CROSS-LINGUISTIC SEMANTIC PRIMING EFFECTS IN ENGLISH LANGUAGE LEARNERS

by

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B.A., National Cheng Kung University, Taiwan, 2014

A thesis submitted to the
Faculty of the Graduate School of the
University of Colorado in partial fulfillment
of the requirement for the degree of
Master of Arts
Department of Speech, Language, and Hearing Sciences
2016

This thesis entitled:
Cross-linguistic Semantic Priming Effects in English Language Learners

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Date 04/14/2016

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IRB protocol # 15-0124

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Cross-linguistic Semantic Priming Effects in English Language Learners

Thesis directed by Associate Professor Kan, Pui Fong

Abstract

This study examined the interactions between Mandarin and English in Mandarin-speaking English language learners. In my preliminary study (Cheng, Yamashita, & Kan, 2015), a group of Mandarin-speaking English learners (n = 32) were tested with a two-stage cross-linguistic priming test. The results showed that participants responded to the English words that were previously presented in their stronger language (in Mandarin; L1). The findings suggested that priming in a stronger language affects the subsequent processing in a speaker's weaker language. In this study, I further examined the cross-linguistic priming effects across various priming conditions. There were four experiments in this study: In Experiment 1, a cross-linguistic non-masked priming task was used to examine the priming effect of the L2 on L1 processing in Mandarin-English bilinguals. In Experiment 2, I compared the results of Experiment 1 to the results of Cheng et al. (2015). The focus was on whether a cross-linguistic non-masked priming effect held if participants were primed in their L2 (i.e., English) and completed the lexical decision task in their L1 (i.e., Mandarin). In Experiment 3, a cross-linguistic masked priming task was used to test a priming effects of the weaker language on the stronger language in Mandarin-English bilinguals. In Experiment 4, by comparing the results of Experiments 1 and 3, I examined whether differences in performance across the cross-linguistic tasks were due to differences in the non-masked and masked priming tasks. The results of Experiment 1 showed a priming effect of speakers' weaker language on their stronger language. A comparison to Cheng et al.'s (2015) results showed that different priming directions were not

significantly influential on participants' response accuracy, but did influence reaction times (Experiment 2). The results of Experiment 3 showed a masked priming effect of the weaker language on the stronger language. Comparing Experiment 1 and Experiment 3, I found that the different types of priming tasks did not significantly affect participants' performance differently (Experiment 4). This study provides additional information about the language interactions in bilinguals who speak Mandarin and English.

Keywords: Interdependent hypothesis, cross-linguistic priming test, masked priming, non-masked priming, asymmetry, lexical-decision task, reaction time, bilinguals

CONTENTS

Introduction & Background

The purpose of this study was to examine the interaction between second language learners' native language and their second language. There exists much debate regarding the extent to which a language learner's native language is activated during the use of a second language and vice versa, or even the extent to which the languages may interfere during language use. My goal was to address this debate by examining adult language learner performance in both their native and second languages. In particular, I examined adult English language learners whose native language was Mandarin. In this study, I use L1 to indicate learners' native language, Mandarin, and L2 to indicate their second language, English.

This study employed a cross-linguistic priming paradigm, which has often been used to investigate interactions between languages. A cross-linguistic priming paradigm typically involves two stages: (1) a priming phase, in which materials (e.g., words) are presented in one language, and (2) a lexical decision task or a free recall task in another language (e.g., Francis, Tokowicz, & Kroll, 2014). Mixed results have been found about whether two languages influence each other in cross-linguistic priming tasks (e.g., Francis et al., 2014; van Hell & Tanner, 2012). Some studies have found positive priming effects of one language on participants' performance in another language (e.g., Lopez, & Young, 1974; Chen & Ng, 1989; Jiang, 1999; Ando, 2012). In a preliminary study (Cheng, Yamashita, & Kan, 2015), I tested Mandarin-speaking young adults by using a cross-linguistic non-masked priming task in which participants were primed in Mandarin (L1) and then did a lexical decision task in English (L2). Consistent with previous studies (e.g., Ando, 2012), primed items in L1 facilitated the responses in the lexical decision task in L2. However, other studies have found no effect of priming from one language on participants' performance on a lexical decision task in another language (e.g.,

Scarborough, Gerard, and Cortese, 1984; Lefever, Macken, & Hoste, 2009). These mixed findings could be related to a number of factors, including priming in a stronger language vs a weaker language (e.g., Jiang & Forster, 2001; see more discussion on p.12) and the conditions of the experiment. In this study, I further examine the potential L1-L2 interactions across various priming conditions. Of interest are (1) the asymmetrical priming effects between L1 (Mandarin) and L2 (English) and (2) differences in performance resulting from differences in masked priming conditions.

My primary research question concerned whether or not priming asymmetry effects can be observed in Mandarin-speaking English language learners. Priming asymmetry between two languages in bilinguals refers to findings that the priming effects from L1 to L2 (i.e., effects of being primed in the stronger language and tested in the weaker language) are often found to be stronger than the effects from L2 to L1 (i.e., effects of being primed in L2 and tested in L1; Jiang & Foster, 2001). Priming asymmetry occurs because of the speaker's different experience with the two languages (i.e., native language (L1) vs. second language (L2); high proficiency language vs. low proficiency language; stronger language vs. weaker language). In this study, the L1- L2 direction refers to the priming condition in which bilinguals are primed in L1 (Mandarin) and then are asked to make lexical decision in L2 (English). The L2 -L1direction refers to the priming condition in which bilinguals were primed in L2 (English) and completed a lexical decision task in L1 (Mandarin). I would like to examine whether there are asymmetrical priming effects between L1 (Mandarin) and L2 (English) in our sample.

My secondary research question concerned the degree to which priming asymmetry effects observed in priming experiments are the result of experimental design. One type of priming paradigm used to investigate orthographic and phonological activation in visual word

recognitions is masked priming. In a masked priming task, the prime is masked by a forward masking symbol (i.e., #####) presented before the prime, or by a backward masking symbol after the prime. These masking symbols are assumed to help to decrease the influence of the visual presentation of the prime. In this study, I examined the differences between non-masked priming tasks and masked priming tasks. Both types of priming tasks involve two phases: (1) a priming phase (in one language), and (2) a test phase (in another language). For the non-masked priming task I used, the participants were auditorily primed by English (L2) words. They then completed the lexical decision task in Mandarin (L1) in response to written words. For the masked priming task in this study, the prime was presented visually for a short time in the priming phase with both forward and backward masks. The masked priming task thus differed from the non-masked priming task in that it involved both a masking component and a visual presentation of the prime.

Four experiments were conducted in this study. Experiments 1 and 2 addressed priming asymmetry. Experiment 1 examined the priming effects of L1 on L2, using a cross-linguistic non-masked priming task (see more information on page 6) in which participants were primed in English (L2) and performed lexical decision task in Mandarin (L1). In Experiment 2, I compared the results of Experiment 1 to the findings in Cheng et al. (2015), in which participants were primed in Mandarin (L1) and completed a lexical decision task in English (L2). Experiments 3 and 4 addressed task effects on performance in cross-linguistic priming tasks. Experiment 3 involved a cross-linguistic masked priming task, in which participants were primed in English (L2) and then completed a lexical decision task in Mandarin (L1). In Experiment 4, I compared the results of Experiment 1 and Experiment 3. All studies involved priming tasks, which have been used to study cross-linguistic interactions between bilinguals' two languages (e.g., Chen & Ng, 1989; Forster, 1998; Ando, 2012; Chen, Zhou, Gao, & Dunlap, 2013).

In what follows, I review the literature about cross-linguistic priming effects and two hypotheses that could potentially explain the findings across studies.

