SQUIB

The effects of language immersion on the bilingual lexicon

Evidence from Chinese-English bilinguals

Peggy P.K. Mok and Alan C.L. Yu
The Chinese University of Hong Kong / University of Chicago

Previous studies have consistently found an asymmetry where priming in the L1-L2 direction is stronger than that in the L2-L1 direction. However, some studies showed that an L2 immersion environment could attenuate bilingual speakers' access to the L1 and result in a 'bilingual disadvantage'. This study investigated how language immersion modulates the priming effects of late adult bilingual speakers. We compared late Chinese-English bilingual speakers with high L2 (English) proficiency in an L1 environment and those in an L2 immersion environment. Both semantic and translation priming in same-language and cross-language conditions were investigated. The results showed no 'bilingual disadvantage' of the immersed participants. The priming asymmetry was weakened for the immersed participants who were more comparable in their reaction time to different language conditions. Both semantic and translation priming were found in L1-L2 and L2-L1 directions, suggesting that both types of priming are similar in nature in the bilingual lexicon.

Keywords: bilingual lexicon, language immersion, priming, Chinese, English

1. Introduction

Previous studies have shown that the bilingual lexicon is dynamic in nature and many factors can affect the relationship between the two languages (e.g., Grosjean, 1998; Pavlenko, 2009). However, the effects of immersion on the bilingual lexicon are not well-understood, although there are growing interests in how an immersion environment affects the way languages are processed by bilingual speakers. The present study investigates how language immersion affects the mental lexicon of high-proficiency late Chinese-English bilingual speakers. Our findings can

Linguistic Approaches to Bilingualism 7:5 (2017), **614–636**. DOI 10.1075/lab.15029.mok
ISSN 1879–9264 / E-ISSN 1879–9272

offer further insights for understanding the effects of language immersion on the bilingual mental lexicon.

1.1 Asymmetry in the bilingual mental lexicon

Many studies have shown asymmetries between the two languages in a bilingual lexicon. For example, priming effects in the L1-L2 direction are found to be consistently large, while those in the L2-L1 direction are smaller or even nonexistent (Chen & Ng, 1989; Keatley, Spinks & de Gelder, 1994; Jiang, 1999; Dong, Gui & MacWhinney, 2005; Basnight-Brown & Altarriba, 2007; Chen et al., 2014). Bilinguals also translate faster from L2 to L1 than from L1 to L2 (Kroll & Stewart, 1994; Sholl, Sankaranarayanan & Kroll, 1995). Such asymmetries are often explained by differences in proficiency and/or dominance between the two languages (e.g., Finkbeiner et al., 2004; Dong et al., 2005), both as important considerations in bilingual studies (Grosjean, 1998). The more proficient or dominant language provides a stronger facilitation, or has more direct access to the conceptual store than the less proficient or dominant language.

In studies involving adult bilingual speakers, L1 is usually regarded as the dominant language because of its early acquisition and native proficiency, while L2 is usually acquired later, and thus being the weaker and less proficient language. However, so far, there is no unanimous agreement of what language dominance is. Cantone, Kupisch, Müller and Schmitz (2008) argued that language dominance should be an area of research in its own right. It can refer to the relative proficiency, the relative exposure and frequency of use of the two languages, or the majority language relative to the social environment etc. (Dunn & Fox Tree, 2009; Daller et al., 2010; Treffers-Daller, 2010; Bedore et al., 2012; Grosjean, 2013).

The language environment is an important factor in affecting language dominance which can change over time. Some bilinguals may be more dominant in their L2 than in their L1 due to environmental factors, such as studying abroad or having an immersion environment (Heredia, 1997; Tokowicz, Michael & Kroll, 2004; Basnight-Brown & Altarriba, 2007). The frequency of use of the two languages, the majority language relative to the social environment, or current language use are important criteria affecting language dominance for both bilingual children and adults (Argyri & Sorace, 2007; Dunn & Fox Tree, 2009; Daller et al., 2010; Bedore et al., 2012).

1.2 Language immersion

There is a growing literature on how studying abroad or being in an L2 immersion environment affects bilingual speakers. Understandably, many of these studies focus on how such a change in language environment can enhance L2 proficiency in various linguistic aspects (e.g., see a special issue on this topic in *Studies in Second Language Acquisition*, volume 26, 2004). There are also recent studies showing how an immersion environment can affect processing of late adult bilingual speakers.

For example, Tokowicz, Michael and Kroll (2004) showed that study-abroad experience has an impact on the type of translation errors made by English-Spanish bilingual speakers. Since study-abroad learners are accustomed to being in situations in which they need to communicate, they are more prone to making incorrect responses that are related in meaning to the correct translation than simply just saying that they do not know the answer. Dussias and Sagarra (2009) found that Spanish monolinguals and Spanish learners of English with little immersion experience preferred to attach a relative clause after the first noun, while Spanish learners of English with ample immersion experience preferred to attach it after the second noun like native English speakers do. By using a picture naming task, Malt, Li, Pavlenko, Zhu and Ameel (2015) found changes in both L1 and L2 word use of Mandarin-English bilingual speakers with late L2 immersion compared to their monolingual counterparts. They suggested that the lexical network remains plastic over an extended time period and that both L1 and L2 representations and interconnections can be modified even with late immersion. These studies demonstrate that being in an immersion environment can influence the interaction between two languages in the mental lexicon.

Of particular interest are studies that found language immersion modulating lexical access of the L1. Having extensive exposure to the L2 may incur a cost in L1 processing by affecting the efficiency of L1 lexical retrieval or dampening the activation of L1. The adverse effect that the L2 immersion environment can have on the L1 is termed the 'bilingual disadvantage'. For example, Baus, Costa and Carreiras (2013) found a decline in the ability to retrieve and use low frequency L1 non-cognate words after a short L2 immersion experience (4 months). Morales, Paolieri, Cubelli and Bajo (2014) observed that Spanish learners of English in a non-immersed environment were influenced by Spanish grammatical gender even in an L2 picture naming task, but those in an English immersion environment were not. They suggested that the immersion environment attenuates access to the native language.

There are two main accounts for the 'bilingual disadvantage' due to immersion: language inhibition versus frequency of use. Linck, Kroll and Sunderman (2009) compared two groups of English learners of Spanish: one group in an immersion environment (3 months) and one group in a classroom setting. Many studies have shown that the bilingual lexicon is nonselective in nature and both languages are always active. They found that the immersed group outperformed the classroom group in L2 proficiency tasks. In addition, in all of their tasks (comprehension, production, translation recognition, and verbal fluency), the immersed group performed worse in their L1 or was less affected by their L1 than the classroom group. They also re-tested a subset of the immersed learners 6 months after they had returned to an L1 environment, and these learners still exhibited insensitivity to L1 lexical interference in translation recognition. Linck et al. (2009) concluded that access to the L1 was attenuated during language immersion (Green, 1998), and the reduced influence or sensitivity of the L1 was the result of L1 inhibition.

