ABSTRACT

Title of Thesis: INVESTIGATION OF BILINGUAL DISADVANTAGE IN VERB AND NOUN RETRIEVAL IN MANDARIN-ENGLISH BILINGUALS

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The bilingual literature has shown a bilingual disadvantage in spoken language compared to monolinguals. This study first investigated how highly proficient Mandarin-English bilinguals retrieved verbs and nouns compared to monolingual English speakers in a picture-naming task. In order to explain why bilinguals are disadvantaged than monolinguals in language processing, this study examined if it was due to the frequency effect, which was predicted by the "weaker-links", or if it was due to the translatability effect, as predicted by the cross language interference. Results captured a bilingual effect, a word category effect, and a smaller bilingual disadvantage for verbs than for nouns in lexical retrieval. The bilingual disadvantage could be explained by the "weaker-links" hypothesis, rather than the cross language interference. But the smaller bilingual verb disadvantage could be partially explained by the cross language interference hypothesis. Clinical implications and future research directions were discussed.

Keywords: bilingual, picture naming, frequency, interference

INVESTIGATION OF BILINGUAL DISADVANTAGE IN VERB AND NOUN RETRIEVAL IN MANDARIN-ENGLISH BILINGUALS

by

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Introduction

A bilingual refers to a person who speaks two languages in a community (Romaine, 2008). According to the U.S. Census (2010), around 20% of the U.S. residents speak a language other than English at home, and Spanish and Chinese top the list of non-English languages spoken in the country. Many bilingual studies in the cognitive and psycholinguistics literature have investigated Indo-European language speakers such as Spanish-English, Greek-English, and Russian-German. However, because the Mandarin-English speaking population is increasing rapidly and this Sino-Tibetan language is less investigated in the literature, the current study focused on Mandarin-English bilingual speakers.

In general, several studies have found cognitive advantages in bilinguals compared to monolinguals (Bialystok, 1999, 2001; but see Hilchey & Klein, 2011), and a poorer performance in spoken language, such as in a picture-naming task. This less efficient performance of bilinguals in spoken language is referred to as the *bilingual disadvantage.* Most prior bilingual studies have examined the production and processing of nouns (i.e. Kohnert, Bates, & Hernandez, 1999; Kohnert, 2002), while very little is known about how bilinguals process and produce other grammatical categories. Among the few studies that compared verb and noun retrieval in bilinguals, different performance patterns have been found. Some studies showed that bilingual verb naming disadvantage is larger than noun naming disadvantage (Van Hell & De Groot, 1998; Hernandez et al., 2008; Jia, Kohnert, & Collado, 2006; Faroqi-Shah, 2012), but a few recent studies discovered that the disadvantage in bilingual verb retrieval is smaller compared to noun retrieval (Faroqi-Shah, Li, & Yoon, in prep; Faroqi-Shah & Milman, 2015). Two studies

comparing bilingual and monolingual children found comparable picture naming performance for verbs (Klassert, Gagarina, & Kauschke, 2014), and bilingual superiority in a semantic association task for verbs and adjectives (Sheng, McGregor, & Marian, 2006). In other words, findings regarding bilingual performance on verbs are scant and somewhat inconsistent with the general idea of a bilingual disadvantage. Hence, a more systematic investigation needs to be conducted on if and how bilinguals perform with different grammatical categories, which can further our understanding of bilingual language representation. Regarding languages per se, Mandarin, which belongs to Sino-Tibetan language families, differs from English and many other Indo-European languages in terms of verbs and nouns. For instance, verbs are much more heavily inflected in English and in many Indo-European languages, making them morphosyntactically more complex. However, Mandarin is a verb-friendly language, as Mandarin verbs are not morphologically inflected by case markings, tense suffixes, agreement markings, or plural markings. Additionally, Mandarin Chinese is a pro-drop language, in which both subjects and objects may drop from finite sentences (Huang, 1989). Therefore, sentences in Chinese can start with a verb. Tardif (1996) proposed that Mandarin verbs are morphologically simpler than English verbs because they are more likely to be at sentence-final position, and are early acquired by children. Therefore, the lack of verb inflections, the sentence-initial position, as well as proposed early acquisition of verbs in Mandarin may facilitate verb processing in L1 than in L2 for Mandarin-English bilinguals. Furthermore, findings about early acquisition of verbs and nouns are not universally consistent. Gentner (1982) claimed that nouns are predominantly learned in children's early vocabularies, but Tardif (1996) found a higher use of verbs than nouns in

Mandarin speaking young children. Due to these differences between- and within-languages, the current study aimed to investigate how Mandarin-English bilingual healthy adults retrieve verbs and nouns compared to monolingual English healthy adults; whether the findings of Indo-European speaking bilinguals can be replicated in Mandarin-English speakers (Klassert et al., 2014; Faroqi-Shah & Milman, 2015; Faroqi-Shah et al., in prep); and to further the theoretical understanding of the bilingual disadvantage.

This paper first reviewed the current literature regarding bilingual language comprehension and production, which was followed by a discussion of bilingual disadvantage in word retrieval as well as theories that attempt to explain this disadvantage. Later on, research questions, methods, and findings of the current study were presented.

Literature Review

Bilingual Word Comprehension

Relatively fewer studies have examined lexical comprehension. Gollan, Montoya, Fennema-Notestine and Morris (2005) asked Spanish-English bilingual adults and monolingual English adults to classify pictures of nouns as natural versus man-made. The results showed that bilinguals could classify pictures as quickly and accurately as monolinguals, which suggested the observed bilingual disadvantage did not appear at the conceptual or semantic level. Bialystok and Luk (2012) compared receptive vocabulary scores obtained from PPVT-III between monolingual English-speaking adults and bilinguals adults (European and Asian language-English) from 20 different studies. According to their analysis, the mean score of receptive vocabulary for monolinguals was

significantly higher than that for the bilinguals. One explanation for the inconsistent findings of the bilingual disadvantage of language comprehension is that, PPVT-III requires lexical access as the word is presented via the auditory mode, but a picture classification task does not require lexical access.

Bilingual Language Production

Language performance in bilingual speakers can be impacted by several factors, such as individual differences in proficiency in each language, and the age of acquisition of the 2nd language (L2). It can also be affected by other linguistic factors such as cognate status, frequency, and grammatical class of lexical items.

Costa and Santesteban (2004) showed evidence that proficiency in each language of bilinguals impacts their language performance. They found that low-proficiency Spanish learners of Catalan and Korean learners of Spanish performed less well in a switching task between L1 and L2 compared to highly proficient Spanish-Catalan bilinguals. Additionally, Blumenfeld and Marian (2007) examined parallel activation of German during English word recognition in two groups of German-English bilinguals, who were either German-native (high proficient in German) or English-native (less proficient in German). During each trial, the participants heard object names in English, and they were asked to identify them among pictures that included a homophone in German. The activation of the German homophone competitor was measured by eye-tracking paradigm. The results revealed that highly proficient German bilinguals co-activated German in the presence of both English-specific targets and cognate targets, but low proficient German bilinguals co-activated German in the presence of cognate targets only. Therefore, the activation of German was stronger in high-proficiency German

bilinguals, indicating that proficiency in each language is associated with bilingual language performance.

Age of acquisition (AoA) is another factor that adds to the variation in bilingual language performance. According to a review by Birdsong (2006), studies that investigated AoA effects on L2 learning outcomes have mostly focused on morphosyntax and pronunciation. Those studies have found that morphosyntactic errors increase as AoA increases, so do pronunciation errors. Faroqi-Shah, et al. (in prep) further revealed the impact of AoA on bilingual lexical retrieval, in which they found AoA significantly predicted the speed of verb and noun naming in Spanish-English bilingual speakers.

Cognates, which are translation equivalents with similar forms across both languages, play another role in bilingual language production. In Hermans et al. (1998), significant interference effect for cognates was found in a picture-word interference experiment. In contrast, Gollan and Acenas (2004) discovered a facilitative effect of cognates. They induced tip-of-the-tongue (TOT) effects for English words in 30 Spanish-English bilinguals, 30 Tagalog-English bilinguals, and 30 English monolinguals given cognates and noncognates. The results showed that bilinguals produced more TOTs than monolinguals even in their dominant language (English) when they were given noncognate words. However, the bilingual TOT rate dropped when the stimuli were cognates, suggesting that cognates play a facilitative role in bilingual language production. Similarly, Costa, Caramazza, and Sebastian-Galles (2000) argued that bilinguals named pictures with cognates more quickly relative to pictures with non-cognates because cognate translations are similar in phonological form across languages, which can produce a facilitation effect in pictures naming.

Frequency of occurrence of words has been argued as an important factor influencing bilingual lexical production. Studies have shown that bilinguals produce words much slower than monolinguals for low-frequency words (Gollan, Montoya, Cera & Sandoval, 2008; Ivanova & Costa, 2008). In order to examine the relationship between frequency of use and lexical accessibility, Gollan et al. (2008) examined how English-Spanish bilinguals performed on picture naming with high- and low-frequency words, comparing to monolingual English speakers. A frequency effect indicates the difference of reaction time (RT) between high- and low-frequency words. They found a larger frequency effect in bilinguals compared to monolinguals, as well as in the non-dominant language (Spanish) compared to dominant language (English). Gollan et al. (2008) suggested that bilinguals are disadvantaged because they use each language less frequently compared to monolinguals.

The Bilingual Disadvantage

Many studies have found a bilingual disadvantage for language production, even among highly proficient bilingual speakers. For instance, bilinguals have more TOT effects than monolinguals (Gollan & Silverberg, 2001; Gollan & Acenas, 2004; Gollan et al., 2005). Roberts, Garcia, Desrochers, and Hernandez (2002) administered the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983) on 42 monolingual English adults, 32 highly proficient Spanish-English bilingual adults, and 49 highly proficient French-English bilingual adults. All the participants were asked to name the pictures in English, and results showed that both bilingual groups obtained much lower scores compared to the monolingual English group. These findings were confirmed by numerous other picture naming studies of bilinguals (Spanish-English: Gollan et al., 2005; Spanish-

Catalan: Ivanova & Costa, 2008). In verbal fluency tests, when they were asked to say as many words as possible from a semantic category (such as animals or fruits) in a given time, bilingual speakers generally produce fewer exemplars than monolingual speakers (Gollan, Montoya, & Werner, 2002; Rosselli et al., 2000). However, such bilingual disadvantage is not universal across different experimental tasks. It was not significant for phonemic verbal fluency, that is, when bilinguals were asked to produce as many words as possible that start with the same sound (Gollan et al., 2002). The lack of bilingual disadvantage in phonemic fluency can be due to greater reliance on executive functions compared to semantic fluency. Additionally, as there is no constraint of word categories in phonemic fluency, the bilingual disadvantage could disappear.

The bilingual disadvantage is not only present at word level, but it also extends to phrase level (Sadat, Martin, Alario, & Costa, 2012) and sentence level (Runnqvist, Gollan, Costa, & Ferreira, 2013). Sadat et al. (2012) tested 35 monolingual Spanish adults and 35 highly proficient Spanish-Catalan bilingual adults, who were instructed to produce noun phrases to colored pictures of objects. They found that bilinguals were much slower in producing noun phrases than monolinguals. In addition, Runnqvist et al. (2013) investigated sentence production in 46 English monolingual, 50 high-proficiency Spanish-English bilinguals, and 49 high-proficiency Mandarin-English bilinguals. Participants were asked to form grammatical English sentences by combining the words they saw. The results showed that both bilingual groups were slower in producing English sentences than the monolingual group.