Priming Paradigms and Cross-linguistic Priming

Priming tasks have long been used to study the interaction of elements within a single language by examining how monolinguals respond to one stimulus, having been initially presented with another stimulus (e.g., Francis, 2014; McGregor & Windsor, 1996; Hashimoto, McGregor, & Graham, 2007). A typically priming paradigm involves two phases: 1) a priming phase and 2) a test phase. In the *priming phase,* a list of items (priming cues, e.g., pictures, words, or sentences) are presented to participants. Then, in the *test phase,* participants are asked to respond to other stimuli (again, pictures or words or sentences in the same language). Many lexical priming studies use a lexical decision task for the test phase (e.g., Chen & Ng, 1989; Ando, 2012; Chen, Zhou, Gao, & Dunlap, 2013). In these studies, participants are typically presented with two kinds of words: first, *target material,* which includes items that are relevant to items presented in the priming phase, and second, *non-target material,* which is not relevant to items in the priming phase. One explanation of the presence of priming effects is that processing a primed stimulus activates the links to the target stimulus (e.g., McGregor & Windsor, 1996). Previous studies have suggested that the activation of the links to the target stimulus during a priming experiment involves multiple cognitive processes such as implicit memory (e.g., Francis, 2014) and executive function (e.g., Muller, Dick, Gela, Overton, & Zelazo, 2006).

The cross-language priming paradigm, on the other hand, has been used to study the interaction of two languages during bilingual language processing (e.g., Francis, Tokowicz, & Kroll, 2014; van Hell & Tanner, 2012; see also the review in Altarriba & Basnight-Brown, 2007). A typical cross-linguistic paradigm involves the use of cross-language word pairs (i.e.,

semantically related or translation equivalents) with a set of words or items in one language presented in the priming phase, and another set of words or items presented in another language in the test phase (e.g., primed words in L1 and lexical decision in L2). For example, in my preliminary study (Cheng et al., 2015), I examined L1-L2 interactions in a group of Mandarin-speakers who learned English as L2 using a cross-linguistic priming task. During the priming phase of the experiment, participants were auditorily presented with Mandarin words. In the test phase, participants performed a lexical decision task in which English written words and nonwords were presented. In other words, participants were primed in Mandarin (their native language, L1) before they participated in the lexical decision task in English (their second language, L2). Positive priming effects were found between Mandarin and English. Participants responded faster when the stimuli were target words than when they were non-target words. Faster reaction times to primed words could be explained as a result of the priming words in L1 activating stored links to the target words in L2.

However, some studies have not shown cross-linguistic priming effects (e.g., Scarborough, Gerard, & Cortese, 1984; Lefever, Macken, & Hoste, 2009), suggesting that processing primed words in one language does not activate the stored links to the target words in another language. In the next section, I review the literature that provides some explanation for the mixed findings regarding second language learners' performance on cross-linguistic priming tasks.

The Independent hypothesis vs. The Interdependent hypothesis

Two hypotheses have been proposed to explain the interaction and organization of two languages in bilinguals: the independent hypothesis and the interdependent hypothesis (e.g.,

Altarriba & Heredia, 2008). These two hypotheses have been used to explain second language learners' performance on cross-linguistic priming tasks.

The independent hypothesis proposes that each language is stored separately in different memory stores and that the two languages do not influence each other. Results from some studies support this hypothesis (e.g., Scarborough, Gerard, and Cortese, 1984; Lefever, Macken, & Hoste, 2009). For example, Lefever, Macken, and Hoste (2009) propose a computational bilingual terminology extraction model based on patterns of sub-sentential alignment observed in parallel corpora. These sub-sentential alignments were trained in texts based on lexical correspondences and syntactic similarities in French. These models were subsequently trained on three groups of bilingual texts (French-English, French-Italian, and French-Dutch) and one monolingual group of texts (French vs. French), then, these models were tested in texts in French. First, a list of French words (the training set) was generated, and it was then translated into English, Italian or Dutch as target words (test sets). Then researchers ran their model on three sets of bilingual pairs of texts (French-English, French-Italian, French-Dutch) and one set of monolingual texts (French-French). The comparison of the accuracy of the bilingual group and monolingual group showed the priming effect improved the accuracy of monolingual group by up to 85-90%. The accuracy of bilingual groups received only 20% improvement in accuracy. These results showed that items presented in French had no effect on English, Italian, or Dutch items. This model suggests that the two languages in bilinguals do not interact with each other. These findings were in line with the independent hypothesis, which posits that two languages are stored in different memory stores.

In contrast to the independent hypothesis, the interdependent hypothesis posits that the memory storage for each of a bilingual's two languages is interconnected and that the memory

stores interact with each other. This explanation is consistent with the revised hierarchical model (RHM; Kroll & Stewart, 1994), in which the languages of bilingual speakers share stored concepts linked to two separate word-form lexicons for their two languages. Accordingly, the interdependent hypothesis suggests that processing information in one language may activate the other language. Previous studies have provided support for the interdependent hypothesis (e.g., Lopez, & Young, 1974; Chen, Zhou, Gao, & Dunlap, 2013). For example, Chen, Zhou, Gao, and Dunlap (2013) examined cross-language translation priming with Chinese-English bilinguals who spoke Mandarin Chinese as their native language. They conducted priming tasks in both L1 (Mandarin)-L2 (English) and L2-L1 directions. The translation priming effect was found only in the L1-L2 direction, but not in the L2-L1 direction. That is, the two languages interacted only when priming was conducted in the participants' stronger language. However, when Chen et al. prolonged the presentation of the L2 priming stimulus, they found a translation priming effect in the L2-L1 direction. The results in Chen et al. (2013) are consistent with the findings in my preliminary study (Cheng et al., 2015), in which Mandarin-speaking English learners performed faster and more accurately in response to English (L2) target words than to English non-target words in the lexical decision task after being primed with Mandarin words (L1). However, the question that whether the bilinguals who are primed in L2 perform better in the testing phase in L1 hasn't been solved in Cheng et al. (2015). Taken together, these findings are consistent with the interdependent hypothesis; when bilinguals are primed in one language, their performance in the other language is influenced.

French and Jacquet (2004) provide a more precise description of the interdependence of language mechanisms in bilinguals by describing which aspects of the language interact and which do not. According to their claim, three aspects are involved in bilingual language

processing: lexical access, lexical selection, and the degree of strength of each of these processes. *Lexical access* refers to the process which activates the right words in a given context, while *lexical selection* refers to how the given words are recognized in each language. With regard to lexical access, some researchers posit the existence of lexical-specific access, that is, access within one language at a time (e.g., Scarborough, Gerard, & Cortese, 1984; Lefever, Macken, & Hoste, 2009). However, several studies argue for the existence of non-selective access, that is, access to both languages simultaneously (e.g., Colomé, 2001; De Bruijn, Dijkstra, Chwilla, & Schriefers, 2001).

McClelland and Rumelhart's (1981) Bilingual Interactive Activation (BIA) model of lexical selection issue provides further explanation for how lexical selection occurs in bilinguals when the two languages interact with each other. The BIA model has been extended single language effects to bilinguals, for example, one expansion states that similar linguistic cues (orthographic, morphological, or phonological similarities) interact across languages. In other words, similar language tags help speakers recognize words. The BIA model is based on studies showing interlingual orthographic neighborhood effects on two orthographically similar languages (i.e., French-English), as well as studies showing cross-language masked orthographic priming effects in both directions when both languages are orthographically similar. One problem with generalizing this model to all bilingual speakers, however, is that the model cannot account for language interaction in bilinguals whose two languages do not exhibit similar linguistic cues.

Kroll and Stewart's (1994) revised hierarchical model provides an explanation for differences in strength of the connection involved in lexical access and selection. According to their model, L2 learners rely on the translation equivalent of L1 words as a *lexical link* when

learning a new L2 word. Furthermore, when the L2 word is learned, speakers establish not only the lexical link across languages, but also the *conceptual link* between word and concept within the L2. Even after the conceptual links between words and concepts are established within each language (i.e., L1-concept, L2-concept), the lexical links between L1 and L2 still exist. These lexical links may differ in strength. For example, the lexical link from L2 to L1 might be stronger than the link from L1 and L2, because when second language learners are just starting to learn words in L2, they may rely more strongly on translating words from L2 to L1 and memorizing them. As a consequence, the conceptual links from L1 to concept might be stronger than the conceptual links from words to concepts in L2 (because speakers are not mapping directly from concept to lexical item in L2, but rather are mapping from the translation equivalent of L1 to L2). Jiang and Forster (2001) found that priming effects in the L1-L2 direction were stronger than those in the L2-L1 direction. In addition, Jiang (1999) found faster reaction times when speakers were primed in L1 and tested in L2 (L1-L2 direction) than when they were primed in L2 and tested in L1 (L2-L1 direction).

