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Semantic competitor priming within and across languages: The interplay of vocabulary knowledge, learning experience and working memory capacity

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Abstract

This paper reports three studies of bilingual lexical processing, using the semantic competitor priming (SCP) method of Lee and Williams (2001). Study 1 found within-language priming for Chinese-English bilinguals with both higher and lower levels of vocabulary knowledge. There was also a cross-language SCP effect, but this was restricted to bilinguals with lower levels of vocabulary knowledge. Study 2 found a cross-language SCP effect for Chinese learning English in the classroom context. Study 3 found both a within- and cross-language SCP effect for bilinguals with study-abroad experience as well as those classroom Chinese learners of English who had a higher working memory capacity. Those findings are interpreted in terms of a dynamic view of bilingual language selection.

When a bilingual intends to speak in one language, translation equivalents and related words in the non-intended language are also activated (Costa, 2005). Given this pattern of co-activation, one would then also like to know whether or not the forms of the non-intended language enter into actual on-line competition with those of the intended language during speech production. Some models of bilingual lexical access (Costa, Miozzo and Caramazza, 1999) assume that cross-language competition "reflects only the flow of activation, not genuine competition for selection" (Kroll, Bobb and Wodniecka 2006, p.121). On this "non-interactive" account, lexical selection is truly competitive only within languages, but not across languages.

In contrast, interactive models assume that the processor considers all activated candidates from both languages. In this framework, successful selection of the proper candidate can be achieved by maintaining a higher level of activation for words from the intended language (see Costa and Santesteban, 2004). Alternatively, the same result can be obtained by inhibiting words in the non-intended language (Green, 1986).

Costa et al. (1999) found cross-language facilitation effects, rather than interference effects, using the picture-word interference paradigm with Catalan–Spanish bilinguals. Naming was facilitated when the distractor was the name of the picture in both same-language and different-language pairs. Moreover, semantically related distractors in the same-language and different-language conditions were similarly interfering. Costa et al. interpreted these results as evidence for the existence of a non-interactive lexical selection mechanism that considers only the activated candidates of the intended language.

The non-interactive view has also received support from studies using the semantic competitor priming (SCP) paradigm. Studying advanced English learners of French, Lee and Williams (2001) found a within-language SCP effect when their participants named the target picture in English and a cross-language SCP effect from English to French. At the beginning of each trial sequence, participants activated the prime by providing the definition of an object in English. Half of the time, the intervening trials were all in English and half of the time they included one trial in French. Lee and Williams found that the intervening use of English was essential for sustaining the priming interference effect. In fact, the intervening use of French completely wiped out the head start the English competitor could have enjoyed in its lexical competition with the target name during picture naming. They argued that this suppression of L1 through intervening L2 trials indicates that language selection at the lemma level is achieved through inhibition of the non-intended L1.

However, findings from picture-word interference studies provide evidence against the view of language-specific lexical access. Hermans, Bongaerts, de Bot and Schreuder (1998) investigated whether words in L1 were activated during picture naming in L2 by Dutch-English unbalance bilinguals. They reported that the Dutch name of a picture was activated during initial stages of the lexical process in English as a foreign language. They concluded that bilingual speakers cannot suppress activation from their first language while naming pictures in a foreign language.

Costa and Santesteban (2004) suggested that language proficiency may affect a bilingual speaker's language selection during the planning of spoken utterances in each language. They found a striking difference between the performance of highly proficient bilinguals and L2 learners in a language-switching task. Asymmetrical switching costs were observed for both

Spanish learners of Catalan and Korean learners of Spanish (i.e., it was harder to switch from the L2 into the L1 than vice versa.), but these switching costs were not present when highly proficient Spanish-Catalan bilinguals were asked to perform the switching task either in their L1 and L2, or in their L1 and in their L3. They explained that the highly proficiently bilinguals may be able to achieve language selection without actively inhibiting cross-language competing candidates whereas the L2 learners may need to make use of inhibitory control to ensure selection in the intended language. They argued that, for a bilingual speaker, an increase in proficiency might lead to a qualitative change from “the reliance on inhibitory control to the reliance on a language-specific selection mechanism during lexical selection” (ibid, p. 505).

