group and 31 highly-proficient Vietnamese-English participants in the late bilingual group. Similar to the participants in Experiment 1, these Vietnamese-American participants were also members from the Vietnamese Catholic church in the Dallas-Fort Worth area of Texas. The early Vietnamese-English bilinguals in this experiment began acquiring English on average at the age of 4.07, with the earliest since birth and the latest at the age of 5. These bilinguals were either born in the United States or had been living in the country for an average of 32.8 years, with the least amount for 17 years and the most for 44 years. The late Vietnamese-English bilingual group, on the other hand, began acquiring English on average at the age of 13.25, with the earliest at age 10 and the latest at age 20. These bilinguals had been living in the country for an average of 26.41 years, with the shortest amount for 5 years and the longest for 41 years, at the time the experiment was conducted. As in Experiment 1, both early and late bilingual participants held at least a high school diploma from the U.S., and/or some college experience from U.S. The self-rating scores showed that early bilinguals (mean overall self-rating 9.44) rated their L2 English proficiency significantly more highly than late bilinguals (mean overall self-rating 8.79), $F(1, 54) = 6.82$, $p < .05$, just as in Experiment 1a. The self-rating scores for L1 Vietnamese proficiency, on the other hand, showed late bilinguals (mean overall self-rating 9.32) self-rated themselves more highly than early bilinguals (mean overall self-rating 7.09), $F(1, 54) = 50.66$, $p < .001$. As in Experiment 1b, the participants in this experiment were compensated for their participation (US\$5).

Materials and design

The materials and design were similar to the previous experiment with the following exceptions: a different set of eight DRM lists were selected, and primes were presented in L1 Vietnamese instead of L2 English. The eight sets of DRM lists were the following – *bread*, *smell*, *mountain*, *river*, *slow* (Roediger & McDermott, 1995), *flag* (Stadler et al., 1999), *long* and *carpet* (Gallo & Roediger, 2002). These 8 lists were selected for the following reasons. First of all, we made sure that the Vietnamese translations of the critical lures were one single word, and not compound words made up of a couple of words. The majority of Vietnamese words are compound words, but since we were not sure how presenting multiple words as primes affected priming, we stuck to one-word translations. Secondly, the Vietnamese translations of all of the eight critical lures had diacritics so that even when these words were presented as masked primes, there would be a visual cue that indicates that a Vietnamese word was presented. Thus, the Vietnamese translations for the critical lures of the DRM lists used in this experiment are respectively – *bánh*, *mùi*, *núi*, *sông*, *chậm*, *cờ*, *dài*, and *thảm*.

Procedure

The procedure for the Experiment 2 was similar to Experiment 1a in that bilingual participants studied a list of L2 English words, and they were tested using the regular three-field masking procedure during the speeded old-new task. The difference between Experiments 1 and 2 is that in this experiment, the prime was presented in L1 Vietnamese (*bánh*) instead of L2 (*bread*). The masking procedure was the same as Experiment 1a. As in Experiment 1, all items and critical lures in the study session and the test session, including the Vietnamese primes, were presented in bold 12 point Courier New font.

Results

Any participant with over an error rate of 20% was excluded, resulting in the removal of eight participants. Thus, there were a total of 28 participants in the early Vietnamese-English bilingual group and 28 participants in the late Vietnamese-English bilingual group. In addition to the removal of the eight participants, the same trimming procedure employed in Experiment 1 was adopted in this experiment. The trimming procedure affected 5.3% of data from the early Vietnamese-English bilingual group and 5.48% of the data from the late Vietnamese-English bilingual group. The data was analyzed in the same way as in Experiment 1. The mean reaction times and error rates are presented in Table 4. The 2x2x4 ANOVA for the reaction times with early Vietnamese-English bilin-

guals did not reveal a main effect of study status, both F 's < 1 , or of priming, $F_1 < 1$, $F_2(1, 92) = 1.27$, $p = .26$. There was a significant interaction between study status and priming, $F_1(1, 24) = 10.17$, $p < .01$, $F_2(1, 92) = 4.77$, $p < .05$. Thus, planned comparisons were conducted, which revealed that there was a significant main effect of old items (15 ms), $F_1(1, 24) = 4.96$, $p < .05$, $F_2(1, 92) = 5.50$, $p < .05$, but not for new items (10 ms), $F_1(1, 24) = 3.57$, $p = .07$, $F_2 < 1$. The ANOVA for the error rate data did not show any significant effects, all F 's < 2.4 .