An alternative account of the 'bilingual disadvantage' is that the frequency of use of the L1 is reduced in an L2 immersion environment. According to the weaker-link hypothesis (Gollan et al., 2005), bilinguals are likely to use either of their languages less often than monolinguals do. Lexical representations in each language have a reduced functional frequency and therefore are less easily accessible. Being in an L2 immersion environment may further reduce the frequency of use of the native language, so that the L1 becomes even less accessible during L2 immersion. Baus et al.'s (2013) findings lend some support to this account because their immersed speakers were slower in naming pictures in their L1 only for low frequency non-cognate nouns. Their findings suggests that the frequency of use is an important factor contributing to the 'bilingual disadvantage'.

To be sure, these two accounts are not mutually exclusive. Morales et al. (2014) stated that both accounts can explain their data equally well. The fact that their immersed bilinguals were not influenced by their L1 Spanish grammatical gender knowledge when performing a picture-naming task in L2 English could be because that their L1 was inhibited during immersion, or because that they were exposed to the L2 significantly longer than the non-immersed group. It is possible that both factors have a role to play in the final analysis.

Previous aforementioned studies on how immersion affects lexical representation mainly used explicit production tasks like picture naming, translation or verbal fluency tasks. Indeed, it is surprising to find that only a few studies have explored the effects of immersion using the priming paradigm, a technique commonly used in studies of the bilingual mental lexicon. It is thus important to investigate if the same disadvantage can also be found using a more implicit task, not only for a thorough understanding of the effects of language immersion, but also to test the pervasiveness and robustness of the 'bilingual disadvantage'. The priming paradigm can provide more sensitive data than the above-mentioned production tasks on the lexical interactions of the two languages in the bilingual mind, because it is an online measure, and because it can show subtle differences in lexical connections between the two languages, which may not surface easily in explicit production tasks involving other processes, such as articulatory planning.

More importantly, in addition to being more sensitive, priming data can also help us to evaluate which account, language inhibition or frequency of use, has a stronger effect on the 'bilingual disadvantage'. If 'bilingual disadvantage' is due to L1 inhibition in language immersion, we would expect to find slower reaction time or weaker priming effects to the L1 for the immersed participants than the non-immersed participants. If the 'bilingual disadvantage' is due to the frequency of use, we would expect to see more comparable reaction time or similar priming effects in both L1 and L2 for the immersed participants but not for the non-immersed participants, as the reduced exposure to L1 and the increased exposure to L2 in an immersion environment would attenuate the asymmetry between L1 and L2 in the bilingual lexicon (also see below).

Previous studies demonstrating asymmetries in the bilingual mental lexicon (stronger L1-L2 than L2-L1 priming effects) discussed earlier mainly used participants in a non-immersed environment. As suggested by Van Hell and Tanner (2012), immersion experience may allow both for faster lexical access and for the development of richer L2 word-to-concept mappings, which would lead to an increase in priming symmetry. Basnight-Brown and Altarriba (2007) found that their Spanish-English bilingual speakers had significant translation priming effects in both language directions but significant semantic priming only in the L2–L1 direction. They argued that because their bilingual speakers were in an English immersion environment, their L2 had become their dominant language, which could explain why semantic priming only occurred in the L2-L1 direction. However, Basnight-Brown and Altarriba (2007) did not have non-immersed participants for comparison.

Only few priming studies of the bilingual mental lexicon have compared immersed versus non-immersed participants thus far. Coderre, van Heuven and Conklin (2013) compared the Stroop effects in monolingual English, English-Chinese (non-immersed) and Chinese-English (immersed) bilingual speakers. However, half of their immersed Chinese-English speakers were actually studying in an English-medium university in China, so their immersion experience was quite different from those who were living in a foreign country where the L2 is the ambient language. Degner, Doycheva and Wentura (2012) compared semantic and affective priming of German-French (non-immersed) and French-German (immersed) bilinguals studying in Germany. They found that while semantic priming occurred in both L1 and L2, and that affective priming was found in L1 for both groups, only the immersed participants showed affective priming in L2. They argued that bilinguals immersed in the L2 culture used their L2 frequently in daily life, which could in turn lead to a higher weighting of affective connotations. Nevertheless, the native language and the second language of the immersed versus non-immersed groups in both Coderre et al.'s and Degner et al.'s studies are different. In order to investigate the effects of immersion more specifically without confounding native languages of the participants, we use participants who have the same L1 and L2 but differing in immersion experience.

1.3 Translation and semantic priming

The type of priming, translation or semantic, is an important consideration in the studies of the bilingual lexicon. Translation priming involves prime-target pairs that are translation equivalents in the two languages, while semantic priming involves prime-target pairs that are semantically related in the two languages. Altarriba and Basnight-Brown (2007) extensively reviewed about a dozen of studies using the semantic priming paradigm and studies using the translation priming paradigm. They found many methodological differences and inconsistent findings among these studies. As translation equivalents have closer semantic relations than related word pairs in the mental lexicon, it may not be surprising to find mixed results.

Some argued that semantic priming and translation priming are different in the bilingual lexicon, and that an immersion environment may influence the type of priming found in different language directions. For example, as mentioned above, Basnight-Brown and Altarriba (2007) found significant translation priming in both language directions using Spanish-English bilingual speakers, but semantic priming was found only for Spanish target words (L2-L1) (Experiment 1). They reasoned that since their bilingual participants were actually English-dominant (living in an immersion environment), their results did conform to the stronger L1-L2 priming found in other studies. Moreover, they found no semantic priming effects in either language direction, but significant translation-priming effects were observed in both language directions in their Experiment 2. They argued that translations were recognized and stored differently from semantically related word pairs in the bilingual lexicon. Similarly, Zhao, Li, Liu, Fang and Shu (2011) investigated cross-language priming effects using both translation and semantic priming with three groups of Chinese-English bilingual speakers: a low English proficiency group in China, a high English proficiency in China (English majors) and an immersion group in the US. They found significant translation and semantic priming in the L1-L2 direction for all groups, but significant translation priming in the L2-L1 direction was only found for the immersion group. These results demonstrated that an immersion environment can affect the priming effects of bilingual speakers.