Following the analysis of Kroll et al. (2006), we might be able to understand these contrasting findings by exploring the various factors that promote language selectivity, as opposed to interactivity. In particular, we are interested in exploring the roles of (1) L2 vocabulary knowledge, (2) working memory capacity, and (3) language learning history in promoting or hindering language selectivity.

First, it is possible that bilinguals and advanced learners with higher levels L2 vocabulary knowledge may demonstrate stronger language selectivity. There is abundant evidence that L2 vocabulary knowledge influences L2 semantic processing at the word level (Li, 2003; Li, 2007; Nation, 2001). L2 vocabulary knowledge refers to what a learner knows about a word in the second language, which covers both the size and depth perspectives of word knowledge. Vocabulary size denotes the number of words a learner possesses of the target language. With reference to the depth of vocabulary knowledge, it includes knowledge about the form, position, function, and meaning of a word (Nation, 1990). Li (2003, 2007) examined the role of L2 vocabulary knowledge on semantic processing of Chinese learners of English using a primed lexical decision task. The results showed that learners with high-level English vocabulary knowledge were significantly quicker and more accurate than those with low-level L2 vocabulary knowledge.

Second, it is possible that bilinguals with greater working memory capacity may show strong language selectivity. Modern theories of working memory (Rosen & Engle 1998) view it as a system not only for storing and processing temporary information, but also for suppressing irrelevant information and allocating cognitive resources (e.g. Just and Carpenter, 1992). High working memory capacity has been found to be particularly critical for bilingual tasks that demand the activation of both languages (Tokowicz, Michael, & Kroll, 2004). It is relatively less useful in more automatic bilingual tasks (Li, 2004; Michael, Dijkstra and Kroll, 2002).

Third, it is possible that bilinguals who acquire their knowledge of L2 in more interactive learning contexts may come to acquire greater control over language selection. Tokowicz, Michael and Kroll (2004) examined the effects of study-abroad experience and working memory capacity on the types of errors made in a single-word translation task from the L1 into L2. Their study suggests that study-abroad experience leads individuals to make more meaning-related responses.

Although L2 vocabulary knowledge, working memory capacity, and learning experience have been shown to influence L2 processing, few studies have looked at their effects on the process of lexical selection. The current study seeks to explore these relations. Using the SCP paradigm, we examined the interplay of vocabulary knowledge, learning experience and individual differences in working memory capacity.

In Study 1, we tested the role of L2 vocabulary knowledge on SCP with Chinese-English bilinguals with more than 12 months study-abroad experience as participants. We hypothesized that bilinguals with higher levels of L2 vocabulary knowledge would benefit more from their study-abroad learning experience than their counterparts with lower level of L2 vocabulary knowledge due to richer vocabulary, and that this difference in lexical knowledge would affect how they achieve language selection in spoken word production.

In Study 2, we tested the role of learning experience on SCP with Chinese-speaking learners of English with no study-abroad experience as participants. We hypothesized that learning experience might affect the way how Chinese-English classroom learners might achieve their language selection in spoken word production.

In Study 3, we explored the role of individual differences in working memory capacity and learning experience on SCP by examining the spoken word production process of Chinese-English bilinguals with study-abroad experience and Chinese-speaking classroom learners of English. We hypothesized that individual differences in working memory capacity and learning experience would also influence the way participants achieve language selection.

Study 1

Method

Participants

Twenty-four paid full-time university students participated in this study. They were relatively fluent Chinese-English speakers with more than 12 months study-abroad experience. At the time of the study, they were studying at a university in Pittsburgh, Pennsylvania. Twenty-two of them were graduate students and two of them were undergraduate students. Half of them were male students and half were female students.

Tasks and Materials

Semantic competitor priming task. We used the SCP paradigm, devised by Wheeldon and Monsell (1994) and modified by Lee and Williams (2001). In Wheeldon and Monsell's experiments, a participant was asked to produce a prime word in response to a given definition. Later, the participants named a target pictured object. The time to name the target picture (e.g., zebra) was longer when the prime was a semantic competitor. For example, a participant might produce the prime form "camel" in response to the definition "an animal which a traveler rides on in the desert". The production of this prime then interferes with the later naming of a semantically related target picture such as "horse" as opposed to some unrelated picture. This effect occurs even if the prime is named three or more trials before the target[1].