The bilingual naming disadvantage exists even in the first language (L1) and the dominant language, which may not be the L1. Ivanova and Costa (2008) tested picture

naming in Spanish monolinguals and highly proficient, L1-dominant Spanish-Catalan bilinguals. The results revealed that bilinguals named pictures slower than monolinguals in both their first and dominant language, as well as in their weaker second language.

The Bilingual Verb Disadvantage

In monolingual speakers, it is well known that verbs are more challenging than nouns, when measuring language acquisition (Kauschke & Frankenberg, 2008), verb naming in healthy adults (Shao, Roelofs, & Meyer, 2012; Szekely et al., 2005), and word retrieval after brain injury (Matzig, Druks, Masterson, & Vigliocco, 2009). A similar verb disadvantage has also been seen in some bilingual studies (Jia et al., 2006; Van Hell & de Groot, 1998; Hernandez et al., 2008; Faroqi-Shah, 2012). Van Hell and de Groot (1998) tested word association in eighty unbalanced Dutch-English bilingual adults, who were presented with words on a screen and were asked to verbally produce the first associated word that came to their mind. This was done in each language separately, Dutch and English. In both language associations, the authors found that it was much more difficult for Dutch-English bilingual adults to retrieve associations to verbs than to nouns. The authors argued that even though networks for both languages in bilinguals are strengthened when a word is processed, verb representations are less likely to be strengthened from cross-language spreading of activation due to less dense conceptual representations, as well as less similar meanings across languages (Genter, 1981).

Bilingualism and verbs pose two separate challenges to lexical retrieval, but it is not clear how much more disadvantaged verbs are in bilinguals. A few studies found the bilingual disadvantage in verb retrieval is rather smaller than in noun retrieval in both bilingual children (Sheng et al., 2006; Klassert et al., 2014), and bilingual adults (Faroqi-

Shah et al., in prep; Faroqi-Shah & Milman, 2015). During a word association task, twelve 5- to 8-year-old Mandarin-English bilingual children and twelve monolingual English children were instructed to produce paradigmatic (synonyms, antonyms, coordinates, superordinates, subordinates) and syntagmatic (words that followed the prompts as in "stand-up", or the thematic relationships as in "sick-medicine") word associations three times in either Mandarin or English given a target word (Sheng et al., 2006). In children, paradigmatic responses are considered a superior semantic ability because this pattern is typical of mature language users. Thus, more paradigmatic responses mean a more developed semantic system of children. The authors found a significant decrease of paradigmatic responses in nouns across trials in bilingual children, but an insignificant decrease of paradigmatic responses in verbs. This finding is in contrast from the bilingual verb disadvantage as shown in Van Hell and De Groot (1998). Sheng et al. (2006) explained that the outperformance of verbs in both L1 and L2 by bilingual children might be due to children's early acquisition of paradigmatic relations for verbs in the verb-friendly language, Mandarin. Another study that found a lack of a verb disadvantage in bilinguals is Klassert et al. (2014), which examined the influence of word category (verb and noun) on picture naming task. Sixty Russian-German bilingual children (4-7 years old) and eighty age-matched Russian-speaking monolingual children were included in this study. They found that monolingual children named nouns more accurately compared to bilingual children, but their performance on verb naming is similar. Both Sheng et al. (2006) and Klassert et al. (2014) suggested a more fragile noun learning in bilingual contexts than verb learning.

Faroqi-Shah, Li, and Yoon (in prep) recently administered a verb and noun

picture-naming task to eighteen highly proficient Spanish-English healthy bilingual adults, who were tested in both English and Spanish on separate days. They compared bilingual English picture naming latencies with monolingual English picture naming latencies obtained from the International Picture Naming Project (Bates et al., 2000). Not surprisingly, bilinguals named both verbs and nouns significantly more slowly than monolinguals (mean difference = 106.5 ms), and naming latencies for verbs were significantly longer than nouns (mean difference = 239.7 ms) for both groups. These findings were consistent with literature, showing an overall verb disadvantage for both monolingual and bilingual groups, and an overall bilingual disadvantage for both nouns and verbs. A relevant interesting finding was a significant interaction between bilingualism and word category, that is, the bilingual disadvantage for nouns was larger compared to verbs (mean difference = 127.1 ms vs. 86 ms). Similarly, Faroqi-Shah and Milman (2015) investigated whether the bilingual disadvantage was influenced by grammatical category. They tested 33 high-proficiency Spanish-English and Asian Indian-English healthy adult bilinguals, and compared them with healthy monolingual English speakers. The participants retrieved verbs and nouns in two different tasks: picture-naming and verbal fluency (animal and action categories). Results showed lower accuracy for bilingual noun naming compared to monolinguals in both picture naming (mean difference=47.1%) and verbal fluency (mean difference = 4.1 items), but such disadvantage was not shown in verb naming. The comparable performance of verb naming between bilinguals and monolinguals contradicts previous finding of bilingual verb disadvantage (Jia et al., 2006; Van Hell & de Groot, 1998; Hernandez et al., 2008; Faroqi-Shah, 2012; Sheng et al., 2006; Klassert et al., 2014). Hence, even though

bilingual speakers show a disadvantage in spoken word retrieval, the magnitude of this disadvantage appears to differ by grammatical class. Therefore, further replication is needed as the findings are scant and the exact mechanism for bilingual disadvantage is still unclear.

To summarize, evidence from the TOT effects, picture naming, phrase production, sentence production, and verbal fluency tests has supported bilingual disadvantage in language production especially when lexical access is involved. One confound of this body of research is that many studies investigated language production in L2, which may or may not have been the dominant language of the bilinguals (but see Ivanova and Costa, 2008; and Kohnert et al., 1998). Further research is needed to replicate these findings examine bilingual verb and noun naming in both languages in order to investigate whether the pattern of word naming between the two languages differ from one and the other. Since the evidence of the bilingual disadvantage in language production is still scant, future research is needed to confirm the observed pattern of the bilingual disadvantage.

Accounts of Bilingual Disadvantage

In order to explain why bilinguals show a linguistic disadvantage, several different accounts have been proposed (Gollan et al., 2008; Van Hell & De Groot, 1998).

1. Weaker links hypothesis. The "weaker links" hypothesis proposes that bilinguals are disadvantaged compared to monolinguals on speaking tasks due to frequency effects, and it is proposed mainly by Gollan and colleagues (Gollan & Acenas, 2004; Gollan et al., 2005; Gollan et al., 2002; Gollan & Silverberg 2001; Ransdell & Fischler, 1987; Mägiste, 1979). According to the explanation, bilingual speakers show a

larger frequency effect than monolinguals because bilinguals use each language less frequently than do monolinguals. Therefore, the observed bilingual disadvantage in lexical processing results from weaker connections between semantic and lexical representations, indicating less accumulated practice overall (Burke, MacKay, Worthley, & Wade, 1991; Gollan et al., 2008). The frequency effect is also larger in L2 compared to L1 during bilingual word recognition, word production, and lexical decision tasks (Van Wijnendaele & Brysbaert, 2002; Gollan et al., 2008; Duyck, Vanderelst, Desmet, & Hartsuiker, 2008; Gollan, Sandoval, & Salmon, 2011). Because of the larger frequency effect in bilinguals, this account of bilingual disadvantage has also been referred to as the frequency lag hypothesis (Emmorey, Petrich, & Gollan, 2013). Second, Gollan et al. (2005) found that high-proficiency bilinguals performed slower than monolinguals in picture naming, but this disparity disappeared after stimuli repetitions. This repetition effect was argued to support the "weaker links" hypothesis because bilinguals improved naming performance when the frequency of use increased.

Even though the "weaker links" hypothesis provided explanations of the bilingual disadvantage in language production, Gollan et al. (2008) did not study verbs. Therefore, one can assume that frequency effects should apply to verbs as well. Faroqi-Shah and Milman's (2015) findings were inconsistent with the "weaker links" hypothesis. They examined verbal fluency (animal and action) and picture naming (nouns and verbs) in high-proficiency bilinguals and monolingual English speakers. The results revealed bilingual disadvantage only for animal fluency and noun naming, but not for action fluency or verb naming. The lack of bilingual verb disadvantage is contradictory with the "weaker links" hypothesis, which predicts similar bilingual disadvantage for nouns and

verbs due to the frequency effect. As to whether the bilingual disadvantage can be explained by the "weaker links" hypothesis is still debatable, further re-investigation is needed.

2. Cross-language interference hypothesis. Another account of bilingual disadvantage in language production is the cross-language interference between translation equivalents (Sandoval, Gollan, Ferreira, & Salmon, 2010). As bilinguals know at least two words for each concept, a given concept would stimulate competition of lexical representations between both languages (Van Hell & De Groot, 1998; Green, 1998; Hermans, 2004; Hermans, Bongaerts, de Bot, & Schreuder, 1998; Lee & Williams, 2001). Hence, bilinguals need to resolve this competition to select a single lexical representation for subsequent articulation, which is over and above the within-language lexical competition that all speakers (monolingual and bilingual) encounter.

Support for the cross-language interference account comes from different experimental tasks such as verbal fluency, word association, and picture-word interference. Sandoval et al. (2010) compared English monolinguals and Spanish-English bilinguals on verbal fluency tasks in order to examine whether the interference from translation equivalents causes the bilingual disadvantage. They found that bilinguals produced fewer accurate responses and were slower compared to monolingual participants, and this difference was greater in the non-dominant compared to dominant language. Additionally, bilinguals produced more low-frequency words and cognates than monolinguals, as well as more intrusion errors in the non-dominant language than in the dominant language. The results together implied interference from the non-target language. In a word association study, Macizo, Bajo, and Martín, (2010) tested twenty-

eight Spanish-English bilinguals, who were asked to determine whether pairs of English words were related. For example, the word "pie" is an interlexical homograph that means "foot" in Spanish. The first trial contained homograph-unrelated words (e.g., *pie-toe*) and control-unrelated words (e.g., *log-toe*), and the second trial included the English translation-related words (e.g., *foot-hand*) and control-related words (e.g., *finger-hand*). Results showed that bilinguals took longer time to respond in the homograph-unrelated condition because both the English and Spanish meanings of the homograph were activated, and bilinguals needed to suppress the irrelevant meaning. In the second trial, longer time was spent to respond in the translation-related conditions because non-target Spanish meaning of the homograph was inhibited. Hermans et al. (1998) further provided experimental support for the cross-language interference account by investigating whether lexical representations from the dominant language are activated during naming in the non-dominant language. They conducted a picture-word interference experiment in L2 with 64 non-balanced Dutch-English bilinguals. The interference stimuli were Dutch or English words that were semantically or phonologically related or unrelated to the target picture. The authors found significant interference effect with phonologically related Dutch distractors, indicating that Dutch (L1) name of the picture is frequently activated during lexical selection in L2.

According to the cross-language interference hypothesis, words that are more translatable across languages should interfere more. But there has been a debate regarding to how translatability of words affects bilingual word naming. As mentioned previously, Hermans et al. (1998) found a significant interference for naming English words that were highly translatable in Dutch. However, Gollan et al. (2005) found a

faster naming speed with high-translatability than low-translatability words for Spanish-English bilinguals. They termed this the "translation facilitation" hypothesis. Costa, Miozzo, & Caramazza (1999) also showed evidence that supported the translation facilitation account. They used a picture-word interference task in Catalan-Spanish bilinguals, who named target pictures more quickly when they were presented with written translation-equivalent distractors. Thus, the effects of translatability, which are a crucial test for the cross-language interference account, are inconsistent.