Factors associated with cross-linguistic priming effects

There are several factors which might affect the results of cross-linguistic priming tasks. The first one concerns potential structural differences between L1 and L2. Mixed findings regarding how two languages in bilinguals are organized (e.g., Scarborough, Gerard, and Cortese, 1984) might be related to the typological and/or orthographic similarities between the two languages of bilinguals (e.g. English-French, or English-Spanish bilinguals) (Ando, 2012). To address this issue, Ando (2012) studied Japanese-English bilinguals, whose two languages are in different scripts. She found there was a significantly lower error rate (i.e., higher accuracy rate) of high frequency words in the Japanese katakana script when these words were primed by

phonologically similar words in both Japanese and English. In another study, Chen and Ng (1989) used semantic facilitation and translation priming to test 24 Chinese-English bilingual adults using a lexical decision task. Results showed that primed translation equivalents in one language showed positive effects on reaction times for tasks in the other language. This result was not consistent with the results of a study by Lefever, Macken, and Hoste (2009). who conducted an experiment on three test sets of English, Italian, and Dutch as bilingual groups, and one test set of French as monolingual group. They found that there was no priming effect on a second language (either English, Italian, or Dutch) when participants were primed with a list of French words.

Another factor that may influence cross-linguistic priming effects is participants' language proficiency in each language. One question concerns whether there is any difference between the priming effects of high proficiency language (e.g., the native language in second language learners) and the weaker language (e.g., the second language in second language learners). Work by Costa and Santesteban (2004) suggests that such a difference exists. They conducted a priming test on L2 learners to see if language proficiency influences the degree to which two languages interact. They found that L2 learners showed stronger influence of the primed language when primed in their stronger language (i.e, L1) and tested in L2 (their weaker language), compared to the condition in which they were primed in L2 and response in L1.

Different priming methods are a third factor that might result in different strengths of priming effects between two languages (Jiang & Forster, 2001). Jiang and Forster (2001) tested asymmetrical priming effects in the L2-L1 direction by using cross-linguistic masked priming tasks on native Mandarin speakers learning English as second language. According to their study, when a masked priming test was used to test Mandarin-English bilinguals, the priming effects in

L2-L1 direction were explained. However, they didn't explain the priming effects in L1-L2 direction in their study. Jiang and Forster (2001) also found a stronger priming effect when Chinese-English bilinguals were primed in L1 (Chinese) and engaged in a lexical decision task in L2 (English), compared to their performance when they were primed in L2 using a masked priming method and tested in L1.

French and Jacquet (2004) mention different tasks as a variable that can influence participants' performance and interpretations of interactions between two languages. However, according to several studies (e.g., Altarriba, 1992; Chen & Ng, 1989; Jiang, 1999; Jiang & Forster, 2001), no matter whether masked or non-masked priming experiments were conducted, priming effects in both directions were found to be significant, with effects in the L1-L2 direction usually found to be stronger than those in the L2-L1 direction. These findings were not consistent with the assumption of Jiang and Forster (2001).

Finally, orthographic similarity might affect the results of priming studies. Most previous studies have examined the interactions between orthographically similar languages in bilinguals or second language learners. Fewer studies have examined speakers who learn two orthographically unrelated languages. Most of orthographic related languages studies found the evidence of asymmetry on priming effect between L1-L2 direction and L2-L1 direction. With Kroll and Stewart's (1994) revised hierarchical model which thought the *lexical link* from L2 to L1 is stronger than L1 to L2, the priming effect between L2-L1 direction might be stronger than L1-L2 direction. However, the influences of *conceptual link* should be considered as well. Besides, though the interdependent hypothesis supports the possibility of an interaction between two languages, the independent hypothesis believes the memory stores which related to two languages are stored separately does not support the priming effects of one language on the other.

The priming effect in L1-L2 direction and L2-L1 direction were found in some studies that used masked priming or non-masked priming. In Jiang (1999), the priming effects in L2-L1 direction were weaker than L1-L2 direction. However, some studies haven't found the priming effects in L2-L1 direction.

In response to this phenomena, this current study examined cross-language priming effects in two orthographic unrelated languages (Mandarin-English). This was done in order to avoid any priming that would be due to interlingual orthographic neighborhood effects or cross-language orthographic priming effects, which occur between two orthographically similar languages. Additionally, this study used the translation equivalent target words as stimuli in order to make use of conceptual (semantic) priming instead of word form (phonological) priming. In this way, the language-specific cues (equivalent to language tags) that bilinguals might use to recognize words were eliminated.

The Current Study

The current study examined the interactions between L1 and L2 in Mandarin-speaking English learners using a cross-linguistic priming task. I examined whether priming effects are present when participants are primed in their weaker language (i.e., English). The findings presented here provide important evidence about the role of language proficiency in the interactions between L1 and L2.

Crucially, this study addresses three gaps in the current research on L1-L2 interactions. First, I address interactions between languages that are not typologically and orthographically related. Because Mandarin and English are two typologically and orthographically dissimilar languages, priming effects observed in participants who speak both Mandarin and English provide different insights from those presented in studies which examine priming effects in

typologically and/or orthographically similar languages. Conclusions about L1-L2 interactions based on evidence observed in these experiments can more easily generalize to L1-L2 interactions in all speakers, and not just bilingual speakers of languages that are orthographically and typologically similar.

Second, I examine whether language proficiency is a contributing factor to the asymmetry of priming effects by looking at interactions in both the L1-L2 and L2-L1 directions. Several studies (e.g., Chen & Ng, 1989; Jiang, 1999; Jiang & Forster, 2001; Chen, Zhou, Gao, & Dunlap, 2013) have found priming effects between two languages when the participants were primed either in stronger language or weaker language. These effects, however, are not consistent. For example, Jiang (1999) mentions that priming effects in the L2-L1 direction are weaker and sometimes inconsistent. In this study, I examined whether there were interactions between Mandarin-speakers' native language and English (L2), two orthographically unrelated languages, by comparing results of experiments in two priming directions (L1- L2 vs. L2-L1). This current study focused on semantic priming effects of two languages when participants were primed in English (L2) and completed a lexical decision task in Mandarin (L1). Results were then compared to a preliminary study (Cheng, Yamashita, & Kan, 2015) which tested an interaction in the L1(Mandarin)-L2(English) direction. By comparing to preliminary data (Cheng et al., 2015), which found priming effects in the L1 (Mandarin)- L2 (English) direction with non-masked priming, we can learn more about the asymmetry involved in priming effects.

Finally, because task-related factors could also contribute to the cross-linguistic priming effect, in this current study, I used both non-masked and masked priming tasks. In the non-masked priming task, participants were auditorily primed by English (L2) words and then completed a lexical decision task in Mandarin (L1) written words. Unlike the non-masked

priming task, the masked priming used a visual presentation for the priming phase. In the masked priming task, the prime was presented visually for a short time with both a forward mask (########) and a backward mask (########). Although the primed materials were presented too briefly to be seen by most participants, previous research has found that the priming effects in masked priming tasks are more effective than visual priming tasks in which primes are not masked (Humphreys, Quinlan, Evett, & Besner, 1987). By comparing the results of both the non-masked and masked priming tasks in the L2-L1 direction, we can observe whether or not task effects are a factor in participants' performance.