On the other hand, Schoonbaert et al. (2009) found significant priming effects in both type of priming (translation and semantic) and language direction (L1-L2 and L2-L1) for unbalanced Dutch (L1) – English (L2) bilinguals in a non-immersion environment. Similarly, Guasch, Sánchez-Casas, Ferré & Garciá-Albea (2011) used balanced Spanish-Catalan bilinguals in a non-immersion environment and found significant translation and semantic priming in both language directions. These results instead suggest that the difference between translation and semantic priming is only quantitative but not qualitative in nature, and that an immersion environment is not necessary.

Some methodological issues may explain the different findings in these studies. Both priming type (translation and semantic) and language direction (L1-L2 and L2-L1) were within-subject factors in Basnight-Brown and Altarriba (2007) and Zhao et al. (2011), while both factors were between-subject factors in Schoonbaert et al.'s (2009) study. In Guasch et al. (2011), language direction was a between-subject factor and priming type was a within-subject factor. Individual differences may have contributed to the mixed results. Only Zhao et al. (2011) had compared immersed and non-immersed participants, while Basnight-Brown and Altarriba (2007) had only one group who was living in an L2 immersion environment. Also, the language pairs in Schoonbaert et al. (2009) and Guasch et al. (2011) were closely related languages (Dutch-English and Spanish-Catalan respectively), which may explain the stronger semantic priming effects found in their studies. As a result, direct comparisons between these findings may not be advisable. Further studies are needed to clarify the nature of translation priming and semantic priming in the bilingual lexicon, and the role of immersion experience on bilingual priming.

1.4 The present study

Our study aims to investigate the effects of language immersion on the bilingual mental lexicon using both translation and semantic priming. To begin with, previous priming studies demonstrating asymmetries in the bilingual mental lexicon mainly used non-immersed participants. There are also very few studies that explored the effects of immersion using the priming paradigm. Our present study addresses both issues by using the priming paradigm to study the bilingual mental lexicon of immersed and non-immersed participants, thus allowing us to evaluate which account of the 'bilingual disadvantage' is more plausible.

As reviewed above, many previous bilingual studies included only the cross-language directions (L1-L2 and L2-L1). Our study extends such design by including same-language directions (L1-L1 and L2-L2) for a more thorough comparison, as suggested by Altarriba and Basnight-Brown (2007). We also include both priming type (translation versus semantic) and language direction as within-subject factors, which allow us to shed light on the controversial nature of translation and semantic priming in the bilingual lexicon.

We aim to examine how the immersion experience affects lexical processing of the two languages of high-proficiency late bilingual speakers. We used Chinese-English late bilingual participants for our study because the scripts for the two languages are very different, and there are no cognates between them. Any priming effect found will not come from form similarity, but can be attributed to the connections of concepts and meanings in the conceptual store.

Based on previous studies showing stronger L1-L2 than L2-L1 priming and the 'bilingual disadvantage' from language immersion, we hypothesized the following for our immersed participants:

1. the L2-L2 priming effects should be stronger and the L1-L1 priming effects should be weaker than the non-immersed participants;
2. the asymmetry between L1-L2 and L2-L1 priming effects should be attenuated;
3. the reaction time to L2 and L1 should be more comparable.

2. Method

2.1 Participants

Two groups of Mandarin-English bilingual participants were recruited: 24 (3 male, 21 female) participants in Hong Kong (non-immersed) and 19 (6 male, 12 female) participants in Chicago (immersed). All participants were Mandarin speakers from mainland China who learnt English in school settings. They started learning English at around nine years old at school and are considered late bilinguals (after the age of seven, Silverberg and Samuel, 2004).

In order to ensure that the immersed and non-immersed participants have similar level of English proficiency, we targeted students doing language studies for the non-immersed group. The non-immersed participants in Hong Kong were all studying for a MA degree in Linguistics in which the medium of instruction was English. They all majored in English for their undergraduate study at various universities in China before coming to Hong Kong. We tested them within the first two months of their arrival in Hong Kong to minimize the possible influence of Cantonese. Although they were in Hong Kong, they used mainly Mandarin Chinese with their peers outside the academic environment. Mandarin is widely spoken in university settings in Hong Kong, and also in many other situations (although to a lesser extent). Mainland Chinese students largely mingled among themselves (e.g. sharing a flat) in Hong Kong. The non-immersed participants were thus still in a Chinese-speaking environment and were Mandarin-dominant.

All of the non-immersed participants had passed an English test of TEM-4 (Test for English Majors administered to second-year university students in China), with 10 receiving *excellent*, 12 receiving *good*, 2 receiving *pass*. Out of the 24 non-immersed participants, 13 had also taken the IELTS (9 being the highest score): six receiving 7.5 and seven receiving 7. For the two participants with a *pass* in TEM-4, one got 7.5 and one got 7 for IELTS. Thus, the non-immersed participants in Hong Kong can be regarded as having a high level of proficiency in English (see similar criterion in Dong et al., 2005; Zhao et al., 2011), but the domain of English use was very limited (Grosjean, 2013). The mean age was 23.5 (SD = .78). They received course credits for participating in the experiment.

The immersed participants in Chicago were more heterogeneous. They were native Mandarin speakers from China studying various subjects at a university in Chicago in an English immersion environment. We did not restrict our recruitment to English majors, as only very few Chinese students would do language studies in the United States. In addition, stricter control for the participants' background was complicated by the fact that immersed participant recruitment was hampered by a general lack of interest in participating in studies outside of their immediate area of interests. The minimum IELTS score for international students to study at the university was 7, so all the immersed participants had at least this level of English proficiency, which was quite comparable to the non-immersed group. Their immersion duration ranged from three months to four years, with over half of the participants being in Chicago for less than one year. Their immersion duration was very comparable to previous studies on language immersion discussed above (e.g. Tokowicz et al., 2004; Zhao et al., 2011; Degner et al., 2012; Morales et al., 2014; Malt et al., 2015). All the immersed participants indicated that they still used their L1 Mandarin. The mean age was 21.89 (SD = 3.36). They received a nominal fee for their participation in this study.

2.2 Materials

There were four language conditions in our experiment: Chinese prime Chinese target (L1-L1, CC), Chinese prime English target (L1-L2, CE), English prime Chinese target (L2-L1, EC) and English prime English target (L2-L2, EE). For each language condition, there were four semantic relations between the prime and the target: translation equivalent (for CE and EC, e.g., 白兔 – rabbit) or repetition (for CC and EE, e.g., basket – basket), semantically related (e.g., banana – apple), semantically unrelated (e.g., oyster – athlete), and non-word target (with a word prime, e.g. usage – nerdige). In each semantic relation, there were eight tokens which were all concrete nouns. So altogether, there were 128 stimuli in a within-subject design (8 tokens × 4 semantic relations × 4 language conditions). The Relatedness Proportion was 0.67 and the Non-Word Ratio was 0.5.