Table 4. Mean reaction times (in milliseconds) and error rates in percentages (in parentheses) for early Vietnamese-English bilinguals, and late Vietnamese-English bilinguals in Experiment 2

	Early bilinguals		Late bilinguals	
	Old	New	Old	New
Related	677 (12.0)	693 (10.0)	726 (14.0)	786 (12.8)
Unrelated	692 (11.3)	682 (9.1)	736 (15.8)	790 (13.5)
Priming	15*	-9	10	4

* $p < .05$, ** $p < .01$, *** $p < .001$

For late bilinguals, one target item (*ROAD*) from one of the DRM lists (*dài*, which means "long"), was excluded from the by-items analysis due to 100% error rate on this particular item on one of the counterbalanced lists. In this list, *ROAD* was presented as a new item in an unrelated condition. This exclusion only affected the analysis for the reaction times and not the error rates. The omnibus ANOVA was conducted for the reaction times and displayed a significant main effect of study status, $F_1(1, 24) = 26.43$, $p < .001$, $F_2(1, 91) = 60.4$, $p < .001$, showing that old items were responded to faster than new items. There was no significant effect of priming, $F_1(1, 24) = 3.53$, $p = .07$, $F_2 < 1$. There was also no significant interaction between study status and priming for the late bilinguals, either, $F_1 < 1$, $F_2(1, 91) = 1.59$, $p = .21$. Planned comparisons were run and revealed that there was no significant priming for old items (10 ms), $F_1(1, 24) = 2.17$, $p = .15$, $F_2(1, 91) = 2.01$, $p = .16$, or for new items (4 ms), both F 's < 1 . The error rate data displayed that there was no significant main effect of study status, both F 's < 1 , or priming, $F_1 < 1$, $F_2(1, 92) = 1.25$, $p = .27$. There was not a significant interaction between the study status and priming, both F 's < 1 . Planned comparisons were run and did not reveal a significant main effect of old or new items, all F 's < 1 .

As in Experiment 1a, in order to test whether there were any speaker group differences between early and late bilinguals for old items, a separate $2 \times 2 \times 4$ ANOVA was conducted, with speaker groups and priming as factors. Interestingly, there was no significant interaction between the two speaker groups for

old items, both F 's < 1. The main effect of priming for old items was significant, $F_1(1, 48) = 7.14$, $p < .05$, $F_2(1, 91) = 7.2$, $p < .01$. When the same analysis was conducted for new items, there was a significant interaction for subject analysis, $F_1(1, 48) = 4.14$, $p < .05$, but not for item analysis, $F < 1$. These results suggest that both early and late bilinguals showed priming for old items when they are grouped together. However, as the analyses on each speaker group demonstrate, early bilinguals showed a strong enough effect to show significant priming for old items while late bilinguals did not.