Even though the cross-language interference hypothesis was supported by a few studies (Sandoval et al., 2010; Macizo et al., 2010; Hermans et al., 1998), none of them studied interference effects on grammatical category differences. The cross language interference account assumes that the bilingual disadvantage for verbs would be smaller than for nouns because of less cross-linguistic overlap in verb meanings. Faroqi-Shah and Milman (2015) provided evidence that supported the cross-language interference account, as the bilingual disadvantage was found in animal verbal fluency and noun picture naming task, when bilinguals were compared to monolinguals. Similarly, Faroqi-Shah et al. (in prep) found a smaller bilingual verb disadvantage than bilingual noun disadvantage in their picture-naming task. Such smaller bilingual verb disadvantage is consistent with the cross-language interference hypothesis, which predicts smaller verb disadvantage due to less cross-language overlap for verbs. Given that the empirical evidence for the cross-language interference account is inconsistent, and since the role of cross-language interference on grammatical differences has not been systematically studied, further research needs to re-investigate the cross-language interference hypothesis.

Summary of Literature

In summary, studies that have compared bilingual and monolingual language performance have found a bilingual disadvantage such as more TOTs effects (Gollan & Silverberg, 2001; Gollan & Acenas, 2004; Gollan et al., 2005), lower verbal fluency scores (e.g., Gollan et al., 2002), and less accurate verb naming scores (e.g., Jia et al., 2006; Van Hell & De Groot, 1998). However, such a bilingual disadvantage is not universally present. As for grammatical category differences, some studies have surprisingly found a larger naming disadvantage for nouns compared to verbs in bilingual children (Sheng et al., 2006; Klassert et al., 2014), and healthy adults (Faroqi-Shah, Li, & Yoon, in prep; Faroqi-Shah & Milman, 2015) although there are contrary findings too (Van Hell & de Groot, 1998). There are two theoretical accounts of the bilingual disadvantage: the "weaker links" hypothesis and the cross-language interference hypothesis. Both of them have mixed empirical evidence and have been tested mainly with nouns. It is unknown if these accounts can accommodate the patterns of verb naming in bilinguals and if examining verb naming in the context of these accounts will help us decide which is a better account of bilingual language representation. The next section begins with introducing the current study and research questions.

The Current Study

The first purpose of the current study is to investigate how Mandarin-English bilingual healthy adults retrieve verbs and nouns compared to monolingual English healthy adults, and whether the previously observed pattern of verb-noun production (smaller verb disadvantage compared to noun disadvantage) in other bilingual groups (e.g., Spanish-English bilinguals of Faroqi-Shah et al., in prep) can be replicated for Mandarin-English bilinguals. In addition, the patterns of verb and noun retrieval in L1

and L2 of Mandarin-English bilinguals will be compared in order to verify if bilingual naming disadvantage could be also seen in L1 (e.g., Ivanova & Costa, 2008).

Even though several studies have investigated bilingual disadvantage in word production, the underlying mechanism that leads to bilingual disadvantage in word naming is less well understood. Therefore, the second aim of this study is to examine the empirical support for the "weaker-links" hypothesis and the cross-language interference hypothesis, which are different mechanisms that have been proposed to account for the bilingual disadvantage in word naming.

The main support for the "weaker links" hypothesis comes from a larger frequency effect for bilinguals compared to monolinguals. However, none of the studies have examined frequency effects on verbs, or on grammatical category differences. Hence, a further investigation of the "weaker links" hypothesis would examine if frequency effects can be replicated for Mandarin-English bilinguals in both languages and for nouns and verbs. If a larger frequency effect was found for monolinguals than for bilinguals, or in L1 than in L2 for bilinguals, or in one grammatical class than in the other, then it weakens support for the "weaker links" hypothesis.

The test for the cross-language interference hypothesis comes from how words that can be translated easily between two language (high translatability) differ from less translatable words (low translatability). Current evidence on translatability is contradictory (Hermans et al., 1998; Gollan et al., 2015; Costa et al., 1999). Translatability effect indicates the impact of lexical translatability on the speed of lexical retrieval, and is obtained from the difference of picture naming speed between low and high translatable items. If a weaker bilingual performance for low translatable items than

for high translatable items was found in both noun and verb naming, then the cross-language interference hypothesis is not supported.

Research Questions and Hypotheses

1. a) How do Mandarin-English bilingual healthy adults retrieve verbs and nouns in English compared to healthy monolingual English speaking adults?

   b) Is the pattern (smaller verb disadvantage compared to noun disadvantage) of verb-noun production in other bilingual groups (e.g., Faroqi-Shah et al., in prep) replicated for Mandarin-English bilinguals in L1 (Mandarin) versus in L2 (English)?

Hypothesis: Based on numerous prior studies that have compared noun and verb production (e.g., Szekeley et al., 2005), an interaction between language group and word type is expected. It is hypothesized that naming latencies will be slower for verbs compared to nouns in both bilingual and monolingual groups, bilinguals will be slower than monolinguals for verb and noun naming in both L1 and L2 (Ivanova & Costa, 2008), and bilingual disadvantage for noun naming will be larger than for verb naming (Faroqi-Shah et al., in prep; Faroqi-Shah & Milman, 2015) in both L1 and L2.

2. Which theory better accounts for the bilingual naming disadvantage across both grammatical categories?

   a. Is there a larger frequency effect in bilinguals compared to monolinguals as proposed by the "weaker-links" hypothesis?

   Hypothesis: According to the "weaker-links" hypothesis (Gollan et al., 2008), a larger frequency effect is expected in bilinguals compared to monolinguals (e.g., Gollan & Acenas, 2004; Gollan et al., 2005; Gollan et al., 2002; Gollan

& Silverberg 2001), particularly larger in L2 than in L1 (i.e. Gollan et al., 2008). In addition, the frequency effects for bilingual verb naming and noun naming are expected to be similar. Thus, there will be a main effect of group but not interaction between word category and group.

b. In bilinguals, is there an association between concept translatability and naming latencies, as predicted by the cross-language interference hypothesis?

Hypothesis: The cross-language interference hypothesis predicts faster translation time in high translatable items than in low translatable items. In addition, faster picture naming speed is hypothesized to be associated with low translatable items, and slower picture naming speed is associated with high translatable items (Hermans et al., 1998).

Methods

Overall design

Bilingual and monolingual groups were compared between each other to answer research questions 1 and 2. For the first research question, language groups (monolingual, bilingual L1, bilingual L2) and grammatical categories (noun, verb) were the independent variables. The dependent variables included reaction time in milliseconds and response accuracy in percent. When the "weaker links" hypothesis was tested to answer research question 2a, language groups (bilingual vs. monolingual) and frequency effect for word categories (verb vs. noun) were the independent measures, naming latencies or percent accuracy was the dependent measures. When the cross-language interference hypothesis was tested, the independent variables were translatability (high vs. low) and grammatical

categories (verb vs. noun), and the dependent measure was naming latencies or percent accuracy for bilingual L1 and L2.

Participants

Thirty-nine Mandarin-English bilinguals were contacted via e-mail and screened for language proficiency. Twenty-one of those bilinguals (15 females, 6 males; Mean age=23, SD =2.7; Mean years of education=16, SD=1.9) and twenty-one monolingual English participants (16 females, 5 males; Mean age=22, SD =4.7; Mean years of education=16, SD=2.1) were recruited and matched for age ($t(40)=-0.83$, $p>0.05$), gender ($t(40)=-0.34$, $p>0.05$) and education ($t(40)=-1.33$, $p>0.05$). All of the participants were right-handed except for three monolinguals who were left-handed. The bilingual group met the criteria that their native language was Mandarin, and have been exposed to English acquisition before the age of 12 years (Szekely et al., 2005). The mean exposure age was 0yr (since birth) for Mandarin and was 7yr for English (SD=2.8) for the bilingual group. Because balanced or nearly balanced proficiency of both languages is likely to consistently co-activate both languages during word production (Blumenfeld & Marian, 2007), this study focused on bilingual participants who were highly proficient. This was determined by ACTFL (American Council on the Teaching of Foreign Languages) scores of oral interviews (Swender, Conrad, & Vicars, 2012) and LexTale (Lemhöfer & Broersma, 2012), which was for L2 (English) (see details below). For the monolingual English group, participants were all native speakers of English with at least high school education, and had no other language exposure before the age of 12 years (Szekely et al., 2005). Based on self-report, participants were excluded if they had a positive history of neurodevelopmental conditions.

Language proficiency screening and testing: The inclusionary criterion of high proficiency bilingualism was determined by oral interviews (see Appendix B for questions) in Mandarin and English, conducted via phone, and were audio recorded for later scoring. There were two oral interview questions. The question for testing Mandarin proficiency was, "*Please describe the steps of making ramen noodles*", and the questions for testing English proficiency was, "*What is the most unforgettable experience in your life*" (see Appendix B for details). Each response was scored according to ACTFL proficiency guidelines (Swender et al., 2012), which outline five major levels of proficiency described in speaking tasks: Distinguished, Superior, Advanced, Intermediate, and Novice. According to Swender et al. (2012), these criteria were based on the content, context, accuracy, and discourse types that were associated with tasks at each level. For example, according to the ACTFL guidelines 2012 (Swender et al., 2012), advanced-level speakers showed abundant language skills, and could produce narratives in a clear manner. They also had sufficient control of basic structures and generic vocabulary to be understood. The topics were handled concretely by means of narration and description in past, present, and future tenses. The qualified bilingual participants all scored Advanced, Superior, or Distinguished level.

An objective vocabulary test, *Lexical Test for Advanced Learners of English* (www.lextale.com) was given to assess bilinguals' English proficiency. LexTale is a lexical decision task that tests vocabulary knowledge for medium to highly proficient speakers of English as a second language, and it takes less than 4 minutes to do. The scoring procedures of LexTALE followed Lemhöfer & Broersma (2012). The automatically returned percentage of correct responses (% $correct_{av}$) was calculated as:

((number of words correct/40*100) + (number of nonwords correct/20*100)) / 2. The qualified participants all scored above 70%. In addition, language dominance rating was obtained on the testing day from Bilingual Language Profile (Birdsong, Gertken, & Amengual, 2012), which is a self-report instrument for assessing language dominance. The range of possible scores for the language dominance index was -218 to 218, with the more extreme scores indicating higher dominance in any one language. A score of zero indicated equal language balance. The mean language dominance index for the bilingual participants was -66.39 (SD =29.6), which was in the middle quartile (25% - 75%). That is, Mandarin was reported to be slightly more frequently used than English, and it was the more dominant language.

Stimuli and Procedures

Picture-naming task. In order to determine the accuracy for Mandarin word items, a naming consistency check for Mandarin nouns and verbs was conducted on 6 native Mandarin speaking subjects, who were not included in the formal study. The six raters were recruited from both Mainland China and United States. The native Mandarin participants from U.S were the ones who have been exposed to rich English less than 6 months. The education background was matched for all of the participants. During the naming consistency check, participants were given black-and-white line drawings of 150 common object and 150 transitive and intransitive action pictures that were selected from the full stimulus set of the CRL international picture-naming project at http://www.crl.ucsd.edu/~aszekely/ipnp/actobj.html (Bates et al., 2000), and they were asked to provide the first three names that came to their mind to name a picture (Li, Wang, & Idsardi, 2015). In order to be selected as final stimuli, all raters had to have the

target word in their list, and at least three of them used the target name as their first choice. Ultimately, 100 objects and 100 actions were used as stimuli for each language (English and Mandarin).