The SOA was 50 ms. A short SOA mainly involves automatic processing of semantic facilitation while a long SOA would involve strategic and controlled processing. Altarriba and Basnight-Brown (2007) recommended SOAs of 200 ms or shorter. Although the primes were not masked, the very short prime duration of 50 ms in our experiment was too short to be noticed by the participants. We asked some participants informally after the experiment where they had noticed the primes. They reported that they only saw something flashing very quickly before some targets, but could not see what the primes were. This could ensure that strategic processing by the participants was minimized.

Common words were used for both Chinese and English stimuli. Word frequency of the stimuli was checked using two online corpora: Corpus of Contemporary American English[1] and the Chinese Internet Corpus.[2] As they differed greatly in both size and scope, the frequency data in the two corpora were not directly comparable. The average frequency of the stimuli in different conditions was 45 (Chinese) and 58 (English) times per million words.

Both Chinese and English stimuli were disyllabic concrete nouns. English stimuli were with five to nine letters. English nonwords were formed first by swapping the positions of the two syllables in disyllabic words. Then the letter sequences may be further modified so that the resultant nonwords look more like real words. None of the English nonwords was fake compounds. Chinese nonwords were formed by combining two real unrelated simplified Chinese characters which do not form a meaningful unit.

2.3 Procedure

The participants did the experiment (a lexical decision task) individually in a quiet room. The stimuli were presented to them using E-Prime 2.0 Professional with a desktop computer in Hong Kong and Chicago. There were four language blocks (CC, CE, EC, EE), and the order of the four blocks were randomized for each subject, and within each block the stimuli were also randomized. A short practice and short breaks between blocks were given. The participants were encouraged to respond as quickly and as accurately as possible. Both accuracy and reaction time were collected. The participants also did a survey about their language background after the experiment.

1. http://corpus.byu.edu/coca/

2. http://corpus.leeds.ac.uk/frqc/internet-zh.num

3. Results

3.1 Reaction Time (logRT)

The participants' reaction time data for the correct responses was first log-transformed before being analyzed in a repeated measures ANOVA. Reaction time data is usually positively-skewed which violates the normality assumption of ANOVA. Therefore, we followed the traditional approach in psychological studies to log-transform the reaction time data (logRT) for analysis (Ratcliff, 1993; Whelan, 2008). Table 1 shows the mean RT of the two groups in ms and in logRT for reference.[3]

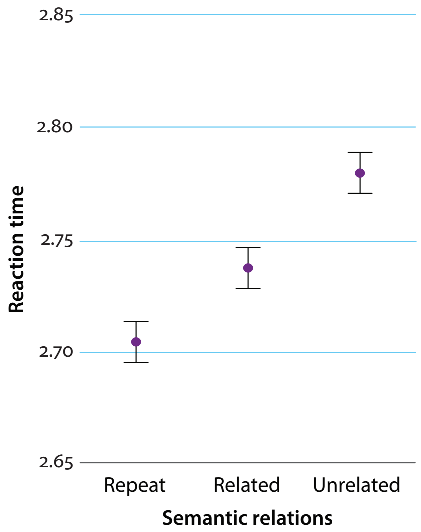
The within-subject factors were: Semantic Relations (Repeat/Equivalent, Related, Unrelated) and Language Conditions (Target-Prime pairs: CC, CE, EC, EE). Their interactions with the between-subject factor, Language Immersion (immersed vs. non-immersed environment), were also checked. If the sphericity assumption of any main effect or interaction was violated, the degree of freedom was adjusted with the Hyunh-Feldt epsilon in generating the F ratios and p values. Post-hoc analyses were done using t-tests with the appropriate Bonferroni adjusted alpha levels. The error bars in the following figures show the standard errors.

First of all, we would like to see if there was any significant priming effect in different language conditions. The main effect of Semantic Relations was significant ($F(1.752, 71.852) = 159.233$, $p < .001$, partial $\eta^2 = .795$, see Figure 1a). Post-hoc analyses show that the logRT was different between all Semantic Relations ($p < .001$). As expected, the logRT for Repeat/Equivalent was the fastest, and that for Unrelated was the slowest. The main effect of Language Conditions was also significant ($F(2.008, 82.341) = 5.603$, $p = .001$, partial $\eta^2 = .120$, see Figure 1b). The logRT for the CC condition was significantly faster than that for all other conditions (CE: $p = .005$; EC: $p = .029$; EE: $p = .03$). Participants responded fastest when both the prime and the target were in their L1 Chinese.

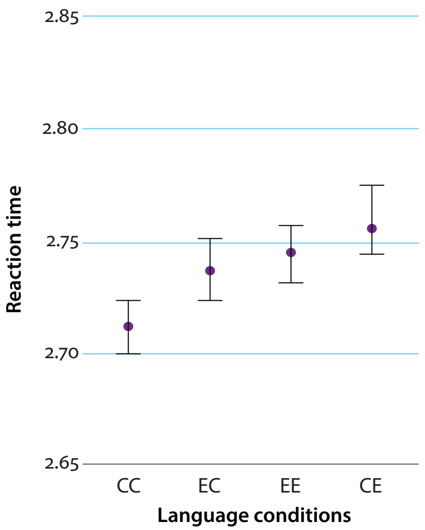
3. Per advice of one of the reviewers, we employed the odd–even split-half estimates of internal consistency to assess the reliability of the logRT (Hughes et al. 2014). Cronbach's alpha was not used because the exclusion of inaccurate trials resulted in each participant having slightly different amounts and patterns of missing data. There were 2064 trials in the even-numbered and odd-numbered test halves. The split-half reliability coefficient with Spearman-Brown correction for logRT is 0.6, suggesting that the reaction time responses are moderately reliable.

Table 1. Means of reaction time in different language conditions by semantic relations.

Semantic relations	CC				EC				EE				CE			
	Non-immersed		Immersed		Non-immersed		Immersed		Non-immersed		Immersed		Non-immersed		Immersed	
	logRT	ms	logRT	ms	logRT	ms	logRT	ms	logRT	ms	logRT	ms	logRT	ms	logRT	ms
Repeat/equivalent	2.66	459	2.67	470	2.74	546	2.71	512	2.74	553	2.66	455	2.76	571	2.71	511
Related	2.73	533	2.73	534	2.75	565	2.71	512	2.79	618	2.72	528	2.75	566	2.70	501
Unrelated	2.75	566	2.74	550	2.78	596	2.75	562	2.81	652	2.75	557	2.86	731	2.78	600



a.



b.