Discussion

The purpose of the second experiment was to investigate whether L2 associative networks are interconnected with L1 words in bilinguals. As in Experiment 1, both early and late bilingual groups studied DRM lists in L2. However, unlike in Experiment 1, during the testing phase, the critical lures as the masked primes were presented in L1 Vietnamese instead of L2 English. Interestingly, results from Experiment 2 reveal that only the early bilinguals demonstrated clear results indicating that these bilinguals recognized old target items faster when they were preceded by the L1 critical lure. This suggests that for the early bilinguals, it does not seem to matter which language the critical lure was presented in – L1 or L2 (as in Experiment 1a). When they study a list of associated L2 words, they can activate associations to other L2 words as well as to L1 words, such that when presented with the critical lure, whether it is in the L1 or in the L2, this assists in the recognition of old items. This supports the idea that the semantic store as well as the associative networks are shared between the two languages in early bilinguals. In contrast, late bilinguals did not show clear effects of priming even though the masked prime was in their L1. This is quite unexpected. Recall that the RHM maintains that meanings of L2 words are retrieved by relying on L1 translations. Furthermore, this model assumes that this is especially the case for bilinguals who are less fluent. However, the results of this experiment indicate otherwise – i.e., there is no suggestion that late bilinguals, in particular, rely on L1 translations. Even though the late bilinguals in this study started learning their L2 later in their lives than the early ones, and they also rated themselves as less fluent in their L2 than the early ones, masked L1 primes did not seem to assist in the recognition of L2 targets.

One might ask if the failure to obtain priming in late bilinguals when the critical lure was presented in L1 can also be explained by the short SOA between the prime and the target. That is, as in Experiment 1, the late bilinguals may not have been able to process the prime within 50 ms such that the prime can impact the processing of the target. We highly doubt that this is the case. First of all, as the

mean self-ratings of L1 Vietnamese suggest, late bilinguals rated themselves much higher than early bilinguals. Also recall that these late bilinguals started learning L2 English at or after 9 years of age. Until then, they were mainly exposed to L1 Vietnamese. If early bilinguals can process masked L1 primes at an SOA of 50 ms, even though they rated themselves quite low in L1 Vietnamese, then late bilinguals should be able to process these masked L1 primes as well.

As in Experiment 1b, this weaker priming from L1 primes to L2 targets in late bilinguals could also be explained in terms of automaticity in these associations between L2 words and L1 words. That is, it might be the case that the additional blank interval is necessary even when the prime is in the dominant language because the associations are not strong enough. Note that in the aforementioned study by Witzel and Forster (2012), L1-L2 priming was obtained in the regular three-field masking procedure. It is possible that lexical associations between L1 and L2 translations are stronger than between the L1 critical lure and L2 target. However, even if this is the case, it would seem that the rapidity of processing L1 primes would provide extra processing time to make connections between the L1 Vietnamese prime and the L2 English target. The reason as to why we suspect that the late bilinguals were not able to show priming from masked L1 primes despite the fact that they showed priming from L2 primes at a longer SOA will be discussed further in the General Discussion section.

General discussion

This study set out to investigate whether early and late highly-proficient Vietnamese-English bilinguals were able to establish associations within L2 words, as well as to L1 words, and how this might differ depending on the age at which these bilinguals were first exposed to L2 English. This was examined by having these bilinguals study L2 words from the DRM lists and testing to see if there is priming for old items in the speeded old-new task when the critical lure was presented as the masked prime. The results showed that early Vietnamese-English bilinguals activated the appropriate critical lures while studying associated L2 words. Interestingly, for these early bilinguals, it did not matter whether the critical lure was presented in the L1 or in the L2. There was priming for old items in both experiments. This indicates that the early Vietnamese-English bilinguals in this study have developed associative networks such that L2 words are connected to one another strongly, as well as to L1 words. In addition, these connections have developed in such a way that they could be automatically activated. Late Vietnamese-English bilinguals, in contrast, do not present a clear picture of how their associations work. First, when the critical lures were in the L2, priming for old

items was observed only when they were given additional time to process the prime, i.e., when the SOA was at 250 ms. Secondly, when the critical lures were in the L1, priming was only obtained when this group of bilinguals were combined with early bilinguals. In other words, late bilinguals by themselves did not show priming for old items.