The final stimuli were included in Appendix C (a) and (b). For each English word item, the frequency value was retrieved from SUBTLEX word-frequency corpus (Brysbaert & New, 2009). For each Mandarin word item, the frequency value was obtained from Wmillion (frequency of the word per million words) in the SUBTLEX-CH word frequency corpus (Cai & Brysbaert, 2010). The object and action stimuli were divided into two groups: high frequency (HF), and low frequency (LF). As per the frequency cut-offs used by Gollan et al. (2008), the frequency range of LF words varied from 0 – 20/million. The frequency values of HF words were greater than 30/million, as the gap between high and low frequency ranges helped to eliminate those words with frequency values that approximated the cut-off scores. The HF and LF verbs and nouns were matched for name agreement (nouns: $t(98)=-1.25$, $p>0.05$; verbs: $t(98)=1.50$, $p>0.05$) (Bates et al., 2000).

Bilingual participants were tested individually in a quiet room for an approximately 2-hour long session, with rest breaks. Tasks for bilingual participants were administered in the following sequence: language proficiency (ACTFL and LexTale), picture naming task in the first language, language dominance (BLP questionnaire), neurologically healthy adults questionnaire, picture naming task in the other language, and translation task. The English picture naming task and Mandarin picture naming task were administered separately as much as possible to eliminate familiarity effects of testing stimuli. Monolingual participants were tested for approximately 1 hour, and the

tasks included English picture naming for verbs and nouns.

The sequence of testing bilingual language (Mandarin vs. English) and word category (verb vs. noun) was counterbalanced across participants. The procedures followed the norming studies of IPNP in Szekely et al. (2005). Participants were instructed to use a single word to name each picture as quickly as they could, and to avoid invalid responses, such as coughs, false starts, and hesitations "um", etc. For the English verb-naming task, participants were asked to produce the uninflected form only. For the Mandarin verb-naming task, participants were instructed to use the best and shortest name for the depicted. Participants were given eight practice items for each testing block of word class. Each testing trial was presented for 3000ms, following a 200ms centered fixation cross "+" on the center of the screen. The next trial began 1000ms after the voice key detected a response or after 3000ms if the voice key did not detect a response. There was a short break after every 25 pictures of stimuli. The stimuli were digitally presented within DMDX – a Windows experiment presentation program (Forster, & Forster, 2003). Participants wore a headset microphone and their response time to each trial was logged by a voice trigger key that was part of DMDX. An experimenter sat next to the participant in the testing room in order to provide instructions and helped record responses. The experimenter also typed up notes during the session to indicate any incorrect responses or invalid responses, such as noises or no responses. Participants' responses were also audio recorded for later verification and analysis purposes.

Translation task. Given that ease of access to translation equivalents in Mandarin and English is unique to each bilingual participant, and that there are no existing norms

for translation, each bilingual participant completed a translation task following both of the picture-naming tasks. The stimuli for this task were the same 200 English verbs and nouns that were used in the picture-naming task.

Words were presented in English one at a time on the screen, as the high-proficiency bilingual participants might not be familiar with reading in Mandarin Chinese. The translation stimuli were presented in two blocks (verbs and nouns), and items were randomized within each individual block. Similar to the picture naming task, each word item was presented for 3000ms, following a 200ms centered fixation cross "+" on the center of the screen. The next trial began 1000ms after the voice key detected a response or after 3000ms if the voice key did not detect a response. There was a short break after every 25 pictures of stimuli. Participants were asked to translate the 200 stimuli words from English to Mandarin as quickly as possible (see Appendix B for specific instructions), and their response time was recorded by a voice key triggered in DMDX. The experimenter stayed with the participant in the testing room to provide instructions and record responses. Comments were also typed up during the session to indicate any incorrect responses or invalid responses, such as noises or no responses.

Data Analysis

The responses were recorded in accuracy percent (%) based on dominant name, which came from the IPNP database (Bates et al., 2000) for English, and from the six raters for Mandarin Chinese. Statistical analyses of all the reaction times of accurate responses were also computed based on logarithmically transformed naming speed to obtain robust coefficient. According to procedures in Szekely et al. (2005), valid responses included those with a codable name and usable response times (when the voice

key was triggered and there were no coughs, hesitations, false starts, etc.). Based on the range of reaction times reported by Szekely et al. (2005), responses faster than 500ms and slower than 3000ms were excluded as outliers: very fast reaction times might occur because the voice key might have been triggered prior to voice onset (such as heavy breathing), and very slow responses might not accurately reflect automatic word access. Invalid and incorrect responses were excluded from further analysis: 7.9% of nouns and 24.1% of verbs were discarded in monolingual picture-naming responses, 17.6% of nouns and 40.6% of verbs were eliminated in bilingual English responses, and 13.4% of nouns and 24.2% of verbs were excluded in bilingual Mandarin responses. This is consistent with prior studies showing lower percent of valid naming for verbs (Jia et al., 2006; Van Hell & de Groot, 1998; Hernandez et al., 2008; Faroqi-Shah, 2012; Faroqi-Shah et al., in prep). A summary of data can be found in Table 1. Reaction time data were statistically analyzed using a linear mixed effects model (Baayen, Davidson, & Bates, 2008).

Table 1. Object and action naming responses of monolingual English and bilingual Mandarin-English speakers.

	Object Naming			Action Naming		
	Bilingual		Monolingual	Bilingual		Monolingual
	Mandarin	English	English	Mandarin	English	English
% valid and correct responses	86.6	82.4	92.1	75.8	59.4	75.9
% valid and correct low-frequency responses	88.7	75.6	92.8	69.7	46.3	70.7
% valid and correct high-frequency responses	84.8	89.2	91.3	81.3	72.6	81

Research Question1. Two separate 3*2 ANOVAs were conducted to answer the

first research question with language group (monolingual, bilingual L1, bilingual L2) and word type (verb, noun) as independent variables.

Research Question 2a. In order to compare the size of the frequency effect, two 3*2 ANOVAs were conducted with language group (monolingual, bilingual L1, bilingual L2) and frequency effect (verbs, nouns) as independent variables, and mean RTs or percent accuracy of picture naming as dependent variables. Frequency effect refers to the difference in RT/accuracy between high and low frequency items.

Research Question 2b. Research Question 2b required naming responses to be sorted into responses for high and low translatability items. For this, the translation speeds (in milliseconds from the translation task) were used to determine lexical translatability. The word items were then sorted into high and low translatability based on the mean translation speed of each participant. High translatability words referred to the word items that were translated faster (shorter RTs) than the mean RT, and low translatability words referred to those that were translated slower (longer RTs) than the mean RT. Prior to analysis of translation responses, 6.3% of invalid (3000<ms<500) and incorrect nouns and 14.6% of invalid and incorrect verbs were eliminated. To examine the cross-language interference hypothesis, 2*2 ANOVAs for Log RTs or percent accuracy of picture naming were conducted with word category (verb, noun) and translatability (high, low) as independent variables for both bilingual L1 and bilingual L2.

Results

Research Question1. Reaction times (RTs) and accuracy for each participant group and language is shown in Figure 1, and the results of the statistical comparisons are summarized in Table 2. RTs were conducted through linear mixed effects analysis.

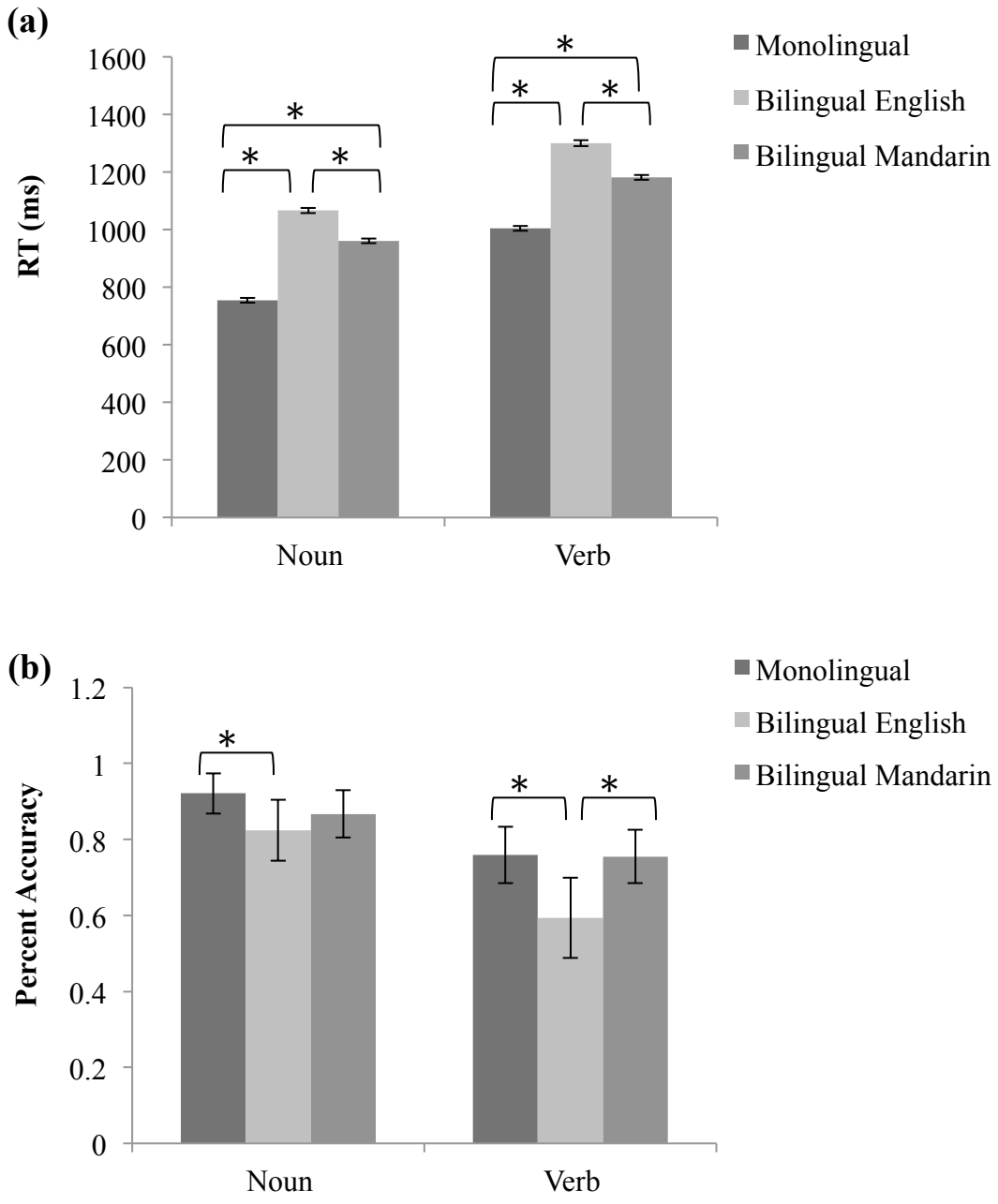


Figure 1. Monolinguals and Bilinguals picture-naming reaction times in milliseconds (a) and percent accuracy (b) for nouns and verbs. Error bars show the standard error (SE) of the raw RTs and percent accuracy.

Table 2. Statistical comparisons between language group and word category for reaction times and percent accuracy.