To summarize, the research questions in this current study were:

1) Do languages in bilingual speakers interact, as evidenced by priming effects between Mandarin and English, two typologically and orthographically distinct languages?
2) Is there an asymmetry in priming effects due to a difference in language proficiency, as evidenced by differences between priming effects observed in the L1-L2 and L2-L1 directions?
3) Are task effects responsible for differences observed in priming effects across studies, as evidenced by a difference between the priming effects in non-masked priming task and masked priming?

These questions are addressed by four experiments. Experiment 1 examined cross-linguistic priming effects using a task in which L2 was the primed language; Experiment 2 compares the priming effects between the L2-L1 direction (as observed in Experiment 1) and the L1-L2 direction (as observed in Cheng et al., 2015); Experiment 3 examined cross linguistic priming effects using a cross-linguistic masked priming task with L2-L1 direction; Experiment 4

compared participants' performance in the non-masked priming task (Experiment 1) and the masked priming task (Experiment 3).

Experiment 1: Cross-linguistic Priming: L2-L1

The purpose of Experiment 1 was to investigate whether a cross-linguistic priming effect was observed when Mandarin-speaking English language learners were primed in their weaker language. This experiment builds upon the findings in my preliminary study (Cheng et al., 2015). by examining cross-language priming in the reverse priming direction. In Experiment 1, English second language learners who speak Mandarin as first language (L1) were tested in a cross-linguistic non-masked priming task. Participants were primed in English before they engaged in a lexical decision task in Mandarin. The specific research question for Experiment 1 was:

1) When primed in L2 (English) in a non-masked priming task, do Mandarin-speaking English learners have more accurate responses and faster reaction times in recognizing target words than in recognizing other word types in their L1?

According to previous studies (e.g., Chen & Ng, 1989; Chen et al., 2014), the priming effect of L2 to L1 might be weak or inconsistent. In this study, if the independent hypothesis is true, participants' reaction times and accuracy in recognizing Mandarin words might be not significantly different after presenting cross-linguistic primes in English. If the interdependent hypothesis is true, reaction times and accuracy of responses to the words which were primed and the words which were not primed should be significantly different.

Method

Participants

Thirty-two Mandarin-speaking young adults were recruited to participate in Experiment 1. To be eligible for Experiment 1, participants had to speak Mandarin as a home language from

birth and had to have been learning English for more than 10 years in school settings in either Taiwan or China. Participants with any visual problems, hearing impairment, language disability, or learning disability were excluded.

According to participants' self reports, all 32 participants had been functionally using English in academic settings for more than 1 year at the time of testing. All of them had grown up in a Mandarin (L1)-dominant environment (i.e., China or Taiwan) and had learned English (L2) as a second language in school settings. All participants reported that Mandarin was their stronger language and that they used L1 more frequently in their daily lives even as they were studying in the US (where English (L2) is the dominant language). Participants' non-verbal cognitive skills were tested using the Test of Nonverbal Intelligence (TONI-2). Participants' language background was evaluated using a questionnaire adapted from the LEAP-Q by Marian, Blumenfeld, and Kaushanskaya (2007). Responses to questions could be written in English and Mandarin. Questions addressed (1) Background information (e.g. birthdates, gender, and education); (2) Language proficiency (e.g. how many languages are functionally used, current language environment); and (3) Language experience (e.g. When did they begin to use each language? When did they learn this language?) (see Appendix A for details).

The characteristics of the participants in Experiment 1 and in Cheng et al. (2015) are summarized in Table 1.

Table 1.

Participants' Background

	Experiment 1	Cheng et al. (2015)
n	32 (17= F; 15= M)	32 (21= F; 11= M)
Age (Mean, SD)	Mean=25.31; SD=6.62	Mean=25.31; SD=2.79
L1/L2	Mandarin/English	Mandarin/English
Education levels	Undergraduate	Undergraduate/Graduate
TONI-2 score	70.37 (%ile Rank)	N/A

Participants in the preliminary study (Cheng et al., 2015) and the current study had similar backgrounds. All participants in Experiment 1 and Cheng et al. (2015) self-reported that they speak Mandarin Chinese as native language, and learned English as second languages. Moreover, all of them reported Mandarin Chinese as their high proficiency language, and most of them used Mandarin to talk with friends, watch TV shows, or read books in their daily life even while living in the US. Participants used English only in school settings (i.e., completing homework, taking tests, and making use of lecture materials).

Stimuli

There are two phases in Experiment 1: (1) the priming phase, in English, and (2) the lexical decision task, in Mandarin. The stimuli for the priming phase included a total of 30 English words (10 words* 3 blocks). The stimuli for the lexical decision phase included 30 written target Mandarin words (10 target words*3 blocks), 30 written non-target Mandarin words (10 non-target words*3 blocks), and 30 nonwords (10 nonwords*3 blocks). The total number of stimuli was equally divided into 3 blocks. Each block included 10 English words in the priming phase, and 10 written target Mandarin words, 10 written non-target Mandarin words, and 10 nonwords in the lexical decision task. In the lexical decision task, target words included Mandarin words which were the translation equivalents of the primed English words. Non-target words were Mandarin words which are not related to primed English words. Nonwords were made from two real Chinese characters which, when combined, have no meaning in Chinese (e.g., 貓黑、小聞). Table 2 summarizes how the stimuli are selected.

Table 2.

Stimuli selection for Experiment 1 (see Appendix B for examples of list of words)

Stimuli	#	Phase	Stimuli development procedures
Spoken Words in English (e.g., Number, House)	30 (10*3 Blocks)	Auditory priming	Generated based on the Corpus of Contemporary American English (COCA) database (Davies, 2008.)
Target Words in Mandarin in written form (e.g., 數字 number、房屋 house)	30 (10*3 Blocks)	Lexical decision task	Translation equivalents of the words in English for the priming phase: ● written Chinese words. Translated by 50 Mandarin native speakers ● Chosen from the translation equivalents which showed 100% agreement across all Mandarin speakers
Non-target word in Mandarin in written form (e.g., 圖片 picture、草原 plain)	30 (10*3 Blocks)	Lexical decision task	Semantically unrelated with target words Generated base on the Corpus of Contemporary American English (COCA) database (Davies, 2008.)
Nonwords in Mandarin in written form (e.g., 貓黑、小	30 (10*3 Blocks)	Lexical decision task	Written Mandarin nonwords: Nonwords were made from two real Chinese characters which, when combined, have no meaning in Chinese Generated based on the ARC nonword database (Rastle,

聞)	Harrington, & Coltheart, 2002)

Research Design in Experiment 1

In Experiment 1, cross-linguistic priming effects were examined using a within-subjects design. Subjects were primed in English, and completed the lexical decision task in Mandarin. The dependent variables were the reaction time and accuracy of lexical decision. The independent variable was word type (target word, non-target word, and nonword).

Procedures

The priming test involved two main steps: (1) the priming phase, and (2) the lexical decision task. The participants were auditorily primed in English words, then, were asked to complete a lexical-decision task, in which written Mandarin words, including nonwords, target words and non-target words, were randomly presented. Table 3 summarizes the procedures.

Table 3.

Steps of priming test for Experiment 1

Step	Language	Modality	Procedures
Step 1: Priming	English	Auditory presentation	Priming: Participants listen to a list of words that are presented in English.
Step 2: Lexical decision task	Mandarin Chinese	Written visual presentation	In this phase, each participant was randomly presented 30 written words using E-prime on a computer screen: a.10 target words in Chinese b.10 non-target words in Chinese c.10 nonwords that looks like Mandarin words They were asked to press the “yes” or “no” button, as soon as possible, to identify items as words or

nonwords.

Each subject was tested individually in a quiet room. All stimuli were presented and responses recorded using E-prime, a software that is able to measure participants' reaction times and accuracy rates of responses to a button-press task. Each subject was tested in three blocks. The order of the three blocks was randomized. In each block, 10 English words were randomly presented in the priming phase, and 30 written words in Chinese, including target words, non-target words, and nonwords were randomly presented in lexical decision task.