Figure 1. Main effects of (a) Semantic Relations and (b) Language Conditions.

The significant interaction between Semantic Relations and Language Conditions ($F(5.442, 223.113) = 14.873$, $p < .001$, partial $\eta^2 = .266$, see Figure 2) shows that priming effects differed according to language conditions. For "Repeat" (triangles in Figure 2), the logRT was shorter in the same language (CC and EE) than in the cross language conditions (CE and EC). The contrasts between CC and CE, CC and EC were significant (all $p < .0028$; the Bonferroni adjusted alpha was at

$p = .0028$). The other pairwise comparisons were not significant. The “Repeat” stimuli in CC and EE were actual repetitions, while they were translation equivalents in CE and EC. This can explain why logRT was faster in the same language conditions than in the cross-language conditions. Language Conditions had little effect on the “Related” (circles in Figure 2). The logRT in the EE condition was slower than that in the CE condition ($p < .001$). For the “Unrelated”, the logRT in the CE condition was significantly longer than all other language conditions.

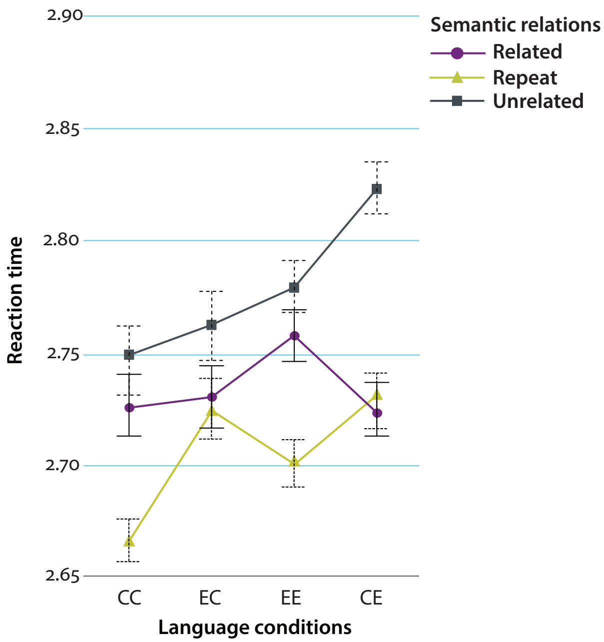


Figure 2. Effects of Language Conditions on Semantic Relations.

Based on the significant Semantic Relations × Language Conditions interactions, we calculated the priming effects in different language conditions using “Unrelated” as the baselines for comparison (Figure 3). The longer the bars, the stronger the priming effects are. All the priming effects were significant (all $p < .005$, the Bonferroni adjusted alpha level was at $p = .006$). Both translation priming (“Repeat” in the CE and EC conditions) and semantic priming (“Related” in the CE and EC conditions) effects were found.

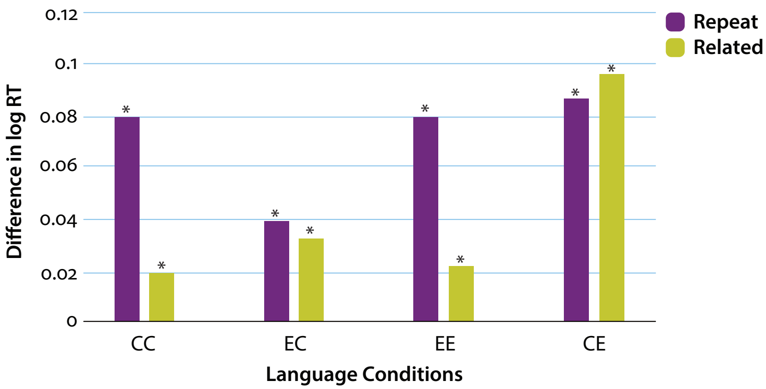


Figure 3. Priming effects in logRT using "Unrelated" as baselines (* p < 0.005).

Although the higher-order interaction of Semantic Relations × Language Conditions × Immersion was not significant ($F(6,246) = 1.614$, $p = .144$), which means that the two groups of participants did not differ in the types of priming, there was a significant interaction between Language Immersion and Language Conditions ($F(3, 123) = 4.006$, $p = .009$, partial $\eta^2 = .089$, see Figure 4). The immersed group responded faster to English targets (CE and EE) than the non-immersed group did. The difference was significant in the EE condition ($p = .004$), and marginally so in the CE condition because of the stringent correction ($p = .029$,

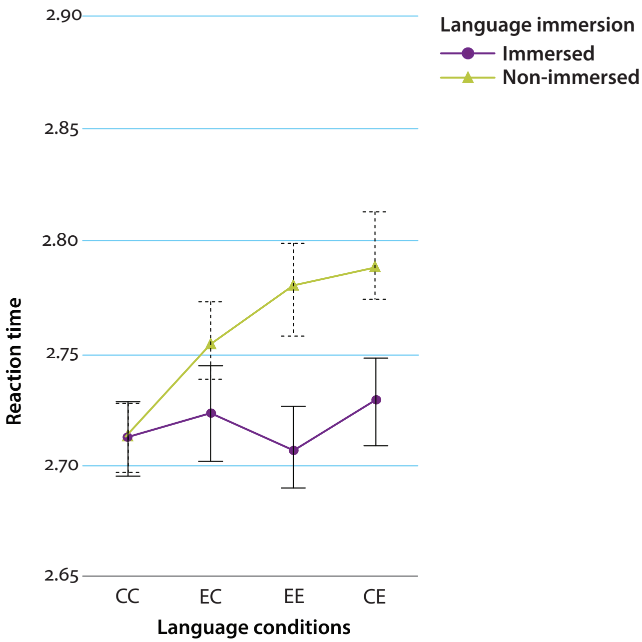


Figure 4. Effects of Language Immersion on Language Conditions

the Bonferroni adjusted alpha was at $p = .0125$). It is interesting to note that the logRT of the two groups did not differ for Chinese targets (especially for CC), and that the difference between the two groups for English targets was enlarged by the slower logRT of the non-immersed group. The logRT was quite similar across different language conditions for the immersed group.