Research Question & Comparison	RT	Accuracy
1. 3 (group: monolingual, bilingual L1, bilingual L2) x 2 (word category: verb, nouns)	**Main effect of group:** F(2,9907)=756.6**	**Main effect of group:** F(2,120)=34.2**
	Monolingual vs. Bilingual L2: mean difference(SE) = -0.278(0.007)*	Monolingual vs. Bilingual L2: mean difference(SE)= 0.13(0.017)*
	Monolingual vs. Bilingual L1: mean difference(SE) = -0.184(0.007)*	Monolingual vs. Bilingual L1: mean difference(SE)= 0.03(0.017)
	Bilingual L1 vs. Bilingual L2: mean difference(SE)=-0.094(0.007)*	Bilingual L1 vs. Bilingual L2: mean difference(SE)= 0.1(0.017)*
	Main effect of word category: F(1,9907)=1445.0** mean difference(SE)= 0.226(0.006)*	**Main effect of word category:** F(1,120)=153.9**, mean difference(SE)= 0.168(0.014)*
	Interaction: F(2,9907)=22.1**	**Interaction:** F(2,120)=6.4**

(**=p<0.01; *=p<0.05)

As can be seen in Table 2, there was a main effect of participant group and word category, and a significant group by category interaction. RT data showed bilinguals in both L1 and L2 were slower than monolinguals, and accuracy data showed bilingual L2 was less accurate than monolinguals, both indicated a bilingual disadvantage. Verb naming was slower and less accurate than noun naming for all three participant groups, showing a verb disadvantage. The interaction effect showed that the bilingual disadvantage was smaller for verbs (L1: 177.2ms; L2: 295.6ms) than it was for nouns (L1: 206.9ms; L2: 311.7ms) for both L1 and L2.

Research Question 2a. Figure 2 illustrates the mean reaction times (ms) and accuracy for frequency effect (high frequency vs. low frequency) for verbs and nouns in each language group, and Table 3 shows the results of the statistical comparisons.

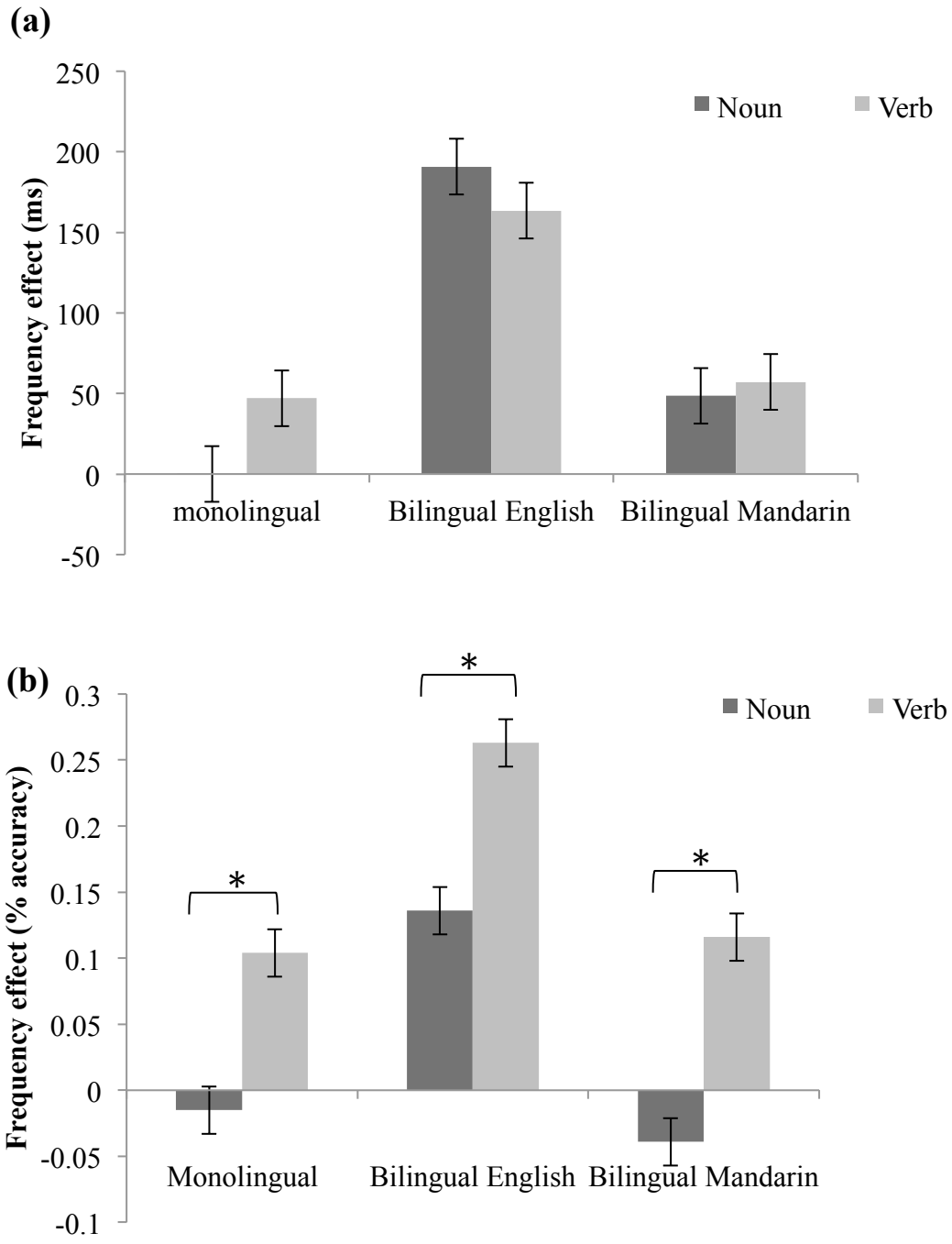


Figure 2. Frequency effect for verbs and nouns in mean reaction times (a) and percent accuracy (b) for each language group; Error bars show the standard error (SE) of the mean RTs and percent accuracy.

Table 3. Statistical comparisons between language and frequency for nouns and verbs when RT and percent accuracy were measured.

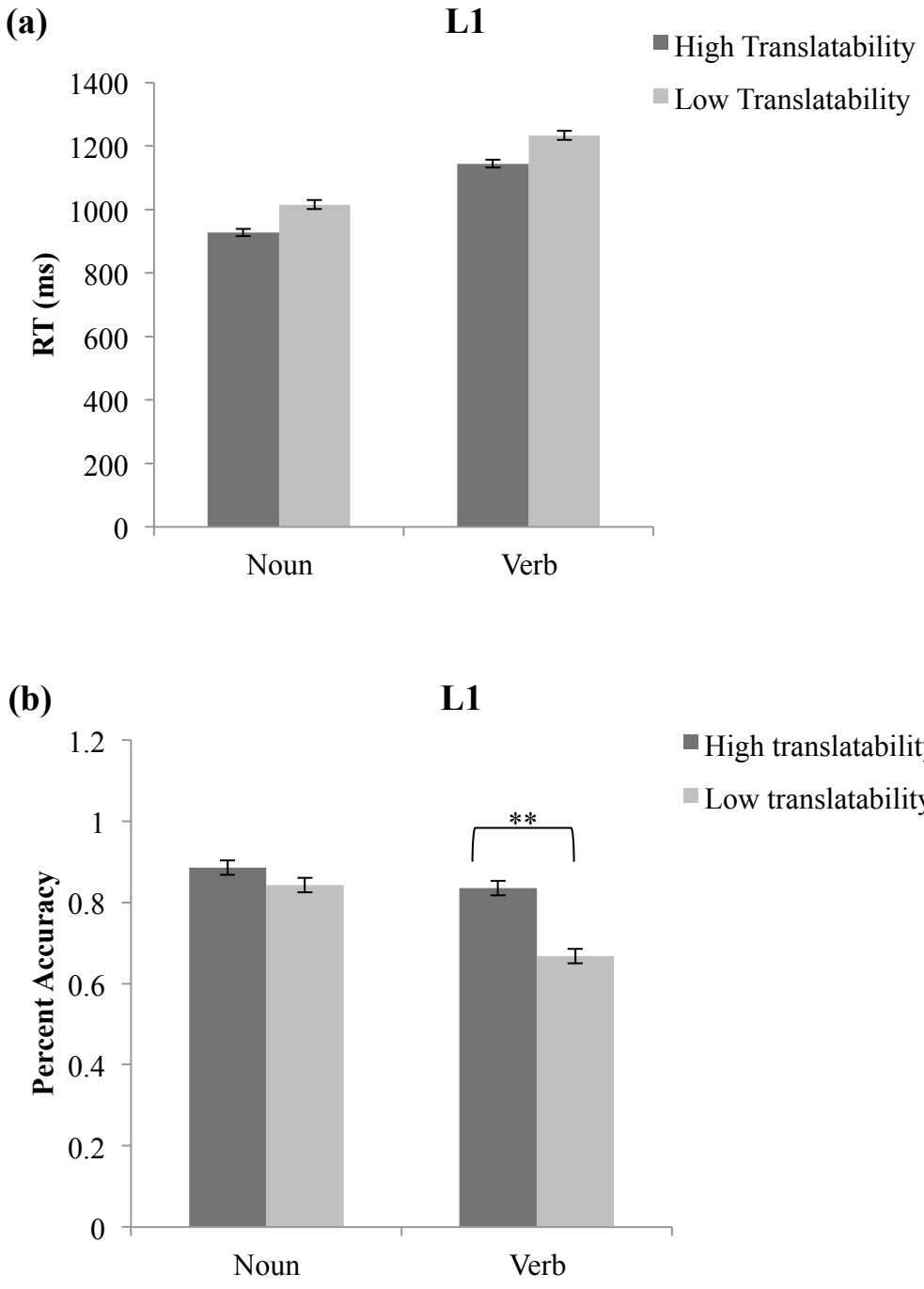
Research Question & Comparison	RT	Accuracy
2a. Frequency Effect between Nouns and Verbs 3(group: monolingual, bilingual L1, bilingual L2) x 2(frequency effect for word category: noun vs. verb)	**Main effect of FE for word category:** F(1,120)=1.54 mean difference(SE)= 0.01(0.01)	**Main effect of FE for word category:** F(1,120)=78.8** mean difference(SE)= 0.13(0.01)*
	Main effect of group: F(2,120)=36.1**	**Main effect of group:** F(2,120)=49.0**
	Bilingual L1 vs. Monolingual: mean difference(SE)= 0.01(0.01)	Bilingual L1 vs. Monolingual: mean difference(SE)= -0.01(0.02)
	Bilingual L2 vs. Monolingual: mean difference(SE)=0.1(0.01)*	Bilingual L2 vs. Monolingual: mean difference(SE)= -0.15(0.02)*
	Bilingual L2 vs. Bilingual L1: mean difference(SE)=0.09(0.01)*	Bilingual L2 vs. Bilingual L1: mean difference(SE)= -0.16(0.02)*
	Interaction: F(2,120)=1.97	**Interaction:** F(2,120)=0.53

(**=p<0.01; *=p<0.05)

As shown in Table 3, there was a main effect of group, showing that bilinguals in L2 had a larger frequency effect than in their L1 and monolinguals. Monolinguals and Bilingual L1 frequency effects did not differ (both for RT and accuracy). There was a main effect of frequency effect for word category in accuracy data, but not in RT data. In addition, the interaction between frequency effect for word category and group was not significant, indicating that the magnitude of the frequency effect for verbs and nouns was comparable across all language groups.