The finding that the prime interferes with the target name retrieval is thought to be due to the strengthening of a prime's representation in memory over its baseline activation. This strengthening makes it a stronger competitor, when it is activated along with other semantically related competitors in parallel with the target representation. In effect, the competitor receives a head start as a result of its prior production (see Lee and Williams, 2001).

Because we wanted to focus on the cross-language SCP effect, we did not manipulate the language change factor. As a result, there were four treatment conditions instead of eight conditions in this task. Each participant was asked to respond orally to three self-paced Chinese definition trials each using a two-character-Chinese-word followed by two picture-naming trials[2]. If a participant did not know the word the definition referred to, he/she was instructed to say "不知道" *(I don't know)*. Before each picture, a cue was displayed on the computer screen, telling the participant what language to use when naming the following picture. Participants were also instructed to name pictures as quickly as possible in either Chinese or English following the language cue before the picture. When they named a picture in Chinese, they were also required to respond with a two-syllable-word. If a participant did not come up with a response, he/she could say “I don’t know” or “不知道” according to the language cue given before the picture.

As to the material selection, 35 target pictures were selected from the pictures provided by the International Picture Naming Project at CRL-UCSD[3]. There are two criteria for this selection: 1) pictures need to be named using two Chinese characters, and 2) percent name agreement on the target pictures should be above 0.8 in both Chinese and English. The selected target pictures were then paired with 35 Chinese two-character words and their definitions were written based on the Contemporary Chinese Dictionary.

Each word pair was accompanied by four additional intervening trials. These included: one unrelated Chinese control definition, two Chinese filler definitions, and one filler picture to be named either in Chinese or English were selected. In order to determine the availability of all the definitions, a pre-test was run among a group of 20 native speakers of Chinese who are full-time graduate students studying at Chongqing University, PR China. After that, a semantic relatedness rating task was administered to another group of 20 Chinese native speakers who were also graduate students studying at the same university. Then, the 32 word pairs were finalized, together with their control definitions and filler definitions, with semantic relatedness rating of 4.29 for the related pairs and 2.11 for the unrelated pairs[4].

A target picture could be named in one of the four conditions: CCEC-P, CCEC-U, CCCE-P and CCCE-U[5]. An example of the sequence of expected responses in one run of trials for each condition is shown in Table 1. Materials were divided into four lists: List A, List B, List C and List

D with eight items in each condition. Participants were assigned randomly to one of the material list with equal number of male and female participants in each list.

[Insert Table 1]

The Controlled Active Vocabulary Test (CAVT). The CAVT[6] was used to measure learners' controlled productive ability to use a word when they are compelled to produce a word in a constrained context. There are 90 sentences and each of them has a word with a missing part, which has to be supplied. The first letter of each item is always provided so that there is only one correct answer for each item. For example: He was riding a bic___. The participants need to understand the meaning of the sentence or activate their knowledge of the missing word before they are able to fill in the blank. A correct answer[7] is scored 1 point in this task, and the highest possible score is 90.

Language history survey. Participants completed a language history survey in which they reported on their L2 learning experiences in L1 Chinese. They all began their English learning in schools in PR China. Some of them began their English learning in a primary school and some in a secondary school. Each participant rated their L1 and L2 reading, writing, speaking and listening proficiency on scales from 1 to 10[8] and indicated their types of L2 language learning exposure as well as the age they began learning the L2 (see Table 2 for more details of the group means for the major measures of the survey).

Working memory span task. We used a modified version of the Conway and Engle (1996) operation span task. In this task[9], 66 mathematical operations were randomly paired with a total of 66 to-be-remembered Chinese words. The mathematical operations were organized into 15 series, and the number of operation-word strings per series varied from two to six, with three series of each length being performed. The order of series length was randomized. Three series of 2 operation-word strings were used for the purpose of practice.

During the task, the participants were presented with operation-word strings, e.g., (6÷2) + 2 = 5? They were instructed to read the operations aloud and decide whether the operations were correct or not by pressing the "Y" or "N" button and at the same time say "dui" (correct) or "cuo" (wrong) aloud. After that, a two-character Chinese word would appear immediately on the screen, and the participants were asked to read aloud the Chinese word presented. Then, the experimenter immediately clicked the mouse, and another operation-word string was presented. This process continued until the recall cue was presented, and then the participants were to recall the Chinese words in order. A mini-recorder was used to record their recall. The instructions for this task were presented in written form in Chinese.