3.2 Accuracy rate

The arcsine-transformed accuracy rates were analyzed in a repeated measures ANOVA with the same number of factors and interaction terms as in the analysis for logRT discussed above. We arcsine-transformed the data because accuracy rates are count data and are binomial and thus violate assumptions of ANOVA.[4]

The factor Language Immersion was not significant and did not interact with any other factor, so both groups of participants behaved similarly in terms of accuracy. Similar to logRT, the Language Conditions × Semantic Relations interaction was significant ($F(5.628, 230.752) = 2.988$, $p = .009$, partial $\eta^2 = .068$). Accuracy of the CE condition was significantly lower than the CC and EE conditions (all $p < .002$). The priming effects in the significant Semantic Relations × Language Condition interaction were calculated using "Unrelated" as the baselines for comparison. The priming effects for both "Repeat" and "Related" were significant only in the CE condition ($p < .001$; the Bonferroni adjusted alpha level was at $p = .006$), because of the low accuracy in this condition. For "Repeat" and "Related", no contrast between language conditions reached significance (at the Bonferroni adjusted alpha level of p = .0028).

Finally, as nonwords were not included in previous analyses, we tested the sensitivity for lexical decision by calculating d-prime using the Signal Detection Theory (Green & Swets, 1966). D-prime was computed based on hit and false alarm rates (Macmillan & Creelman, 1990). A larger d-prime means a better ability to differentiate true word targets and nonwords. The d-prime results were entered in a 2 (Language Immersion) × 4 (Language Conditions) repeated measures ANOVA. There was a significant main effect of Language Conditions ($F(2.436, 99.866) = 4.822$, $p = .008$, partial $\eta^2 = .105$). However, no significant difference between any pair of language conditions was found in the post hoc tests. No main effect of Language Immersion was found, and the interaction between Language Immersion and Language Conditions was also not significant. We can conclude

4. We also conducted the reliability analysis for the accuracy data, and the Cronbach alpha for the accuracy score is only 0.17. The low alpha is probably due to the fact that most of the responses were accurate, which means there was little variation in the data. As such, the accuracy results reported below should be taken with caution.

that the two participant groups did not differ in their sensitivity towards the Chinese or English targets.

4. Conclusion

Our data show significant priming effects in both L1-L2 and L2-L1 directions for our high-proficiency late Chinese-English bilingual speakers. Similar to previous studies, there is an asymmetry in the priming direction with a stronger effect in the L1-L2 direction (see Figure 3), but the L2-L1 priming is also present. Translation and semantic priming in both language directions are observed for our bilingual speakers.

We have also found evidence that an immersion environment affects bilingual priming patterns, but not in the form of 'bilingual disadvantage'. The immersed participants did not perform worse in their L1 than the non-immersed counterparts. Figure 4 illustrates the effects of immersion clearly: the two groups of participants did not differ in their reaction time to their L1, especially in the CC condition. Instead, the immersed English environment has narrowed the gap of reaction time difference between the two languages for the immersed participants, as compared to the non-immersed group. The immersion experience has instead brought an L2 processing advantage to the immersed participants as they could respond to L2 targets with a speed similar to L1 targets. The asymmetry between the two languages in their mental lexicon is reduced. The accuracy and the d-prime data also confirms that there is no difference in their responses to the L1 between the two participant groups. In light of these results, we found no evidence of the so-called 'bilingual disadvantage' in our immersed participants.

As for the other research questions, we did find a weaker priming asymmetry between the two language directions for the immersed participants, and that their reaction time to L1 and L2 were more comparable. Although our data did not illustrate any 'bilingual disadvantage' in the immersed participants, our results have nonetheless implications for the plausibility of the two accounts for the 'bilingual disadvantage' discussed in the Introduction, namely, language inhibition versus frequency of use.

Our results suggest that it is unlikely that the L1 of our immersed participants was inhibited, as our data demonstrates that they responded as quickly to their L1 as to their L2. Compared to the non-immersed participants, their reaction time to the L2 had clearly speeded up. As both languages are always active in the bilingual speakers, the increased frequency of use of the L2 in an immersion environment has increased its activation level to that of the L1. The Complementarity Principle (Grosjean, 2013) also explains how domain of language use can affect language dominance. Being in an L2 immersion environment means that the L2 is frequently being used in many domains, and often, many more domains than the L1. Our non-immersed participants mainly used English in a limited domain (i.e. during academic study). As a result, the activation of L2 remains high in the mental lexicon of immersed participants because of the increased extent and frequency of use. It can even be higher than the L1 for these bilingual speakers, which can explain the 'bilingual disadvantage' found by some previous studies. Thus, our data lends more support to the frequency of use account than the inhibition account. In addition to priming, more online implicit tasks (e.g., eye-tracking), can further evaluate the plausibility of language inhibition and frequency of use.

The Revised Hierarchical Model (RHM: Kroll and Stewart, 1994) can account for the effects of language immersion quite well, as the RHM captures the developmental change in linking between L1 and L2 and the conceptual store. The RHM predicts that processing asymmetries for each language direction should occur as a function of how strong the connections are. According to the RHM, the conceptual links are stronger between L1 words and the conceptual store than between L2 words and the conceptual store. As L2 proficiency increases, the links between L2 words and concepts will become stronger and speakers begin to rely more on these direct conceptual links rather than on the lexical links between L2 and L1. Although the RHM is more concerned about changes in L2 proficiency, it can be extended to account for changes due to language immersion as well. With similar L2 proficiency, language immersion increases speakers' exposure to L2 which will also strengthen the conceptual links between L2 and the conceptual store, to the extent that these links may even outgrow those for L1. The strength and direction of connections between different levels of representations are not static in the bilingual mind. An important strength of the RHM is its dynamic nature which can account for these environmental changes. Our findings show that the conceptual links will become stronger as exposure to L2 increases (i.e., more comparable to L1).

The effects of the length of immersion on the bilingual lexicon need to be further examined. Some previous studies demonstrated that a short immersion experience can already have an impact on the two languages of bilingual speakers (e.g., three months in Linck et al., 2009), while others have shown that a longer immersion experience is needed for its effects to emerge (e.g., 15 months or more in Tokowicz et al., 2004). All of our immersion participants had been in the US for less than four years, and over half of them had been there for less than one year. Their immersion duration was very similar to previous studies on language immersion. They were in the process of restructuring their languages (Grosjean, 1998). For those who had been there longer, they may have already completed restructuring their languages. Given the dynamic nature of the bilingual lexicon, future research may focus on the longitudinal development of bilingual speakers who experience a longer change in linguistic environment, such as before and after studying/working aboard for an extended period. Comparisons with their performance before the change, during immersion, and at different stages after the change, and also with those having shorter immersion experience can provide valuable insights into the processing and representation of the two languages in the mental lexicon during restructuring.