Research Question 2b. This question investigated whether there was an association between translatability and naming latencies, in order to test the cross-language interference hypothesis. The results of the statistical comparisons are shown in

table 4. The reaction times (RTs) and percent accuracy for high and low translatability verbs and nouns in bilingual L1 and bilingual L2 were illustrated in Figure 3.



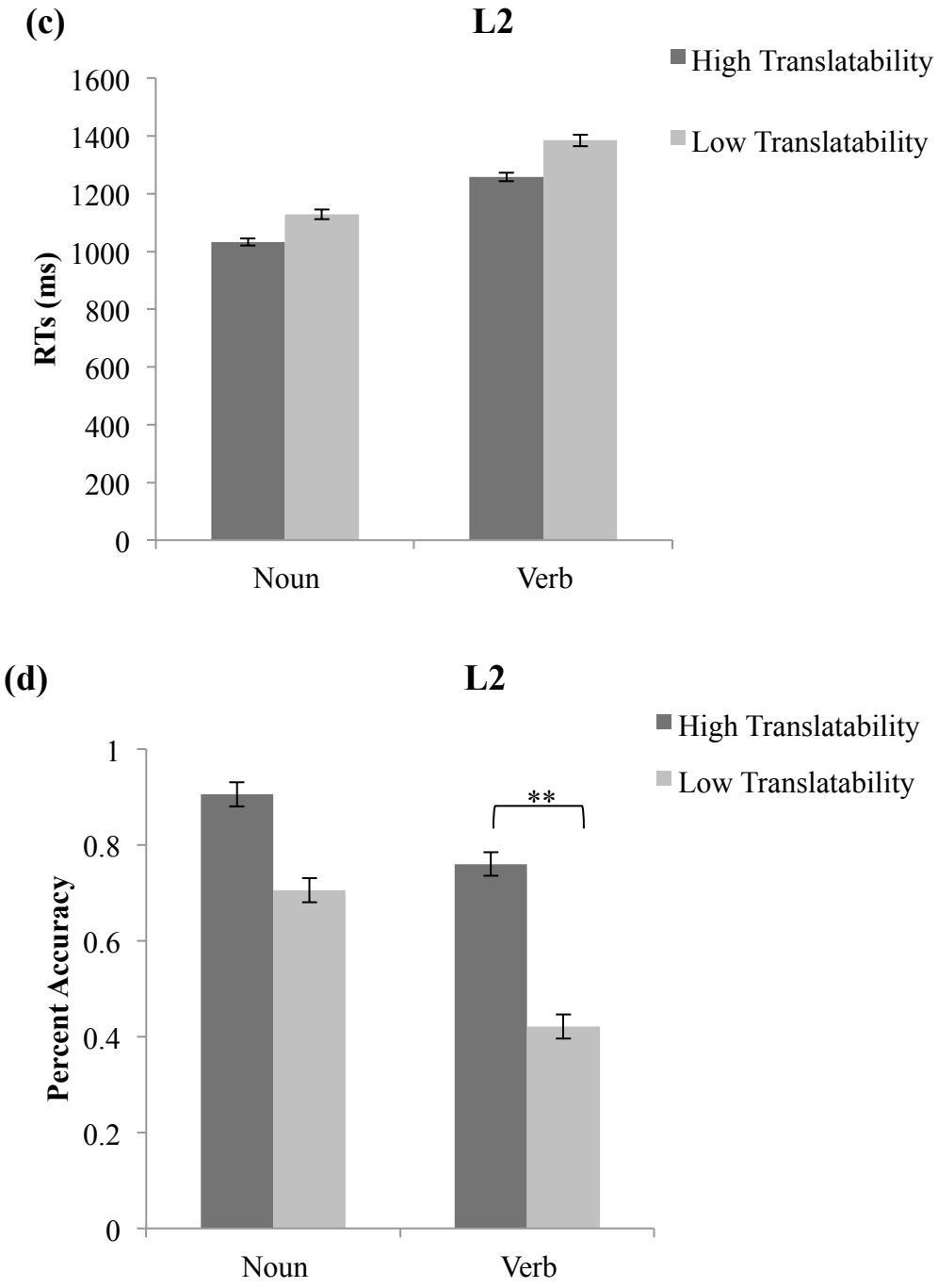


Figure 3. RTs in milliseconds and percent accuracy for high- and low-translatability verbs and nouns in L1 (a), (b), and in L2 (c), (d). Error bars show the standard error (SE) of the raw RTs and percent accuracy.

Table 4. Statistical comparisons between language and translatability for nouns and verbs when RTs and percent accuracy were measured.

Research Question & Comparison	RT	Accuracy
2b. L1 2 (translatability: high vs. low) x 2 (word category: verb vs. noun)	**Main effect of translatability** F(1,3403)=50.1** mean difference(SE)= 0.08(0.01)* **Main effect of word category** F(1,3403)=358.2** mean difference(SE)=0.20(0.01)* **Interaction:** F(1,3403)=0.25	**Main effect of translatability:** F(1,80)=36.3** mean difference (SE)= 0.12(0.014)* **Main effect of word category** F(1,80)=40.9** mean difference(SE)=0.11(0.02)* **Interaction:** F(1,80)=12.5**
Post-hoc pairwise comparisons T for translatability effect (high vs. low) for verbs and nouns	t(40)=1.48 mean difference(SE)=0.03(0.02)	t(40)=4.4** mean difference(SE)=0.12(0.03)
2b. L2 2 (translatability: high vs. low) x 2 (word category: verb vs. noun)	**Main effect of translatability** F(1,2976)=51.4** mean difference (SE)= 0.09(0.01)* **Main effect of word category** F(1,2976)=234.2** mean difference(SE)=0.19(0.01)* **Interaction:** F(1,2976)=0.073	**Main effect of translatability:** F(1,80)=116.5** mean difference (SE)= 0.27(0.025)* **Main effect of word category** F(1,80)=73.7** mean difference(SE)=0.21(0.02)* **Interaction:** F(1,80)=7.7**
Post-hoc pairwise comparisons T for translatability effect (high vs. low) for verbs and nouns	t(40)=0.48 mean difference(SE)=0.02(0.03)	t(40)=3.7** mean difference(SE)=0.14(0.04)

(**=p<0.01; *=p<0.05)

According to Table 4, RT data and accuracy data both showed main effects for translatability and word category in both languages of the bilinguals. Low-translatability words were slower and less accurate than high-translatability words, and verbs were slower and less accurate than nouns (Figure 3). Accuracy data in addition showed significant translatability by word category interactions for both L1 and L2. The

translatability effects for verbs were larger than for nouns for both L1 ($t(40)=4.4$, $p<.01$) and L2 ($t(40)=3.7$, $p<.01$), as shown in Figure 3(b) and 3(d).

Discussion

This study aimed to investigate the bilingual disadvantage in Mandarin-English speakers by comparing monolingual English and Mandarin-English bilingual speakers in picture naming. Additionally, the "weaker-links" hypothesis and the cross-language interference hypothesis were tested to investigate which one could better explain the bilingual disadvantage in lexical retrieval for both nouns and verbs.

The bilingual effect

The first research question asked how do Mandarin-English bilingual healthy adults retrieve verbs and nouns in English compared to healthy monolingual English speaking adults, and whether the pattern of verb-noun production in other bilingual groups could be replicated for Mandarin-English bilinguals in L1 (Mandarin) versus in L2 (English). This study found a bilingual disadvantage compared to monolinguals, in both L1 and L2, and the bilingual disadvantage was larger in L2 than in L1. The presence of a bilingual disadvantage in both L1 and L2 and the larger disadvantage in L2 was consistent with previous studies that examined bilingual populations such as Spanish-English, Catalan-English and French-English, (e.g., Roberts et al., 2002; Gollan et al., 2002; Gollan et al., 2005; Ivanova and Costa, 2008). However, none of the prior bilinguals studies have investigated the bilingual disadvantage for verb and noun retrieval in Mandarin-English bilinguals. This is one of the very few word retrieval studies of bilinguals speaking an East Asian language, and one of a few bilingual studies of Asian languages (e.g., Faroqi-Shah et al., 2016). All of the bilinguals in the current study were

highly proficient, and were exposed to L2 before 12 years old. So it is interesting to see that learning a second language at an early age can slow bilinguals down even in L1, which is also the dominant language.

The word category effect

Verbs were slower and less accurate compared to nouns in both monolinguals and bilinguals, and this finding was consistent with prior studies about verb retrieval in monolinguals (e.g., Kauschke & Frankenberg, 2008; Shao et al., 2012; Szekely et al., 2005; Matzig et al., 2009), healthy bilinguals (Jia et al., 2006; Van Hell & de Groot, 1998; Hernandez et al., 2008;), and bilinguals with brain damage (e.g., Faroqi-Shah, 2012). However, none of these prior bilingual studies directly compared verbs and nouns in a picture naming task with both reaction times and percent accuracy being measured, which was innovative in the current study. In order to account for the greater difficulty with verb retrieval, Vigliocco et al. (2011) suggested that verbs are more complex in their semantic, syntactic, and morphological representations, which leads to greater demands of processing compared to nouns. According to *emergentist* views about the difference between grammatical categories, grammatical class was a property emerging from a combination of semantic constraints, in which verbs were more semantically abstract, and could refer to events and actions that were temporally transient, but nouns were more semantically concrete, which could be counted and referred to objects (Vigliocco et al., 2011; Warrington & Shallice, 1984). Additionally, some action pictures could be more conceptually complex than object pictures (Gentner, 1982), and perception of an action in a picture requires participants to mentally depict the action event. Consistent with this, a regression analysis by Faroqi-Shah et al. (in prep) also found visual complexity of the

picture was a predictor for both action and object naming speed. Thus the slower naming speed and lower accuracy for verbs than for nouns could be attributed to their semantic, morphosyntactic complexity, as well to picture complexity.

The bilingual disadvantage was found larger for nouns (206.9ms in Mandarin and 311.7ms in English) than for verbs (177.2ms in Mandarin and 295.6ms in English) in both L1 and in L2. This finding was consistent with two prior studies of bilingual adults. Faroqi-Shah et al. (in prep) found a bilingual disadvantage of 127.1ms for nouns and 86ms for verbs in Spanish-English bilinguals, and Faroqi-Shah and Milman (2015) found lower accuracy for bilingual noun naming compared to monolinguals in both picture naming (mean difference=47.1%) and verbal fluency (mean difference = 4.1 items). There were a few potential explanations to this finding. First, nouns may be semantically more similar across languages compared to verbs, which implies that nouns might encounter greater cross-language interference from the non-target language compared to verbs (Van Hell, 2002; Van Hell & De Groot, 1998). Thus, it might take longer to resolve the stronger cross-language competition during noun retrieval compared to resolving the weaker cross-language interference during verb retrieval. Support for the argument that verbs have smaller similarity across languages comes from Bultena, Dijkstra, and Van Hell (2013), who investigated cognate effect and word class ambiguity effect using a lexical decision task in Dutch-English bilinguals (L2 only). In bilingual processing, translation equivalents with form overlap were cognates, and words with forms that were shared between two word classes had word class ambiguity (e.g., to cook and the cook). Bultena and colleagues (2013) found that both verb processing and noun processing were facilitated by cognate status, and facilitation for word class ambiguity was only found for

verbs. Bultena et al. (2013) suggested that verbs showed a word class ambiguity effect because verb representations were more complex than nouns, leading to less cross-language overlaps and smaller between-language interference. Second, the smaller verbs disadvantage that was found in Mandarin-English bilinguals could be due to the verb-friendly feature of Mandarin Chinese. Verbs in Mandarin Chinese were morphologically simpler than verbs in English, and they are more likely to be in the sentence-final position (Huang, 1989). Mandarin verbs were also found acquired earlier in young children by Tardif (1996). Therefore, verbs might induce less effort to retrieve in Mandarin-English bilinguals compared to nouns, which caused a larger latency gap between bilinguals and monolinguals. However, this language feature was not able to account for the bilingual verb disadvantage that was found in other bilingual studies (e.g., Faroqi-Shah, in prep; Faroqi-Shah & Milman, 2015), which studied different bilingual populations. The next paragraph further discussed the cross-language interference for verb and noun retrieval, and how it could partially explain the smaller bilingual verb disadvantage in this study.