Procedure

Participants were tested individually in the Psylab of Carnegie Mellon University[10]. They were instructed to complete the SCP task first. Then they were asked to take the Controlled Active Vocabulary Test in L2 English. After a short break, the participants were required to complete a language history survey in their L1, and finally, they were asked to take a working memory span task in Chinese.

Results

CAVT data

Participants were grouped on the basis of their CAVT scores. Twelve participants in the CAVT high group had a mean score of 78.17 (SD 6.60) and 12 participants in the CAVT low group had a mean score of 57.17 (SD 9.00). Results of an independent *t*-test revealed a significant difference between the mean scores of the two groups [t (22) = 6.515, p <.0001].

Language history survey data

We compared the CAVT high and low groups in terms of (1) their age, (2) the age at which they began to learn L2, (3) the number of years they had studied L2, and (4) the number of months of study-abroad experience (see Table 2). There were no reliable group differences on those dimensions (*p*s > .05). We also compared the overall proficiency rating of the two groups for their L1 and L2, and we found that participants in the CAVT high group gave a higher L1 overall proficiency rating than their counterparts [t (22) = 2.442, p < .05], and they also rated their L2 overall proficiency higher than their counterparts [t (22) = 2.173, p < .05].

[Insert Table 2]

Both subgroups rated their L1 proficiency significant higher than their L2 (for the CAVT high group: t (11) = 7.453, p < .01; for the CAVT low group: t (11) = 6.106, p < .01). Thus, we considered Chinese as their L1 dominant language and English as their second language for both groups.

Working memory capacity data

The average working memory capacity (WMC) span score was 21.88 (range = 6 to 49), and the average accuracy rate on the mathematical operations was 84.65% (range = 56.67% to 96.67%). We also compared the mean differences of the span scores in the CAVT high and low groups. The mean span score was 23.25 (SD 12.58) for the former group and 20.5 (SD 8.22) for the latter group. No significant difference was found between these two groups [(t (22) = .634, p=.533].

Semantic competitor priming data

Target picture naming data[11] were excluded, if there was no response after three seconds.

Trials were also excluded if the wrong language was used, if the picture was named incorrectly, if the subject said "I don't know", or if the expected competitor was not elicited as the definition response for the prime. If a target item had more than one third of the data excluded, then it was discarded from further analysis. Using these criteria, four items were discarded from the analyses. If a participant had more than one third of the target naming data discarded, those data were excluded from the final analyses. Target picture naming data for correct responses which fell beyond 2.5 SD of the group means in each condition were also excluded from final analyses. Data from all the 24 participants met this criterion.

Subject analyses of variance (ANCOVA) were conducted in SPSS using a 2 (Language of target pictures: L1 vs. L2) × 2 (SCP: primed vs. unprimed) × 2 (L2 vocabulary knowledge: high vs. low) mixed design, and working memory span scores were treated as a covariate to eliminate potential confounding effects in the analyses[12].

[Insert Table 3] [13]

To determine the within- and cross-language SCP effect, we calculated the mean naming latencies to target pictures for correct responses and the mean error rate. In the analyses of naming latencies, the main effect of Language was significant [F (1, 21) = 12.675, p < .001]. Target pictures were named about 122 ms more quickly in L1 Chinese than in L2 English. But the interaction between the Language and L2 vocabulary knowledge was not significant [F (1, 21) = 2.626, p = .120]. Neither the main effect of SCP [F (1, 21) = .632, p = .436] nor the interaction of SCP with Language was significant [F (1, 21) = 1.168, p = .292]. However, there was a three-way interaction of the Language, SCP, and L2 vocabulary knowledge [F (1, 21) = 4.619, p < .05]. Bilinguals with higher levels of L2 vocabulary knowledge named primed target pictures more slowly than unprimed target pictures (1248 ms vs. 1190 ms; priming effect is 58 ms) in L1, but they named primed target pictures faster than unprimed target pictures in L2. On the other hand, bilinguals with lower levels of L2 vocabulary knowledge named primed target pictures more slowly than unprimed target pictures both in L1 Chinese (1463 ms vs. 1422 ms; priming effect is 41 ms) and L2 English (1584 ms vs. 1411 ms; priming effect is 173 ms). There was also a main effect of L2 vocabulary knowledge [F (1, 21) = 5.766, p <.05]. The bilinguals in the CAVT high group named the target pictures about 156 ms faster than those in the CAVT low group (1314 ms vs. 1470 ms).