Our findings can also shed light on the architecture of the bilingual lexicon. It was discussed in the Introduction that the nature of semantic and translation priming in the bilingual lexicon is debatable. We have found significant effects for semantic priming and translation priming in both L1-L2 and L2-L1 directions. More importantly, the different scripts in Chinese and English and the typological differences between the two languages ensure that any cross-language priming effect in our study would be due to the interconnection of the two languages in the mental lexicon and not due to orthographic form similarity. The stronger effect of translation priming than semantic priming found in various studies is not surprising as there is more conceptual overlap between translation equivalents than semantically related words across languages, but this alone is not sufficient for Basnight-Brown and Altarriba (2007) to argue that they are stored and processed differently in the bilingual lexicon. Our findings are in line with Schoonbaert et al. (2009) who proposed that the difference between translation and semantic priming is only quantitative but not qualitative in nature, as both are conceptually mediated and not based on direct lexical connections.

Some studies suggested that the architecture of the bilingual lexicon depends on the age of acquisition. Silverberg and Samuel (2004) found semantic priming and mediated form priming (both implicate a shared conceptual level for the two languages) for early Spanish-English bilinguals who learned English before the age of seven in an immersion environment, but no such priming was found for late high-proficiency bilinguals who learned English in school after the age of seven. Instead, the late proficient learners showed form priming only which implicates that they have incorporated L2 words into the existing lexical level representation of their L1. Silverberg and Samuel modeled that the conceptual level is shared by the two languages for early learners only, while late proficient learners only have a shared lexical level with two separate conceptual stores. Similarly, Sabourin, Brien and Burkholder (2013) suggested that an early L2 age of acquisition was needed for L2-L1 translation priming to be present for their English-French participants. Late learners with proficiency similar to the early learners did not show such priming. They argued that the effect of age of acquisition is even more important than proficiency in shaping the bilingual lexicon. From this perspective, it is worth noting that both the immersed and non-immersed speakers in our study are late learners with high L2 proficiency who started learning English after the age of seven. Our findings show clearly that significant translation and semantic priming effects are found in both language directions. Thus, the two languages are shared at the conceptual level, and that highly proficient late bilingual speakers have direct access to word meaning from the two languages. Similar results were obtained by Degner et al. (2012), Guasch, et al. (2011) and Perea, Duñabeitia and Carreiras (2008).

There are some limitations of the current study. First, although all immersed participants have an IELTS score of 7.0 or above, as this is the minimal requirement of all overseas students in that university in Chicago, we did not collect their exact scores so no statistical comparison can be done between the two groups of participants. Second, we did not control for the number of senses of the words in our stimuli. A recent study shows that this factor can affect priming (Chen et al., 2014). Further priming studies on the effects of immersion should control for these more carefully.

In conclusion, we have demonstrated how immersion affects the two languages in the bilingual lexicon. Instead of inducing a 'bilingual disadvantage', the increased exposure to L2 in immersion environment has brought an L2 processing advantage to the immersed participants and has weakened the asymmetry between the two languages. We have also shown clear cross-language priming effects in both language directions for both translation and semantic priming using typologically different languages, which suggests that the two languages of highly proficient late bilingual speakers are shared at the conceptual level, and that translation and semantic priming are qualitatively similar in the bilingual mind. Our work encourages further research of the mental lexicon as the two languages restructure in the mind of bilingual speakers.

Acknowledgements

The authors would like to thank Donghui Zuo and Yanjun Yin for their contribution throughout the project. This research was partially supported by the Direct Grant for Research 2011–12 First Round, The Chinese University of Hong Kong awarded to the first author. She would also like to thank her department for funding support.

References

Altarriba, J. & Basnight-Brown, D. M. (2007). Methodological considerations in performing semantic- and translation-priming experiments across languages. *Behavior Research Methods*, 39, 1–18. doi: 10.3758/BF03192839

Argyri, E. & Sorace, A. (2007). Crosslinguistic influence and language dominance in older bilingual children. *Bilingualism: Language and Cognition*, 10, 79–99. doi: 10.1017/S1366728906002835

Basnight-Brown, D. M. & Altarriba, J. (2007). Differences in semantic and translation priming across languages: The role of language direction and language dominance. *Memory & cognition*, 35, 953–965. doi: 10.3758/BF03193468

Baus, C., Costa, A. & Carreiras, M. (2013). On the effects of second language immersion on first language production. *Acta Psychologica*, 142, 402–409. doi: 10.1016/j.actpsy.2013.01.010

Bedore, L. M., Pena, E. D., Summers, C. L., Boerger, K. M., Resendiz, M. D., Greene, K., Bohman, T. M. & Gillam, R. B. (2012). The measure matters: Language dominance profiles across measures in Spanish–English bilingual children. *Bilingualism: Language and Cognition*, 15, 616–629. doi: 10.1017/S1366728912000090

Cantone, K., Kupisch, T., Müller, N. & Schmitz, K. (2008). Rethinking language dominance in bilingual children. *Linguistische Berichte*, 215, 307–343.

Chen, B., Zhou, H., Gao, Y. & Dunlap, S. (2014). Cross-language translation priming asymmetry with Chinese-English bilinguals: A test of the Sense Model. *Journal of Psycholinguistic Research*, 43, 225–240. doi: 10.1007/s10936-013-9249-3

Chen, H. C. & Ng, M. L. (1989). Semantic facilitation and translation priming effects in Chinese-English bilinguals. *Memory & cognition*, 17, 454–462. doi: 10.3758/BF03202618

Coderre, E. L., Van Heuven, W. J. B. & Conklin, K. (2013). The timing and magnitude of Stroop interference and facilitation in monolinguals and bilinguals. *Bilingualism: Language and Cognition*, 16, 420–441. doi: 10.1017/S1366728912000405

Daller, M. H., Yildiz, C., de Jong, N. H., Kan, S. & Başbaĝi, R. (2010). Language dominance in Turkish–German bilinguals: methodological aspects of measurements in structurally different languages. *International Journal of Bilingualism*, 15, 215–236. doi: 10.1177/1367006910381197

Degner, J., Doycheva, C. & Wentura, D. (2012). It matters how much you talk: On the automaticity of affective connotations of first and second language words. *Bilingualism: Language and Cognition*, 15, 181–189. doi: 10.1017/S1366728911000095

Dong, Y., Gui, S. & MacWhinney, B. (2005). Shared and separate meanings in the bilingual mental lexicon. *Bilingualism: Language and Cognition*, 8, 221–238. doi: 10.1017/S1366728905002270

Dunn, A. L. & Fox Tree, J. E. (2009). A quick, gradient Bilingual Dominance Scale. *Bilingualism: Language and Cognition*, 12, 273–289. doi: 10.1017/S1366728909990113

Dussias, P. E. & Sagarra, N. (2009). The effect of exposure on syntactic parsing in Spanish-English bilinguals. *Bilingualism: Language and Cognition*, 10, 101–116. doi: 10.1017/S1366728906002847

Finkbeiner, M., Forster, K., Nicol, J. & Nakamura, K. (2004). The role of polysemy in masked semantic and translation priming. *Journal of Memory and Language*, 51, 1–22. doi: 10.1016/j.jml.2004.01.004

Gollan, T. H., Montoya, R. I., Fennema-Notestine, C. & Morris, S. K. (2005). Bilingualism affects picture naming but not picture classification. *Memory & cognition*, 33, 1220–1234. doi: 10.3758/BF03193224

Green, D. M. & Swets, J. A. (1966). *Signal Detection Theory and Psychophysics* New York: Wiley.