Results

Response times and accuracy of responses were analyzed using R in an analysis of variance (ANOVA) with repeated measures on the factor "word types" in a crossed design. he independent variable was word type, which included three levels: Mandarin target words (translational equivalents to English primes), Mandarin nonwords, and Mandarin non-target words.

A repeated measures ANOVA showed significant differences between the accuracy rates of responses to the three word types for accuracy of performance ($F(2, 62) = 9.03$, $p<.001$). Multiple comparisons showed that accuracy rates of responses to words was significantly higher than for nonwords ($p < .01$). In addition, there were significant differences between accuracy rates of responses to target words and non-target words ($p <.01$), between accuracy rates of responses to target words and nonwords ($p <.001$), and between accuracy rates of responses to non-target words and nonwords ($p <.001$). With regard to reaction time, a repeated measures ANOVA showed significant differences between response times to the three word types ($F(2, 62) = 108.05$, $p<.001$). Multiple comparisons showed that responses to words were significantly faster than for nonwords ($p < .001$). In addition, there were significant differences between

response times to target words and non-target words (p <.001), between response times to target words and nonwords (p <.001), and between response times to non-target words and nonwords (p <.001). These findings suggest that the two languages are interconnected. Results are summarized in Table 4.

Table 4.

Mean and Standard Deviation of Accuracy and Reaction Times in the Priming task

	Accuracy (number correct)					
	Target words		Non-target words		Nonwords	
	L1-L2	L2-L1	L1-L2	L2-L1	L1-L2	L2-L1
Mean	9.73	9.9	9.3	9.71	9.03	9.32
Standard Deviation	0.75	0.36	2.24	0.65	0.98	0.79
	Reaction Time (in ms)					
Mean	682.57	604.48	771.33	654.24	930.22	873.16
Standard Deviation	170.56	29.36	260	132.9	330.11	213.35

Note: The maximum accuracy score for each word type was 10. L1-L2= Primed in Mandarin and test in English, L2-L1= Primed in English and test in Mandarin

Experiment 2: A Comparison of Priming Directions

The purpose of Experiment 2 was to compare priming effects of different directions (L1-L2 vs. L2-L1) to see whether there is an asymmetry of priming effects in different directions. I compared the results of Experiment 1 to the results of my preliminary study (Cheng et al., 2015), in which I showed priming effects when English second language learners were primed in Mandarin (L1) and completed a lexical decision task in English (L2). Specific research questions for Experiment 2 were:

1) Is there an asymmetry of priming effects between the L1-L2 priming direction and the L2-L1 priming direction when Mandarin-speaking English learners were tested in non-masked priming task, as evidenced by a comparison of the results of Experiment 1 to the findings of Cheng et al. (2015)?

Experiment 2 compares the results of Experiment 1 to those of the preliminary study from Cheng et al. (2015). Two groups of participants were examined: the participants in Experiment 1 (the L2-L1 group) and the participants from Cheng et al. (2015) (the L1-L2 group). Consistent with the interdependent hypothesis, results from the preliminary study (Cheng et al., 2015), showed that the mean accuracy rates and reaction times of responses to target words were higher and shorter than those for non-target words. In Experiment 1, also consistent with the interdependent hypothesis, a priming effect was observed in the L2-L1 direction. This result is consistent with some studies (e.g., Chen & Ng, 1989; Jiang, 1999; Jiang & Forster, 2001). A question remains as to whether there is a difference between the priming effects in different directions. The asymmetry of priming effects in L1-L2 and L2-L1 directions has previously been shown in several studies (e.g., Jiang, 1999; Jiang & Forster, 2001). If there is asymmetry of priming effects in the two directions, there should be significant difference showed in Experiment 2.

Method

Participants

The participants of the Cheng et al. (2015) study were 32 college-age English learners who use Mandarin (L1) as a home language (see participant characteristics in Table 1). Similar to Experiment 1, participants spoke Mandarin as a native language started learning English in 7th grade in academic settings in their home country. All of them were able to communicate in basic

English conversations. The comparison of the participants in Experiment 1 and Cheng et al. (2015) was presented in Table 1 (see page 18).

Stimuli

The stimuli set in Cheng et al. (2015) was similar to Experiment 1. The main difference was that the priming items in Cheng et al. (2015) were auditorily presented Mandarin words, and items in the testing phase were in English.

Research design in Experiment 2

In Experiment 2, the results of Experiment 1 were compared to those of Cheng et al. (2015) using a between-subjects 2 (Primed languages) x 3 (Word types) analysis of variance (ANOVA) with repeated measures design. The data were analyzed using the computer program R. The dependent variables were accuracy and reaction time. The independent variables were word type (target word, non-target word, and nonword) and priming direction (L1-L2 group vs. L2-L1 group).

Procedures

The procedure in Cheng et al. (2015) was similar to that of Experiment 1. The main differences were that the priming phase in Cheng et al. (2015) involved an auditory rather than visual presentation, and that Mandarin words were presented in priming phase, while the lexical decision task was completed in English.

Results

The results of Cheng et al. (2015) showed significant differences between the accuracy and reaction time of responses to the three word types in the lexical decision task. Results showed that reaction times to target words were significantly shorter than reaction times of responses to non-target words. However, in reaction time, responses to target words were not

only significantly faster than responses to nonwords, but also significantly faster than responses to non-target words. That is, primed words in Mandarin facilitated the identification of their translation equivalents in English. These findings suggest that the two languages (i.e., Mandarin and English) in second language learners interact with each other.

The comparison of the results of Experiment 1 with those of Cheng et al. (2015) showed that for accuracy, there was a main effect of word type ($F(2,124)=5.75$, $p<.01$). There was no significant main effect, however, of priming direction (L1-L2 vs. L2-L1) ($F(1,62)=2.22$, $p=0.14$). Furthermore, there was no significant interaction between word type and priming direction ($F(2, 124)= 1.79$, $p>.05$). Multiple comparisons showed that there was no significant interaction between priming direction and word vs. nonword ($p=0.95$); in other words, the effect of word type (words—including target and non-target—vs. nonwords) on the accuracy of responses to was the same in both priming directions. Though there was a significant difference between accuracy of responses to target word and non-target words ($p <.001$), there was no significant difference in target words and nonwords ($p =0.77$), nor in non-target word and nonwords ($p =0.78$). There is no difference between being primed in the stronger language or weaker language in participants' accuracy. Results are summarized in Table 4.

For reaction time, there was a main effect of word type ($F(2,124)=93.63$, $p<.001$) on reaction time. Further comparision of different word types revealed that there were significant differences between target words and non-target words ($p <.001$), target words and nonwords ($p <.001$), and non-target words and nonwords ($p <.001$). Moreover, there was a significant main effect of priming direction (L1-L2/L2-L1) on reaction time ($F(1,62)=4.26$, $p<.05$), such that the participants who were primed in Mandarin (the L1-L2 direction) had longer reaction times in the lexical decision task. There was no interaction between word type and priming direction ($F(2,$

124)=2, p=0.14). This finding indicates that the reaction times to different word types for those who were primed in English (L2-L1 direction) were not significantly different from the reaction times of those who were primed in Mandarin (L1-L2 direction).

Discussion: Experiment 1 and Experiment 2

The results of Experiment 1, in which primes were presented auditorily in English, showed a significant difference between the three word types with regard to effects on accuracy and reaction time. Results showed that the reaction time to target words was significantly shorter than non-target words. That is, the presentation of words in English facilitates the identification of their translation equivalents in Mandarin. Moreover, with regard to reaction time, target words were identified significantly faster than both nonwords and non-target words. These findings suggest that in second language learners, the speaker's two languages (i.e., Mandarin and English) interact with each other during language processing.

In Experiment 2, there was a significant effect of priming direction on reaction times such that responses in the L2-L1 direction were faster than those in the L1-L2 direction. However, there was no significant difference in the effects of word type on either reaction times or accuracy of response across priming directions. These results suggests that the priming phase had similar effects on reaction times regardless of priming direction (L1-L2 / L2-L1).