Effect of translatability on lexical retrieval

The current study found that bilinguals named words with low-translatability more slowly compared to words with high-translatability. It contradicted previous evidence, which showed words that were more translatable were slower and less accurate than words that were less translatable (Sandoval et al., 2010; Macizo et al., 2010; Hermans et al., 1998). None of the prior studies have used picture-naming task that was used in the current study, and none of them have investigated the cross-language interference effect between different word categories. Also in the current study, the cross-language interference account was tested based on lexical translatability, which was measured in response speed for each individual in a translation task. But most prior

studies examined the cross language interference differently, such as by presenting translation equivalents on the screen in picture-word interference experiments (Hermans et al., 1998). One study that examined bilingual TOT effects also measured lexical translatability (Gollan and Acenas, 2004), which required bilinguals to translate English words into their L1 (in paper and pen format). They measured the translatability based on percent of accuracy, but not naming speed. Since the picture-naming task in the current study was time constrained, we thought that measuring the translatability in naming speed could better explain the bilingual lexical retrieval.

The cross-language interference hypothesis (Green, 1998; Hermans et al., 1998; Lee and Williams, 2001) also predicted a smaller bilingual verb disadvantage than noun disadvantage, assuming that verbs were less translatable compared to nouns. The significant interactions between translatability and word category that were found in accuracy data suggested that verbs with low translatability were also less accurate in picture naming. This finding could partially explain the smaller bilingual verb disadvantage in this particular study, as it was possibly because more inaccurate data were eliminated for verb naming compared to noun naming. However, it could not explain other bilingual studies that also found the same pattern. For example, Faroqi-Shah & Milman (2015) investigated the bilingual disadvantage in a verbal fluency task (animal and action categories). The smaller bilingual verb disadvantage in their study however was not due to the elimination of any inaccurate responses.

These findings instead coincided with the "translation facilitation" hypothesis (Gollan et al., 2005; Gollan & Acenas, 2004; Costa et al., 1999). It was highly likely that the co-activation of two languages for high translatability words cued each other and

strengthened the lexical representations in each language. For high-translatability words, each picture activated both lexical representations in Mandarin and in English. But the picture stimuli for low-translatability words might just have activated the target language. It was also possible that the lexical representation in the nontarget language provided a boost to the semantic representation of the picture, which then boosted the access to select the target lexical representation.

Effect of word frequency on lexical retrieval

Bilinguals showed a larger frequency effect in L2 than in L1 than in monolinguals. It confirmed evidence from previous studies that the frequency effect was more marked in bilingual L2 than in bilingual L1 (Van Wijnendaele & Brysbaert, 2002; Gollan et al., 2008; Duyck et al., 2008; Gollan et al., 2011). None of these prior studies have directly compared frequency effect for verbs and nouns in picture naming. Some of them focused on nouns using different tasks, such as phonological priming (Van Wijnendaele & Brysbaert, 2002), and lexical decision (Duyck et al., 2008). The current finding supported the "weaker links" hypothesis by suggesting that when a language was less frequently used, a more exaggerated frequency effect was found.

Since 1960a, some monolingual studies have found frequency effects in picture naming (e.g., Oldfield & Wingfield, 1965; Bartram, 1974; Griffin & Bock, 1998;). More recent bilinguals studies also have found such frequency effect in similar tasks (e.g., Gollan et al., 2005; Gollan et al., 2008). The findings of frequency effect on lexical retrieval could be accounted by different models. The models of language production (activation hypothesis) have suggested that lexical representations accumulated baseline levels of activation as the degree of use increased, then baseline levels of activation were

promoted upwards with increased use, and lexical representation was selected when activation levels reached thresholds (Caramazza, 1997; Griffin & Bock, 1998; Levelt et al., 1999). Models of lexical access on the other hand had explained the frequency effect in bilinguals. These models had frequency effect as an asymptotic learning process and predicted a steeper slope of the logarithmic function where L2 words were represented, leading to a larger frequency effect in L2 than in L1 (e.g., McCusker, 1977).

The magnitude of frequency effect for each language was similar between verbs and nouns. This finding supported the "weaker-links" hypothesis (Gollan et al., 2008) because it predicted the frequency effect that was found in object naming should also be observed in action naming for bilinguals. But at this time, it is hard to explain the smaller bilingual verb disadvantage in picture naming by using the "weaker-links" hypothesis, as it seemed that the frequency effect should be equally observed during bilingual lexical retrieval, which was not the case in the current study.

Conclusions and Future Research Directions

The findings of this study confirmed evidence from prior bilingual studies that bilinguals were slower and less accurate than monolinguals for nouns (Gollan & Silverberg, 2001; Gollan & Acenas, 2004; Gollan et al., 2005; Gollan et al., 2008; Roberts et al., 2002), and extended the findings of the very sparse literature on bilingual verb access (Faroqi-Shah & Milman, 2015; Faroqi-Shah et a., in prep; Sheng et al., 2006; Klassert et al., 2014; Jia et al., 2006; Van Hell & de Groot, 1998; Hernandez et al., 2008;) with a relatively unexplored bilingual group. Given that there was a robust and larger frequency effect in bilinguals than monolinguals, this study supported the "weaker-links" account of bilingual disadvantage (Gollan et al., 2008). Further, the translatability effect

failed to support cross-language interference as a source of bilingual disadvantage (Van Hell & De Groot, 1998; Green, 1998; Hermans, 2004; Hermans, Bongaerts, de Bot, & Schreuder, 1998; Lee & Williams, 2001; Sandoval et al., 2000) because words with low translatability were in fact named more slowly and less accurately rather than more quickly and more accurately than words with high translatability.

While verbs were generally harder and less accurate than nouns for all speakers (Kauschke & Frankenberg, 2008; Shao et al., 2012; Szekely et al., 2005; Mätzig et al., 2009; Jia et al., 2006; Van Hell & de Groot, 1998; Hernandez et al., 2008; Faroqi-Shah, 2012), there was a smaller bilingual disadvantage for verbs than for nouns. This finding replicated previous emerging data (Sheng et a., 2006; Klassert et al., 2014; Faroqi-Shah et al., in prep; Faroqi-Shah & Milman, 2015). The smaller verb disadvantage could not be supported by the weaker-links hypothesis (Gollan et al., 2008), which predicts the same magnitude of bilingual disadvantage for verbs and nouns. But it was partially supported by the cross-language interference hypothesis (Green, 1998), which predicts more accurate verb naming due to less cross-language competition for verbs compared to nouns. The findings from the current study implied that bilingual lexical representation is influenced by word categories in highly proficient Mandarin-English bilinguals.

There were a few drawbacks of the current study. First, this study was unable to tease out the respective interactions between word frequency and lexical translatability. As we know that age of acquisition (AoA) and word frequency were highly correlated for lexical retrieval (e.g., Ivanova & Costa, 2008; Barry, Hirsh, Johnson, & Williams, 2001), and frequency could account for lexical translation (e.g., de Groot, 1992), it was hard to examine whether words that were acquired earlier and used more often in bilinguals were

also easily translated. Second, past literature has shown significant impact of age of acquisition on lexical retrieval for bilinguals (e.g., Barry et al., 2001; Ivanova & Costa, 2008). Even though the current study targeted highly proficient bilinguals who were exposed to L2 before 12 years old, the impact of AoA for verbs and nouns was not examined.

Current findings warrant future research on lexical retrieval for other unexplored bilingual populations, as well as for bilinguals with language deficits. First, since lexical retrieval in high-proficiency bilinguals can be complicated by many factors, including word frequency, lexical translatability, AoA, etc., future research is needed to tease apart which factors play roles and slow down bilinguals. Second, current study on lexical retrieval for different grammatical categories in healthy bilinguals can guide future bilinguals studies of aphasia. Prior studies on monolinguals with aphasia have reported a more severe verb deficit than nouns but others reported a more nouns deficit over verbs, and the magnitude of the double dissociation between nouns and verbs is very variable (Mätzig et al., 2009). So, in order to study whether noun-verb dissociation can be seen in other bilingual populations with aphasia, such as Mandarin-English bilinguals, future research is needed to examine how their lexical retrieval deficit is associated with grammatical categories. Last, it needs to be noted that the "weaker-links" account and the cross language interference account are not mutually exclusive. The current study supported the "weaker-links" hypothesis as a source of bilingual disadvantage, and it also partially supported the cross-language interference account to explain the smaller bilingual verb disadvantage. So, future research on other unexplored bilingual populations can continue testing these two hypotheses in order to facilitate the

understanding of which one can better explain the bilingual disadvantage in lexical retrieval.

Appendix A – Oral Interview Questions

1. English: "What is the most unforgettable experience in your life?"
2. Mandarin: "Please describe the steps of making ramen noodles."

   "请用中文说明做泡面的步骤"。

Appendix B – Task Instructions

1. Picture-Naming Task:
   A. English Noun-Naming: "In this experiment you will be naming objects, which are illustrated in the pictures. Before each picture appears, you will see a fixation point +. Your task is to give the English name for the object. Try to do so as quickly and accurately as you can. Please try to avoid coughing, repeating words, and using *uh* or *umm* before you name the word."
   B. English Verb-Naming: "In this experiment you will be naming actions, which are illustrated in the pictures. Before each picture appears, you will see a fixation point +. Your task is to give the English name (present tense) for the action as quickly and accurately as you can. Try not to use tense markers (e.g., *-ing, -ed*). Please try to avoid coughing, repeating words, and using *uh* or *umm* before you name the word."
   C. Mandarin Noun-Naming: "In this experiment you will be naming objects, which are illustrated in the pictures. Before each picture appears, you will see a fixation point +. Your task is to give the Chinese name for the object. Try to do so as quickly and accurately as you can. Please try to avoid coughing, repeating words, and using *uh* or *umm* before you name the

word."

D. Mandarin Verb-Naming: "In this experiment you will be naming actions, which are illustrated in the pictures. Before each picture appears, you will see a fixation point +. Your task is to give the Chinese name for the action as quickly and accurately as you can. Please try to avoid coughing, repeating words, and using *uh* or *umm* before you name the word."

2. Translation task:

A. *Noun translation:* "You will see an English word of an object on the next screen. Please translate it into Mandarin as quickly as you can."

B. *Verb translation:* "You will see an English word of an action on the next screen. Please translate it into Mandarin as quickly as you can."