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition*, 1, 67–81. doi: 10.1017/S1366728998000133

Grosjean, F. (1998). Studying bilinguals: Methodological and conceptual issues. *Bilingualism: Language and Cognition*, 1, 131–149. doi: 10.1017/S136672899800025X

Grosjean, F. (2013). Bilingualism: A short introduction in Grosjean, F. & Li, P. (eds.), *The Psycholingusitics of Bilingualism*, 5–25. Hoboken: Wiley-Blackwell.

Guasch, M., Sánchez-Casas, R., Ferré, P. & Garciá-Albea, J. E. (2011). Effects of the degree of meaning similarity on cross-language semantic priming in highly proficient bilinguals. *Journal of Cognitive Psychology*, 23(8), 942–961. doi: 10.1080/20445911.2011.589382

Heredia, R. R. (1997). Bilingual memory and hierarchical models: A case for language dominance. *Current Directions in Psychological Science*, 6, 34–39. doi: 10.1111/1467-8721.ep11512617

Jiang, N. (1999). Testing processing explanations for the asymmetry in masked cross-language priming. *Bilingualism: Language and Cognition*, 2, 59–75. doi: 10.1017/S1366728999000152

Keatley, C. W., Spinks, J. A. & de Gelder, B. (1994). Asymmetrical cross-language priming effects. *Memory & cognition*, 22, 70–84. doi: 10.3758/BF03202763

Kroll, J. F. & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language*, 33, 149–174. doi: 10.1006/jmla.1994.1008

Linck, J. A., Kroll, J. F. & Sunderman, G. (2009). Losing access to the native language while immersed in a second language: Evidence for the role of inhibition in second language learning. *Psychological Science*, 20, 1507–1515. doi: 10.1111/j.1467-9280.2009.02480.x

Macmillan, N. A. & Creelman, C. D. (1990). Response bias: Characteristics of detection theory, threshold theory, and "nonparametric" indexes. *Psychological Bulletin*, 107, 401–413. doi: 10.1037/0033-2909.107.3.401

Malt, B. C., Li, P., Pavlenko, A., Zhu, H. C. & Ameel, E. (2015). Bidirectional lexical interaction in late immersed Mandarin-English bilinguals. *Journal of Memory and Language*, 82, 86–104. doi: 10.1016/j.jml.2015.03.001

Morales, L., Paolieri, D., Cubelli, R. & Bajo, M. T. (2014). Transfer of Spanish grammatical gender to English: Evidence from immersed and non-immersed bilinguals. *Bilingualism: Language and Cognition*, 17 (4), 700–708. doi: 10.1017/S1366728914000017

Pavlenko, A. (ed.) (2009). *The Bilingual Mental Lexicon: Interdisciplinary Approaches*. Bristol: Multilingual Matters. doi: 10.1080/13670050.2010.538260

Perea, M., Duñabeitia, J. A. & Carreiras, M. (2008). Masked associative/semantic priming effects across langauges with highly proficient bilinguals. *Journal of Memory and Language*, 58, 916–930. doi: 10.1016/j.jml.2008.01.003

Ratcliff, R. (1993). Methods for Dealing with Reaction-Time Outliers. *Psychological Bulletin*, 114(3), 510–532. doi: 10.1037/0033-2909.114.3.510

Sabourin, L., Brien, C. & Burkholder, M. (2013). The effect of age of L2 acquisition on the organization of the bilingual lexicon: Evidence from masked priming. *Bilingualism: Language and Cognition*, 17(3), 542–555. doi: 10.1017/S1366728913000643

Schoonbaert, S., Duyck, W., Brysbaert, M. & Hartsuiker, R. J. (2009). Semantic and translation priming from a first language to a second and back: Making sense of the findings. *Memory & cognition*, 37, 569–586. doi: 10.3758/MC.37.5.569

Sholl, A., Sankaranarayanan, A. & Kroll, J. F. (1995). Transfer between picture naming and translation: A test of asymmetries in bilingual memory. *Psychological Science*, 6, 45–49. doi: 10.1111/j.1467-9280.1995.tb00303.x

Silverberg, S. & Samuel, A. G. (2004). The effect of age of second language acquisition on the representation and processing of second langauge words. *Journal of Memory and Language*, 51, 381–398. doi: 10.1016/j.jml.2004.05.003

Tokowicz, N., Michael, E. & Kroll, J. F. (2004). The roles of study-abroad experience and working-memory capacity in the types of errors made during translation. *Bilingualism: Language and Cognition*, 7, 255–272. doi: 10.1017/S1366728904001634

Treffers-Daller, J. (2010). Operationalizing and measuring language dominance. *International Journal of Bilingualism*, 15, 147–163. doi: 10.1177/1367006910381186

Van Hell, J. G. & Tanner, D. (2012). Second Language Proficiency and Cross-Language Lexical Activation. *Language Learning*, 62: Suppl. 2, 148–171. doi: 10.1111/j.1467-9922.2012.00710.x

Whelan, R. (2008). Effective analysis of reaction time data. *The Psychological Record*, 58, 475–482.

Zhao, X., Li, P., Liu, Y., Fang, X. & Shu, H. (2011). Cross-language priming in Chinese-English bilinguals with different second language proficiency levels. *Proceedings of The 33rd Annual Conference of the Cognitive Science Society*, Austin, TX.

Authors' addresses

Peggy P.K. Mok
The Chinese University of Hong Kong
Department of Linguistics and Modern Languages
Leung Kau Kui Building
The Chinese University of Hong Kong, Shatin
HONG KONG

peggymok@cuhk.edu.hk

Alan C.L. Yu
University of Chicago
Department of Linguistics
1115 E. 58th Street
Chicago, IL 60637
United States

aclyu@uchicago.edu

Publication history

Date received: 30 July 2015
Date accepted: 29 January 2016
Published online: 4 May 2016