Experiment 3: Masked Priming

The purpose of Experiment 3 was to investigate whether the cross-linguistic (L2-L1) priming effect observed in the non-masked priming paradigm in Experiment 1 is also observed when a masked priming task is used. The main difference between the non-masked priming task in Experiment 1 and the masked priming task in Experiment 3 is that participants in Experiment

3 were primed with English words in a brief visual presentation with both forward and backward masks. The specific research question for Experiment 3 was:

1) Are there any cross-linguistic priming effects on Mandarin-speaking English learners' lexical decision performance in L1 (Mandarin) when participants are primed in L2 (English) using a masked priming task?

Experiment 3 used a cross-linguistic masked priming task to examine L1-L2 interactions in English second language learners. Cross-linguistic priming effects in a masked priming task have been observed previously in the L1-L2 direction. In Chen and Ng (1989), Chinese-English participants were primed in their stronger language (L1), Mandarin. Better performance for target words in lexical-decision task showed the translation equivalent primes in one language facilitated participants' performance in the other language to lexical-decision task. The results of Chen and Ng (1989) support the interdependent hypothesis. However, although Chen and Ng (1989) found priming effect using a masked priming task, the priming direction was different than the direction examined here in Experiment 3. Regarding the L2-L1 direction, Chen et al. (2014) used a masked priming task to examine priming effects in both the L1-L2 and L2-L1 directions. However, they only found the priming effect in L1-L2 direction.

Method

Subjects

Participants were same 32 Mandarin speakers who participated in Experiment 1 (see participant characteristics in Table 1).

Stimuli

Though the items were selected from the same pool of words used in Experiment 1, the words used in Experiment 3 were different than the words used in Experiment 1. A total of 30

English words served as primes, and 30 translation equivalent two-character Mandarin words serve as target words. In addition, 30 two-character Mandarin words that were not semantically related to the English prime words were chosen as non-target words and 30 Chinese two character nonwords. These words were equally divided into 3 blocks. Chinese nonwords were made from two real Chinese characters which, when combined, have no meaning in Chinese. The words Experiment 3 were not related to those used in Experiment 1. Table 6 presents how the stimuli in Experiment 3 were selected.

Table 6.

Stimuli selection for Experiment 3 (see Appendix C for examples of list of words)

Stimuli	#	Phase	Stimuli development procedures
Written words in English (e.g., exercise, fall)	30 (10*3 Blocks)	Visual priming with forward and backward masks	Generated based on the Corpus of Contemporary American English (COCA) database (Davies, 2008.) Appendix from Chen et al. (2014).
Target Words in Mandarin in written form (e.g., 練習 exercise、落下 fall)	30 (10*3 Blocks)	Lexical decision task	Translation equivalents of the words in English used in the priming phase: ● written Chinese words Translated by 50 Mandarin native speakers ● Chosen from the translation equivalents which showed 100% agreement across all Mandarin speakers

Non-target word in Mandarin in written form (e.g., 作用 effect、珍珠 pearl)	30 (10*3 Blocks)	Lexical decision task	Semantically unrelated with target words Generated based on the Corpus of Contemporary American English (COCA) database (Davies, 2008.)
Nonwords in Mandarin in written form (e.g., 通組、日晾)	30 (10*3 Blocks)	Lexical decision task	Written Mandarin nonwords: Nonwords were made from two real Chinese characters which, when combined, have no meaning in Chinese Generated based on the ARC nonword database (Rastle, Harrington, & Coltheart, 2002)

Design

This study used a within subjects design. The dependent variables were reaction time and accuracy of response in a lexical-decision task. The independent variable was word type (target word, non-target word, and nonword).

Procedures

Two general steps were involved in Experiment 3: (1) a Priming phase, and (2) a Lexical-decision task. The participants were visually primed with English words with both forward and backward masks. The priming phase consisted of the following sequence: First, the participant was presented with a forward mask (##########) for 500ms, followed by an English primed word (translational equivalent to target Mandarin words) in lowercase letters for 50ms, followed by a backward mask for 150ms. In the lexical-decision task, each of the Mandarin words was

presented for 500 ms. There were 3 blocks in Experiment 3. Each block included a priming phase and a lexical decision task. In each block, there were 10 English primed words in the priming phase, and 10 words of each word type (target word, non-target word, and nonword) in the lexical decision task. The target words were translation equivalents of the English prime words. The non-target words were Mandarin words which were not semantically related to the English prime words, and the nonwords were two-character Mandarin nonwords.

Results

Response data were analyzed using the computer program R in an analysis of variance (ANOVA) with repeated measures on the factor "word type" in a crossed design. The dependent variables were accuracy and reaction time; the independent variable was word type, which included three levels: target words, nonwords, and non-target words.

A repeated measures ANOVA analysis of accuracy showed a significant effect of word type on accuracy of performance ($F(2, 62) = 13.56$, $p<.001$). Multiple comparisons showed that accuracy for responses to words was significantly higher than for nonwords ($p < .001$). In addition, there were significant differences between response accuracy rates for target words and non-target words ($p <.05$), target words and nonwords ($p <.001$), and non-target words and nonwords ($p <.01$).

Regarding reaction time, a repeated measures ANOVA showed a significant effect of word type on reaction time ($F(2, 62) = 95.06$, $p<.001$). Multiple comparisons showed that response time to words was significantly higher than response time to nonwords ($p < .001$). In addition, there were significant differences between response times to target words and non-target words ($p <.001$), target words and nonwords $p <.001$), and non-target words and nonwords

(p <.001). These findings suggest that the two languages are interconnected. Results are summarized in Table 7.

Table 7.

Mean and Standard Deviation of Accuracy and Reaction Time in Priming task.

	Target words	Non-target words	Nonwords
Accuracy (number correct)			
Mean	9.91	9.75	9.33
Standard Deviation	0.21	0.31	0.79
Reaction Time (in ms)			
Mean	570.81	620.47	774.91
Standard Deviation	147.6	146.6	253.41

Note: The maximum accuracy score for each word type was 10.

Experiment 4: Non-masked vs. Masked Priming

The purpose of Experiment 4 was to compare the priming effects of the non-masked priming task and masked priming task in order to determine whether there is a difference of priming effects in different priming tasks. This was accomplished by comparing the results of Experiments 1 and 3. The specific research question for Experiment 4 was:

1) Were there any significant differences between Mandarin-speaking English learners' performance in the non-masked priming task and that in the masked priming task?

There are reasons to believe that different priming strategies may affect participant performance in different ways. Humphreys, Quinlan, Evett, and Besner (1987) indicated that most participants reported they were unable to see the primed material clearly as a result of the primed words being presented for only a short time in addition to being masked with both forward and backward masks. However, they found the priming effects in masked priming tasks

were more effective than visual priming tasks in which participants are not masked in the *priming phase.* In addition*,* Forster (1998) stated that masked priming test taps into automatic and strategy-free lexical processing in semantic priming task. Experiment 4 compares the results of Experiment 1 and Experiment 3 to see whether the type of priming influences results. If there is a difference between priming effects in non-masked priming task and masked priming task, results of Experiment 4 should show a significant difference in participant performance between Experiments 1 and 3.

Method

Participants

Participants were the same 32 Mandarin speakers who participated in Experiment 1 and Experiment 3 (see participant characteristics in Table 1).

Research design for Experiment 4

In Experiment 4, the results of Experiment 1 and Experiment 3 were compared using a between-subjects mixed design ANOVA. The data were analyzed using the computer program R in a 2 (Priming type) x 3 (Word type) analysis of variance (ANOVA) with repeated measures. The dependent variables were accuracy and reaction time. The independent variables were word type (target word, non-target word, and nonword) and priming type (Non-masked priming vs. Masked priming).

Procedures

The procedure in Experiment 3 was similar to Experiment 1. The main difference was that the participants in Experiment 1 were auditorily presented with Mandarin words (the non-masked priming task), while in Experiment 3, they were visually presented with Mandarin words (the masked priming task).