Appendix C (a) – Noun Stimuli

English Word	Chinese Translation	SUBTLEX English frequency per million	SUBTLEX Chinese frequency per million	Name Agreement	Frequency category
baby	婴儿	509.37	42	0.422542669	HF
bag	纸袋	94.04	32.82	0.827590922	HF
ball	球	104.96	212.27	0	HF
balloon	气球	8.67	8.88	0	LF
bear	北极熊	57.41	43.82	0.680077046	HF
bed	床	187.12	193.91	0	HF
bird	鸟	45.45	64.75	1.036118214	HF
book	书	176.98	213.2	0	HF
boy	男孩	529.82	142.46	0.661188403	HF
brush	刷子	14.16	2.15	0.382542669	LF
cake	蛋糕	45.06	59.23	0	HF

camel	骆驼	5.02	6.86	0.056537941	LF
candle	蜡烛	8.02	15.29	0	LF
cane	拐杖	8.33	4.8	0.336424943	LF
hat	帽子	64.18	46.29	1.046034764	HF
car	汽车	483.06	70.74	0	HF
cat	猫	66.33	105.05	0.309665545	HF
chair	椅子	49.24	35.29	0	HF
chicken	母鸡	61.73	87.37	1.252720397	HF
church	教堂	69.67	64.87	0.282292189	HF
city	城市	169.1	99.83	0.944909298	HF
comb	梳子	6.06	2.77	0	LF
corn	玉米	14.22	19.7	0	LF
crab	螃蟹	6.9	6.08	0.52217919	LF
crown	皇冠	13.69	6.02	0.435434155	LF
desk	桌子	43.9	48.92	0	HF
doctor	医生	263.94	467.38	0.657786422	HF
dog	狗	192.84	351.99	0	HF
dolphin	海豚	2.76	6.2	0.141440543	LF
door	门	292.06	264.68	0	HF
ear	耳朵	32	34.91	0	HF
eye	眼睛	111.78	169.11	0.169415065	HF
fence	栅栏	16.06	5.6	0.141440543	LF
fire	篝火	215.49	105.41	0.282292189	HF
fish	鱼	83.49	75.48	0.028563419	HF
foot	脚	64.92	114.35	0.141440543	HF
fork	叉子	8.82	3.91	0	LF
fountain	喷泉	6.9	5.6	0.691236931	LF

frog	青蛙	11.82	10.11	0	LF
giraffe	长劲鹿	1.49	1.79	0.028563419	LF
girl	女孩	557.12	393.39	0.46708144	HF
globe	地球仪	5.22	0.54	0.141440543	LF
goat	山羊	10.53	9	0.309665545	LF
grapes	葡萄	3.94	7.09	0.468995594	LF
gun	手枪	213.2	353.24	0.686679242	HF
harp	竖琴	2.63	1.34	0.38804787	LF
heart	心	244.18	266.94	0	HF
horse	马	92.88	202.58	0	HF
puzzle	拼图	7.33	7.24	0.141440543	LF
key	钥匙	86.86	111.81	0.162293623	HF
king	国王	129.25	53.6	0.028563419	HF
kite	风筝	2.29	3.13	0	LF
ladder	梯子	9.25	7.04	0	LF
lamp	台灯	12.88	1.91	0.40217919	LF
leaf	树叶	5.2	3.61	0.056537941	LF
letter	信件	82.61	222.08	1.659088208	HF
lion	狮子	15.35	12.76	0.028563419	LF
lobster	龙虾	7.33	8.14	0.962688672	LF
lock	锁	56.57	83.17	0.028563419	HF
man	男人	1845.75	5810.26	0.382542669	HF
map	地图	31.82	35.95	0	HF
mask	面具	19.8	19.94	0.141440543	LF
mop	拖把	4.14	2	0.327444919	LF
mushroom	蘑菇	2.14	6.68	0	LF
music	乐谱	151.65	142.37	1.627582576	HF

nail	钉子	18.65	6.2	0.028563419	LF
nose	鼻子	69.75	40.96	0.056537941	HF
nurse	护士	44.98	40.96	0.309665545	HF
panda	熊猫	2.12	6.05	1.941546491	LF
pants	裤子	58.75	55.77	0.591514253	HF
pear	梨	1.33	0.48	0	LF
pencil	铅笔	9.86	7.27	0	LF
pig	猪	39.14	59.95	0	HF
pillow	枕头	11.39	14.52	0	LF
pipe	烟斗	19.39	2.44	0.223547819	LF
pool	泳池	14.31	16.07	0.948242065	LF
pot	锅	9.1	10.28	1.522358225	LF
present	礼物	31.26	118.88	1.515713633	HF
pumpkin	南瓜	3.28	8.94	0.028563419	LF
rainbow	彩虹	2.77	8.14	0.196788422	LF
gun	步枪	213.2	353.24	0.874421576	HF
ring	戒指	92.75	47.16	0	HF
road	公路	111.94	208.46	0.48217919	HF
rocket	火箭	11.84	15.68	0.541188403	LF
scarf	围巾	4.69	6.68	0.141440543	LF
scissors	剪刀	6.69	11.6	0.083911298	LF
shark	鲨鱼	14.98	18.57	0.336424943	LF
shoe	皮鞋	30.39	35.26	0.028563419	HF
snail	蜗牛	1.76	1.58	0.169415065	LF
sock	袜子	8.98	15.65	0.056537941	LF
spoon	勺子	7.61	4.56	0.028563419	LF
squirrel	松鼠	5.47	7.18	0.607363556	LF

sun	太阳	69.67	42.3	0	HF
tent	帐篷	17.49	11.63	0.028563419	LF
tiger	老虎	18.53	10.97	0.598637129	LF
train	火车	95.06	45.7	0.056537941	HF
tree	大树	65	64.09	0.028563419	HF
turtle	乌龟	17.04	6.95	0	LF
window	窗户	86	40.75	0	HF
woman	女人	434.63	428.9	1.405820084	HF

Appendix C (b) – Verb Stimuli

English Word	Chinese Translation	SUBTLEX English frequency per million	SUBTLEX Chinese frequency per million	Name Agreement	Frequency Category
dive	跳水	12.82	1.49	0.5	LF
drink	喝水	247.39	417.45	0.769179903	HF
ski	滑雪	8.1	8.97	0.627097479	LF
cut	剪	229.76	30.82	0.5	HF
blow	吹	97.57	55	0.508268971	HF
bark	吠	5.49	2.86	0.056537941	LF
bite	咬	40.78	68.68	0.282292189	HF
bounce	拍球	9.84	1.85	0.86814334	LF
brush	刷牙	14.16	5.34	0.141440543	LF
yell	喊	18.41	2.86	1.791007011	LF
carry	搬运	65.9	107.25	0.837541154	HF
catch	接球	135.51	133.58	0.269665545	HF
chase	追	32.8	86.92	0.52217919	HF
clap	鼓掌	4.73	1.91	0.686679242	LF

climb	登山	19.75	2.3	0.242292189	LF
slam	关	5.8	2.09	2.38328569	LF
comb	梳头	6.06	3.85	0.269665545	LF
play	弹琴	354.53	60.6	2.174990567	HF
cough	咳嗽	8.78	5.66	1.247716293	LF
crawl	爬行	12.04	1.61	0	LF
cry	哭	65.65	113.66	0.141440543	HF
dance	跳舞	148.04	103.11	0.327444919	HF
decorate	裱花	2.31	15.05	1.938758539	LF
dig	挖土	46.22	51.15	1.254927986	HF
drive	开车	153.14	56.28	0.141440543	HF
drown	溺水	10.59	3.52	0.296424943	LF
dry	吹头发	42.82	55	1.692314279	HF
eat	吃	251.88	832.07	0.540466249	HF
erupt	喷发	0.39	1.25	1.635574252	LF
look	观察	1947.27	3056.83	1.901425828	HF
stretch	做操	14.67	5.69	2.256398385	LF
feed	喂鸡	42.39	336.43	0.79685684	HF
fill	加油	43.94	131.49	1.764279191	HF
float	漂浮	7.47	9.24	1.095488211	LF
fly	飞翔	85	116.08	0	HF
fold	折叠	8.63	11.66	1.091045661	LF
arrest	搜身	59.55	62.72	1.536422395	HF
whisper	私语	7.9	1.85	1.645353751	LF
hammer	敲击	12.47	2.06	1.285444956	LF
hang	晾晒	147.75	103.23	1.684055836	HF
hatch	破壳	12.82	1.91	0.909733964	LF

hide	捉迷藏	69.69	78.46	1.025461716	HF
hit	击球	275	36.75	0.96821277	HF
howl	嚎叫	2.06	1.7	0.826746372	LF
iron	熨烫	17.94	3.04	0.056537941	LF
jump	跳跃	69.82	253.26	1.387451265	HF
kick	踢球	73.41	67.55	0.242292189	HF
kiss	亲吻	121.16	82.66	0	HF
kneel	下跪	5.33	9.78	1.108825034	LF
knit	编织	1.9	7.66	1.597237345	LF
laugh	大笑	62.86	197.58	0.269665545	HF
lift	拎	34.14	157.48	1.829192078	HF
unlock	开门	5.49	0.03	1.934981432	LF
magnify	观察	0.59	9.99	2.005587347	LF
measure	测量	10.53	6.29	0.141440543	LF
melt	融化	7.31	8.41	0.721279866	LF
mix	搅拌	16.35	2.59	2.032306	LF
open	打开	320.41	148.72	2.092292317	HF
operate	做手术	13.37	1.7	2.017684724	LF
parachute	跳伞	3.18	4.89	1.386244755	LF
peel	削皮	5.35	9.66	0.680580433	LF
plow	耕地	1.88	0.95	1.811173828	LF
polish	擦拭	9.67	1.13	1.511504334	LF
pop	爆炸	67.47	30.52	0.92324109	HF
pour	倒入	15.12	0.39	0.282292189	LF
pray	祈祷	36.22	57.98	0.905593613	HF
pull	拉	146.45	245	0.959481532	HF
push	推车	70.55	67.04	0	HF

raise	举手	55.2	51.81	2.502181252	HF
read	看书	241.22	138.94	0.136802784	HF
roar	咆哮	4.02	3.93	1.669219693	LF
salute	敬礼	7.25	6.26	0.136802784	LF
carve	雕刻	3.1	17.89	1.388106897	LF
sew	缝纫	5.49	1.67	0.662801059	LF
wash	洗头	40.73	104.18	2.012897623	HF
sharpen	磨刀	1.12	4.86	1.567949826	LF
shave	剃须	13.76	7.87	0	LF
sing	唱歌	97.59	47.43	0.169415065	HF
sink	沉	16.92	2.12	1.513014722	LF
sit	坐	311.35	423.41	0.309665545	HF
skate	溜冰	5.9	7.04	0.7814792	LF
sleep	睡觉	227.94	239.4	0.083911298	HF
smell	修	83.14	69.66	0.453802118	HF
smile	微笑	58	30.61	0.336424943	HF
sneeze	咳嗽	2.94	2.03	1.277353956	LF
splash	泼洒	4.22	7.33	1.441526382	LF
squeeze	挤	15.08	1.31	0.249679908	LF
steal	偷	53.33	163.98	0.912032175	HF
stir	搅拌	5.9	10.64	1.317775212	LF
suck	吸吮	34.88	59.2	1.297352204	HF
sweep	扫地	9.51	5.1	0.412882882	LF
teach	教学	72.84	152.83	1.862724459	HF
talk	通话	855	267.84	1.036647343	HF
throw	扔	128.82	123.56	0.382542669	HF
tie	系鞋带	44.43	30.11	0.169415065	HF

wait	等	830.25	1014	0.989587521	HF
walk	走路	215.86	1945.3	0	HF
watch	看电视	330.02	3056.83	0.422542669	HF
wink	眨眼	3.53	7.24	0.656416503	LF
write	写字	126.8	405.08	0.56217919	HF

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