For the error rate data, the analyses did not show a main effect of Language [F (1, 21) = 0.584, p = .453], SCP [F (1, 21) = 3.226, p = .087], or an interaction between the two factors [F (1, 21) = 2.40, p = .135]. Neither did the analysis yield an interaction between Language, SCP and L2 vocabulary knowledge [F (1, 21) = 0.095, p = .760]. However, there was a main effect of L2 vocabulary knowledge [F (1, 21) = 5.545, p <.05] and an interaction between Language and L2 vocabulary knowledge [F (1, 21) = 11.59, p < .01]. The error rate for the bilinguals in the CAVT high group was significantly lower than that in the CAVT low group (2.16% vs. 4.32%). Further, for the bilinguals with a high level of L2 vocabulary knowledge, the error rate in naming target pictures in L2 was significantly lower than that in naming target pictures in L1 (0.79% vs. 3.57%), but for those bilinguals with a lower level of vocabulary knowledge, this reverse pattern was observed, which means that their error rate was higher when they named the target pictures in L2 than in L1 (5.21% vs. 3.42%).

Discussion

Study 1 yielded three important results. One was the three-way interaction of Language, SCP, and L2 vocabulary knowledge in the latency data. For all participants, a within-language SCP effect was observed when the language of the target picture was L1 Chinese. However, the pattern was different when the Language was L2 English. In that case, a cross-language SCP was only observed for bilinguals with lower levels of L2 vocabulary knowledge. The second important result was that L2 vocabulary knowledge had an effect on both naming latencies and the error rate. The bilinguals in the CAVT high group named the target pictures faster than those in the CAVT low group and further their error rate was lower than that of their counterparts in the CAVT low group. The third important result was the interaction between Language and L2 vocabulary knowledge. Bilinguals with a high level of vocabulary knowledge named target pictures in L2 more correctly than target pictures in L1. However, bilinguals with lower L2 vocabulary knowledge named target pictures in L1 more correctly.

The findings of this study provide evidence for a cross-lexical competition when Chinese-English bilinguals with study-abroad experience are engaged in a SCP task. They also point to the possibility that L2 lexical knowledge might constrain language selection during the planning of spoken utterances in each language.

We can also ask whether there is evidence in these data for a language-specific selection mechanism. If so, is this reliance on a language-specific selection mechanism associated more with high levels of L2 vocabulary knowledge or more extensive learning experience? In order to answer those questions, we will examine the role of learning experience on within- and cross-language inhibitory priming using a group of Chinese-English classroom learners with no study-abroad experience using the same SCP task.

Study 2

Method

Participants

The participants were 27 first-year students enrolled in the graduate program of Linguistics and Applied Linguistics at Chongqing University, PR China and 10 first-year graduate students in science and engineering programs at Zhejiang University, PR China. All of them had Chinese as their native language and English as their second language. They had received English classroom instruction since secondary education. At the time of this study, participants from the first group took four or five academic courses[14] in Linguistics and Applied Linguistics, while participants from the second group took the course of College English[15]. None of the participants had any experience of studying or living in English speaking countries.

Procedure

Participants were tested individually in their home institutions and data collection was spread out in a period of two weeks. The general procedure and experimental tasks were the same as those described in Study 1.

Results

CAVT and language history survey data

Participants were measured on their L2 vocabulary knowledge using CAVT. Their scores ranged from 46 to 68 with a mean a mean score of 54.2 (SD = 5.84), and their mean score of CAVT was similar to that of the CAVT low group in Study 1[16]. On average, participants were 24.96 (SD = 3.06) years old and they began their English learning in secondary schools at the age of 12.67 (SD = 0.87) and they studied English in a classroom setting for an average of 11.75 years

(SD = 2.05). Participants gave an average of total rating of 34.92 (SD = 4.54) for their ability in their native language and 28.67 (SD = 4.33) for their ability in L2 English.