Results

The analysis of accuracy revealed that there was a main effect of word type ($F(2,62)=28.17$, $p<.001$). Further comparison of different word types revealed that there were significant differents between accuracy rates of responses to target words and non-target words ($p <.001$), target words and nonwords ($p <.001$), and non-target words and nonwords ($p <.001$). There was no main effect of priming type (Non-masked priming vs. Masked priming) ($F(1,31)=0.03$, $p>.05$), and there was no significant interaction between word type and priming types ($F(2, 62)=0.01$, $p>.05$). These results suggest that there is no difference between the priming effects of the non-masked priming task and the masked priming task on participants' accuracy in a lexical decision task.

Regarding reaction time, there was a significant main effect of word type ($F(2,62)=201.11$, $p<.001$). Further comparison of different word types revealed a significant difference between response times to target words and non-target words ($p <.001$), target words and nonwords ($p <.001$), and non-target words and nonwords ($p <.001$). There was no significant effect of priming type (Non-masked priming vs. Masked priming) ($F(1,31)=0.17$, $p>0.05$), and there was no significant interaction effect between word type and priming type (Non-masked priming vs. Masked priming) ($F(2, 62)=1.74$, $p>0.05$). These results suggest that the reaction times for Experiment 3 were not significantly different from those of Experiment 1. There is also no difference between participants' reaction times in the non-masked priming task or the masked priming task. Results are summarized in Table 8.

Table 8.

Mean and Standard Deviation of Accuracy Rates and Reaction Times in Priming task.

	Accuracy (number correct)

	Target words		Non-target words		Nonwords	
	Experiment 1	Experiment 3	Experiment 1	Experiment 3	Experiment 1	Experiment 3
Mean	9.82	9.91	9.51	9.75	9.19	9.33
Standard Deviation	0.59	0.21	1.65	0.32	0.89	0.81
			Reaction Time (in ms)			
Mean	642.34	570.81	710.38	620.47	901.24	774.91
Standard Deviation	157.09	147.6	219	146.6	280.63	254.41

Note: The maximum accuracy score for each word type was 10.

Discussion: Non-masked Priming (Experiment 1) vs. Masked Priming (Experiment 3)

In Experiment 3, results showed a significant difference between responses to the three word types both in terms of accuracy as well as reaction time. Results showed that reaction time to target words was significantly faster than to non-target words. That is, priming words in English facilitated the identification of their translation equivalents in Mandarin. In addition, reaction times to target words were significantly faster than to nonwords, and significantly faster than to non-target words. These findings suggest that the two languages (i.e., Mandarin and English) in these second language learners interact with each other.

The comparison of Experiment 1 and Experiment 3 also showed that there was no significant interaction between priming type and word type. That is, priming in L2 had similar effects on performance with respect to accuracy or reaction time, regardless of whether priming was auditory (non-masked, as in Experiment 1) or visually masked (as in Experiment 3) (visually masked priming).

A summary of the results of all four experiments is presented in Table 9.

Table 9.

Summary of the 4 experiments.

Accuracy

		F	df	df	p	Multiple comparisons
Cheng et al. 2015	L1- L2	7.39	2	62	<.05	Target Word >nonword
Experiment 1	L2 - L1	9.03	2	62	<.001	Target Word > non target >nonword
Experiment 2	L1-L2 vs L2-L1	2.22	1	62	>.05	1) no sig. in L1-L2 vs L2-L1 2) Target Word >non target 3) no sig interaction in primed languages*word types
Experiment 3	L2 - L1 (masked)	13.56	2	62	<.001	Target Word > non target >nonword
Experiment 4	Masked vs non-masked	0.03	1	31	>.05	1) no sig. in Masked vs Non-masked 2)Target Word > non target >nonword 3) no sig interaction in primed languages*task types

Reaction time

		F	df	df	p	Multiple comparison
Cheng et al. 2015	L1- L2	36.67	2	62	<.001	Target Word < non target <nonword
Experiment 1	L2 - L1	108	2	62	<.001	Target Word < non target <nonword
Experiment 2	L1-L2 vs L2-L1	4.26	1	62	<.05	1) L2-L1 > L1-L2 2)Target Word < non target <nonword 3) no sig interaction in primed languages*word types
Experiment 3	L2 - L1 (masked)	95	2	62	<.001	Target Word < non target <nonword
Experiment 4	Masked vs non-masked	0.17	1	31	>.05	1)no sig. in Masked vs Non-masked 2)Target Word < non target <nonword 3) no sig interaction in primed languages*task types

General Discussion

This study examined the interaction between two languages in second languages learners, focusing on Mandarin as the native language and English as the second language of the participants involved. The study primarily examined the asymmetry in priming effects of the L1-L2 and L2-L1 directions. A secondary concern of the study involved the comparison of two kinds of priming tasks, a non-masked priming task and a masked priming task, to see if there

were differences in performance as a result of the different tasks. There were four experiments conducted in this study: Experiment 1, a cross-linguistic non-masked priming task in which priming in the L2-L1 direction was examined; Experiment 2, a comparison of priming effects in the L2-L1 and L1-L2 directions examining asymmetry in non-masked priming tasks; Experiment 3, a cross-linguistic masked priming task in which the L2-L1 direction was used; and Experiment 4, a comparison of non-masked priming and masked priming effects in the L2-L1 direction.

In Experiment 1, priming effects in the L2-L1 direction of Mandarin-speaking English language learners were examined using a cross-linguistic non-masked priming task. Participants were auditorily primed in English (L2) and completed a lexical decision task in Mandarin (L1). The results demonstrated the non-masked priming effects of L2 on L1. In Experiment 2, the results of Experiment 1 were compared to preliminary data (Cheng et al., 2015), in which participants had been auditorily primed in Mandarin (L1) and completed a lexical decision task in English (L2). The comparison of results from Experiment 1 with those of Cheng et al. (2015) revealed a difference in the non-masked priming effects between the L2-L1 direction and the L2-L1 direction. In Experiment 3, the same group of participants from Experiment 1 were primed in English (L2) with priming words masked by both forward and backward masks. They then completed a lexical decision task in Mandarin (L1). Results revealed masked priming effects of L2 on L1. In Experiment 4, a comparison of the results of Experiment 1 and Experiment 3 showed a difference between the effects of non-masked priming and masked priming in second language learners.

In four different experiments, I examined the interactions between L1 and L2 in Mandarin-speaking English language learners using various cross-linguistic priming tasks, which involve the presentation of words in one language during a priming phase and a subsequent

lexical decision task in another language (see Table 9 for the summary of the 4 experiments). There were three important findings. First, both Experiment 1 and Experiment 3 showed significant non-masked and masked priming effects of L2 on L1. That is, participants responded with higher accuracy and shorter reaction times to target Mandarin words (translation equivalents of English prime words). This finding was consistent with the interdependent hypothesis, which states that the two languages of bilinguals interact. Second, there was a significant difference found in the reaction times, but not the accuracy, of participants who were primed in English (L2) and completed a decision task in Mandarin (L1) versus participants who were primed in Mandarin (L1) and completed the decision task in English (L2). In this comparison, the effects of primed language were only found in reaction time, and the L2-L1 direction showed stronger effect than L1-L2 direction. That is, the participants in L2-L1 group performed faster in target words than the participants in L1-L2 group. Though a significant difference was found in reaction times when comparing L1-L2 group and L2-L1 group, in further comparison with word categories, the difference was not found. Third, there was no significant difference between participants' performance in the non-masked priming task and the masked priming task. Participants had similar performances regardless of whether they participated in the non-masked priming task or the masked priming task.