Given that early bilinguals in our study showed priming for both L2 and L1 prime conditions, and late bilinguals showed priming from L2 primes at a longer SOA and from L1 primes (albeit it being unreliable), it seems safe to conclude that bilinguals can develop associations in their L2, as well as to L1 words. This seems to support that bilingual semantic memory works in terms of spreading activation. That is, L2 users are not limited to activating meaning based on pure semantics, but also learn culturally what words are associated with one another in their L2, presumably from co-occurrence information. It is interesting to consider, however, why early bilinguals were able to then associate these L2 words back to L1, but late bilinguals could only do so in a less reliable manner.

This general pattern of results from early and late bilinguals seems to confirm the findings from studies by Howe and colleagues (Howe, 2007, 2011; Howe et al., 2008). In his studies, Howe found that adults have more false memories than children, and bilingual adults had more cross-language false memories than bilingual children. From this, we predicted that early bilinguals would show priming in both within- (Experiment 1) and cross- (Experiment 2) language experiments than late bilinguals, given that they had time to develop such associations due to early exposure to L2 English. This is exactly how the results of our study came out. Early bilinguals showed that they have developed associations not just to other L2 words, but also to L1 words. Furthermore, these associations seem to be automatically activated. Late bilinguals, on the other hand, required additional processing time when the primes were in L2, and did not show a reliable priming effect when primes were in L1, indicating that for these bilinguals activating associations was not so automatic.

Thus, the question still remains as to why there are such differences between the two bilingual groups. Both groups were highly-proficient in their L2, and therefore, both groups yielded facilitation from L2 primes (at least to a certain degree). However, why did the late bilinguals not show reliable priming from L1 primes? Following the findings from Howe and colleagues (Howe, 2007, 2011; Howe et al., 2008), this might be because of the limited development of L2 associative networks in late bilinguals. Howe's work suggests that in order for associative networks to activate critical lures automatically, some proficiency in the language, or for bilinguals in both languages, may be necessary. Although our late bilinguals were highly proficient in their L2, recall that they still required additional processing times for L2 primes. This suggests that late bilinguals' L2 pro-

ficiency is not as high as early bilinguals. Because of their lower L2 proficiency, late bilinguals may not have been able to develop their associative networks for L2 words such that it would interconnect with L1 words.

An alternative interpretation might suggest that this difference is not due to differences in L2 English proficiency between these two bilingual groups, but to differences in L1 Vietnamese proficiency. It might be the case that late bilinguals, in fact, have developed associations in L1 that were specific to Vietnamese language use. As mentioned, the DRM lists were normed in English, and so the associations are culturally-specific to English speakers. Thus, these late bilinguals could activate the critical lure in L2 English. However, presumably language use in Vietnamese is quite different from language use in English. With that being the case, these bilinguals might not have associated L2 words to L1 words. Early bilinguals, in contrast, were exposed to L2 English from an early age and were more dominant in L2. Therefore, some of them might not have developed associations unique to Vietnamese, and their L1 may have been relying more on associations in English.

Along similar lines, what may have affected the difference between the two bilingual groups such that one group shows connections from L2 associations to L1, but not the other, may be how these bilinguals acquired their two languages. Note that these early bilinguals have immigrated to the U.S. at a very early age, and if not, were born in the U.S. In other words, these bilingual speakers were raised by Vietnamese-speaking parents and went to an English-speaking school, and so they learned both L1 Vietnamese and L2 English together in the same context. Late bilinguals, on the other hand, were in a monolingual Vietnamese environment until at least the age of 9, and only then, were exposed to English upon coming to the U.S. Because of this, they were not only dominant in Vietnamese, but their L1 Vietnamese developed in a monolingual manner, separately from L2 English. As mentioned previously, these DRM lists are culturally biased because they were normed with English speakers. For example, the list for the critical lure *long* had the word *John*. In order for the participants to make the association between *John* and *long*, they would need to either know that *long John* is thermal wear or be aware of the American fast food chain *Long John Silver's*. Early bilinguals who learnt both L1 Vietnamese and L2 English in the U.S. could have made the connection between *John* and *long* in both L2 English and L1 Vietnamese. Conversely, late bilinguals may have made this connection between *John* and *long* in L2 English, but because their L1 Vietnamese was acquired back in Vietnam, they may not have developed this connection in L1 Vietnamese. This might have prevented L2 English to converge with their L1 Vietnamese, and hence, the weaker priming from L1 primes.