Semantic competitor priming task data

Seven participants who were not able to name nine or more of the target pictures were excluded from the analyses[17]. One participant was also excluded, because the recording volume was not aloud enough. In order to keep the number of participants in each material list equal, data were included from 24 participants of the total 29 eligible participants. All subsequent analyses reported are based on this revised set of 24 participants.

Subject analyses of variance were conducted using a 2 (Language: L1 vs. L2) × 2 (SCP: primed vs. unprimed) design. Both mean lexical latencies of target pictures for correct responses and mean error rate were analysed (see Table 4 for the means).

[Insert Table 4]

In the analyses of naming latencies, the effect of Language was significant [$F (1, 23) = 20.154$, $p < .001$]. Target pictures were named about 227 ms more quickly in L1 Chinese than in L2 English. The effect of SCP was not significant [$F (1, 23) = 3.998$, $p = .06$]. Although there was a numerical difference of 76 ms between the mean RT for the primed target pictures and the unprimed ones, the difference was not reliable. However, the interaction between the two factors approached significance [$F (1, 23) = 5.99$, $p < .05$]. The nature of the interaction was just as Lee and Williams (2001) reported: Unbalanced bilinguals demonstrated a cross-language SCP effect when they named the target pictures in L2 rather than in L1.

In the analyses of error rate, the effect of Language was significant, with a higher error rate in naming the target picture in L2 than in L1 (7.49% vs. 1.96%) [$F (1, 23) = 63.175$, $p < .001$].

None of the other effects were significant.

Discussion

One important result of this study was the Language × SCP interaction yielded from the analyses of target picture naming latencies. We found a cross-language SCP effect when the classroom learners named the target picture in L2 English, which confirms the robustness of cross-language inhibitory priming effect from L1 to L2 as demonstrated by the unbalanced bilingual speakers in Lee and Williams (2001), as well as the bilinguals with study-abroad experience in the CAVT low group in Study 1. As noted earlier, participants in this study had a similar level of vocabulary knowledge as those bilinguals with study-abroad experience in the CAVT low group, so the cross-language SCP effect was obtained regardless of study-abroad learning experience.

When the classroom learners named the target picture in L1 Chinese, the cross-language inhibitory priming was not obtained. This agrees with the result reported in Lee and Williams (2001).

Study 3

Method

Participants

Sixteen bilinguals with study-abroad experience (SAE) and 16 classroom learners (CL) participated in this study. For the SAE group, the CAVT score ranged from 41 to 68 with a mean of 59.42; for the CL group, it ranged from 46 to 59 with a mean score of 51.94.

Results

Participants in the CL group were measured on their working memory span using the same span task as described in Study 1. In general, participants in this group responded correctly to 89.25 % of the mathematical operations (range = 26.70% to 100%). They were then divided into a high span and a low span group, with a mean span of 25.43 for the high span group and 10.33 for the low span group.

The SAE group was also grouped on the basis of their performance in the working memory span task with a correct rate of accuracy of 87.55 % for the mathematical operations (range = 60.67% to 90.67%). The mean span score of the high span group was 27.14 while the mean span score of the low span group was 15.57. The SAE group and CL group did not differ in their CAVT scores [$F(3, 28) = 1.995$; $p = .142$] and post-hoc tests did not reveal any significant differences ($ps > .2$).

[Insert Table 5]

Results from one-way ANOVA yielded a significant between-group difference of working memory span scores [$F(3, 28) = 13.24$, $p < .001$]. Further, post-hoc tests revealed a significant difference between the mean high and low span scores of the SAE group ($p < .01$) as well as a significant difference between those of the CL group ($p < .001$). Moreover, post-hoc tests did not show a difference between the two high span groups ($p = .947$) or between the two low span groups ($p = .333$).

To determine the role of working memory capacity (WMC) and learning experience (LE) on within- and cross-language SCP, we used a 2 (Language: L1 vs. L2) × 2 (SCP: primed vs. unprimed) × 2 (WMC: high vs. low) × 2 (LE: SAE vs. CL) mixed ANOVA design. The analyses on the latency data revealed a significant main effect of Language [$F(1, 28) = 9.26$, $p < .01$].