Cross-linguistic priming effects: L1-L2 and L2-L1 directions:

This study examined priming effects in both L1-L2 and L2-L1 directions. In this study, the L1-L2 direction referred to the priming effect of the stronger language (in this study, the participant's' native language, Mandarin) on the weaker language (the participants' second language, English). The L2-L1 direction referred to the priming effect of the weaker language on the stronger language. In Experiment 2, a comparison of the results from Experiment 1 and the

preliminary data from Cheng et al. (2015) revealed that a difference between the two priming directions only existed with respect to reaction time. In addition, the results supported the claim that L2-L1 direction performed faster and higher acciracy than L1-L2 direction. This result was inconsistent with several studies (i.e., Jiang, 1999; Jiang & Forster, 2001; Costa & Santesteban, 2004) which found stronger priming effects in the L1-L2 direction than the L2- L1 direction. However, the significant difference between the reaction times of responses in the two directions only appeared in the comparison of the two groups primed in L1 or L2. When further comparing the reaction times of L1-L2 direction and L2-L1 direction in different word categories (target word, non-target word, and nonword), there was no significant difference found. It is possible that the results of Experiment 2, in which there was no significant difference in participants' performance when primed in Mandarin or primed in English, might be due to the lexical link from L2 to L1 being stronger than the lexical link from L1 to L2 (Revised Hierarchical model; Kroll & Stewart, 1994). A difference between these lexical links would make priming effects of L2 to L1 (L2-L1 direction) stronger than L1 to L2 (L1-L2 direction). It should be noted that the investigation of priming asymmetry effects in this study was conducted with a non-masked priming task, and previous studies were tested the effects with masked priming task. For masked priming, there was an enhancement in complete priming task. Since incomplete primes only partially match the target, the complete primes showed stronger effects in masked priming task.

Masked and non-masked priming effect

In the non-masked priming task in Experiment 1, participants were auditorily primed by English (L2) words and did the lexical decision task in response to Mandarin (L1) written words. The difference with the masked priming in Experiment 3 is that the masked priming used visually presented primes. In masked priming, the prime is presented visually for a short time

with forward and backward masks. In Experiment 4, the comparison between Experiments 1 and 3 showed no significant difference in either accuracy or reaction time across priming tasks.

The findings of priming effects in Experiment 1 and Experiment 3 were consistent with several studies (e.g., Chen & Ng, 1989; Jiang, 1999; Jiang & Forster, 2001; Chen, Zhou, Gao, & Dunlap, 2013) that found priming effects between two languages regardless of whether participants were primed in their stronger or weaker language. However, the results in the comparison were inconsistent with French and Jacquet's (2004) study. They thought that task effects could be a variable influencing participants' performance and therefore the interpretations of results suggesting interactions between the two languages in second language learners. Humphreys, Quinlan, Evett, and Besner (1987) also found that priming effects in masked priming tasks were more effective than visual priming tasks in which participants are not masked in the priming phase. Moreover, Foster (1998) found that compared (primed words in a word) to masked priming, non-masked task presented more obvious effect in incomplete priming (primed words in part of morpheme or phoneme) than complete priming (primed whole words).

The inconsistency between the results of Experiment 4 and these studies may be due to differences in experimental design. The non-masked priming tasks used in these studies were not identical to the non-masked priming task used in Experiment 1. For example, Forster (1998) examined the priming effects in incomplete priming and complete priming. When masked priming was used, there was an enhancement in the complete priming task. Since incomplete primes only partially match the target, the complete primes showed stronger effects in masked priming task. In Experiment 1, I used the translation equivalent of prime words and auditory priming, which differed from the paradigm used by Forster (1998).

Limitations of the study

Future work could further examine the priming effects of the L1-L2 direction in a masked priming task (Experiment 3). By comparing further studies with Experiment 3, we could get more information on the asymmetry of cross-linguistic priming effects observed in this study despite the limitations of priming tasks. Forster (1998) has discussed problems with priming tasks. For example, there is a possibility that the nonwords used in lexical decision task could be recognized as words because they have been chosen from close neighbors of actual words. In addition, in some priming tasks, the participants are required to provide verbal responses, which makes it possible that priming could occur on an articulatory level. In light of these situations, priming effects can be difficult to explain. There is no study, however, which can decisively prove that the results of priming tests are solely task effects. As a result, Forster (1998) has suggested that priming tasks are useful tools. Nonetheless, it would be to our advantage to try different methodologies to examine the interactions between the two languages of second language learners.

Conclusion

In conclusion, this study, together with Cheng et al. (2015), revealed non-masked priming effects in both L2-L1 and L1-L2 directions and masked priming effects in the L2-L1 direction. These findings were consistent with the interdependent hypothesis, which states that the two languages of bilinguals do interact. There was, however, no difference found between non-masked priming effects and masked priming effects. Taken together, the results indicate potential L1-L2 interactions in adult Mandarin-speaking English language learners.

The findings presented here are consistent with RHM (Kroll & Stewart, 1994), BIA (McClelland & Rumelhart, 1981), and the interdependent hypothesis. Both the BIA (McClelland & Rumelhart, 1981) and RHM (Kroll & Stewart, 1994) claim that when bilinguals recognize a

word or linguistic form in one language, they usually rely on the information from the other language, whether consciously or unconsciously. This idea is consistent with the claims of the interdependent hypothesis, in which the memory storages for each of a bilingual subject's two languages are both interconnected and interactive with each other. French and Jacquet (2004) state that the study of bilingual memory could help the more general study of memory and processing. Understanding general language processing of bilinguals and how bilinguals' brains work in bilingual memory benefits not only bilingual research, but also monolingual research. Moreover, the interdependent hypothesis holds implications for intervention and treatment for bilinguals with speech and language impairments.

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APPENDIX (A) Sample language questionnaire

請依照語言熟練的先後順序列出您能使用的語言

Please list all the languages you know in order of dominance

1._____ 2_____ 3._____ 4._____ 5._____

請依照掌握語言的先後順序列出您能使用的語言(母語為先)

Please list all the languages you know in order of acquisition (your native language first)

1._____ 2_____ 3._____ 4._____ 5._____

APPENDIX (B) Sample of stimuli in Experiment 1
Block 1

Prime English words	Target word	Target word Simplified Mandarin	Non-target word	Non-target word Simplified Mandarin	Nonword	Nonword Simplified Mandarin
Number	數字	数字	圖片(Picture)	图片	*貓黑*	*猫黑*
House	房子	房子	草原(Plain)	草原	*羊栗*	*羊栗*
Eye	眼睛	眼睛	嘴巴(Mouth)	嘴巴	*豬灰*	*猪灰*
Car	汽車	汽车	輪船(Ship)	轮船	*狼紫*	*狼紫*
Door	大門	大门	窗戶(Window)	窗户	*新誌*	*新誌*
Art	藝術	艺术	音樂(Music)	音乐	*小聞*	*小闻*
Food	食物	食物	飲料(Drink)	饮料	*論剖*	*论剖*
Family	家庭	家庭	人類(Human)	人类	*物紙*	*物纸*
Girl	女孩	女孩	男孩(Boy)	男孩	*世葉*	*世叶*
Father	爸爸	爸爸	哥哥(Brother)	哥哥	*樹紀*	*树纪*

APPENDIX (C) Sample of stimuli in Experiment 3
Block 1

Prime English words	Target word	Target word Simplified Mandarin	Non-target word	Non-target word Simplified Mandarin	Nonword	Nonword Simplified Mandarin
Earth	地球	地球	發生(Happen)	发生	*頭別*	*头别*
Exercise	練習	练习	作用(Effect)	作用	*通組*	*通组*
Fall	落下	落下	珍珠(Pearl)	珍珠	*日諒*	*日谅*
Key	鑰匙	钥匙	結果(Result)	结果	*子嚇*	*子吓*
Make	製作	製作	現象(Phenomena)	现象	*合生*	*合生*
Park	公園	公园	告訴(Tell)	告诉	*屏穴*	*屏穴*
Play	玩耍	玩耍	實際(Reality)	实际	*飲肋*	*饮肋*
Book	書本	书本	因為(Because)	因为	*妊料*	*妊料*
Couple	一對	一对	證明(Prove)	证明	*沙慟*	*沙恸*
Doctor	醫生	医生	弱點(Weak point)	弱点	*墨投*	*墨投*