The finding that late bilinguals have not connected L2 associative networks to L1 words, but early bilinguals have, is difficult to explain. Although we have posited that it could be the L1 proficiency, L2 proficiency, or language learning contexts, none of these explanations are conclusive. More research is necessary to determine what affects how bilinguals develop their associations such that for some bilinguals, their associative networks seem to be more interconnected between L1 and L2 (as in our early bilinguals), and for others, they seem to be more independent of one another (as in our late bilinguals).

Another issue that needs to be addressed is whether the late bilinguals require additional processing time for masked primes. Earlier in the paper, we mentioned that it is quite common for late bilinguals not to be able to completely process masked L2 primes such that it would make an impact on the targets, and in episodic recognition tasks, in particular (Finkbeiner, 2005; Jiang & Forster, 2001; Witzel & Forster, 2012). We noted that this might have to do with being exposed to an L2 late. This is interesting in that, as mentioned, Howe et al. (2008) maintain that children may have developed associations, but they were not able to activate them automatically. This might be the case for late bilinguals and their associations with other L2 words as well. Specifically, that late bilinguals required additional processing time for L2 primes might suggest that these associations are not as automatic. In other words, for these late bilinguals, it might take longer to reactivate the L2 critical lure. However, could this be the case for L1 primes? That is, late bilinguals may not have been able to automatically activate critical lures in L1, even though there were associations between L2 words and L1. According to the RHM, late learners are more likely to rely on L1 during learning of the L2. Thus, there should be more associations from L2 words to L1 words than within L2 words. The late bilinguals, however, did not rely on the L1 as predicted by the RHM. As previously mentioned, there are more reasons to believe that associations have developed in L1 Vietnamese in these late bilinguals, but in a culturally-unique Vietnamese manner. One might ask why these late bilinguals did not exhibit more shared associative networks between the two languages just like the early bilinguals in this study or the adult bilinguals in Howe et al. (2008). Again, the L1 Vietnamese in our early bilinguals may behave more like their L2 English given their L1 proficiency as well as their environment. As for the adult bilinguals in Howe et al. (2008), they were English-French bilinguals in Canada. Although it is reported that they were mainly living in an English community, their experience with two languages may be more similar to our early bilinguals than to our late bilinguals.

As far as the bilingual lexical processing models are concerned, it seems as though at least for associations, there is not much of L1 dependence. This is based on the fact that L2-dominant early bilinguals still showed priming from

both L1 and L2 primes, as well as the fact that late bilinguals only showed priming from L2 primes and priming unreliably from L1 primes. As such, our findings seem to support the DFM and the Sense model. These two models posit that the quality of meanings activated for L1 and L2 words differ, even though some of it is shared. In our study, early bilinguals seem to show that they are more shared semantically even in terms of associations. Late bilinguals, on the other hand, may have developed more independent sets of associations for L1 and L2 words. Either way, associations are developed not necessarily on reliance to L1 translations, as in the RHM.

Lastly, the independent associations for L1 and L2 words in late bilinguals could support the episodic L2 hypothesis (Jiang & Forster, 2001; Witzel & Forster, 2012). This episodic L2 hypothesis posits that late bilinguals store their L2 in episodic memory, not in lexical memory where L1 is stored. If both L1 and L2 are stored in the same memory system, then we could assume that there might be more interaction between the associative networks in L1 and L2. If it is the case that L1 and L2 associative networks in late bilinguals have developed independently, then it could be the case that L2 associative networks have developed in the episodic system. Our study did not attempt to test this hypothesis originally, and thus, it makes it difficult to conclude if this is indeed the case.

In sum, this study showed that bilinguals can develop native-like associative networks in L2. However, how these L2 associative networks interact with L1 depends on the age that presumably the environment in which L2 was learnt.

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