Target pictures were named more quickly in L1 Chinese than in L2 English (1331 ms vs. 1465 ms).

The analyses also showed a significant interaction between SCP and WMC [$F(1, 28) = 4.571$, $p<.05$] (see Table 6). Primed target pictures were named 146 ms more slowly than unprimed target pictures for the participants of higher WMC in the SAE group and CL group. However, this pattern was not observed with the participants of lower WMC in the two groups. Although there seemed to be a numerical difference of mean naming latency for the primed target pictures and the unprimed target pictures (1711 ms vs. 1624) when the participants with lower WMC in the SAE group named primed target pictures in L2 English, this difference was not reliable ($p = .602$).

[Insert Table 6]

Furthermore, the analyses yielded a significant interaction between WMC and LE [$F(1, 28) = 6.006$, $p<.05$]. The participants of higher WMC in the SAE group named all target pictures more quickly than those of lower capacity (1314 ms vs. 1588 ms), whereas the participants of higher WMC in the CL group named all target pictures more slowly than those of lower span (1391 ms vs. 1299 ms). None of the other effects were significant ($ps > .11$).

The analyses on error rate data showed a significant main effect of Language, with a lower error rate in naming the target picture in L1 than in L2 (2.87% vs. 5.68%) [$F(1, 28) = 15.091$, $p< .01$]. The interaction between Language and LE was also significant, $F(1, 28) = 13.747$, $p< .01$. The participants in the CL group named the target pictures in L1 Chinese with a much lower error rate than they did with the pictures in L2 English (1.79% vs. 7.27%), while participants in the SAE group named the pictures in L1 Chinese and L2 English with a similar error rate (3.95% vs. 4.08%).

There was no main effect SCP, but there was a significant three-way interaction of Language, SCP, and WMC [$F(1, 28) = 4.266$, $p < .05$]. Participants with higher WMC named primed targets with a higher error rate than unprimed targets (4.34% vs. 1.79%) in L1 Chinese, but they named the primed and unprimed targets with a similar error rate in L2 English ($p = .656$). However, for the participants with lower capacity, the pattern was reversed. They named primed and unprimed target pictures in L1 Chinese with a similar error rate ($p = .818$). However, in L2 English they named primed targets with a higher error rate than unprimed targets (6.63% vs. 3.57%).

Discussion

With regard to the error rate data, there were two important results. The first was the interaction between language and learning experience. The participants in the CL group tended to be less skillful when naming targets in L2 English. However, their counterparts in the SAE group showed no difference between the error rates for L1 and L2. As noted earlier, the SAE group and CL group did not differ in their CAVT scores; the interaction effect seems to suggest that study-abroad experience leads to a more accurate L2 naming in a language-switching task of this type.

The second result of importance for the error data was the significant three-way interaction of Language, SCP, and WMC. The fact that the lower WMC participants failed to demonstrate within-language SCP indicates that they may not be keeping the prime active in memory. The fact that higher WMC participants show the SCP effect for L1 indicates that they have the basic verbal processing needed to display the SCP effect for errors as well as latencies, but that their relatively low level of L2 experience makes the effect of SCP relatively weaker in L2 English in terms of error data.

For the latency data, both within- and cross-language SCP effects were observed for the participants with higher WMC. Higher WMC may allow participants to keep the Chinese competitor in mind when naming pictures in both L1 Chinese and L2 English. Although Studies 1 and 2 revealed a robust cross-language SCP effect from L1 to L2 for bilinguals with study-abroad experience and classroom learners with no study-abroad experience, only a weaker trend was demonstrated for the participants with lower WMC in the SAE group. For the participants with lower WMC in the CL group, no such trend was seen at all. It seems that, for the participants with study-abroad experience, their lack of cognitive resources could be compensated for to some extent by their experience in the target language context.

General Discussion

The main goal of the studies presented here was to determine to the extent to which the functioning of the language selection mechanism is influenced by the factors of L2 vocabulary knowledge, learning experience, and individual differences in working memory capacity. As noted earlier in this paper, there is disagreement on whether bilingual language selection mechanism is language-specific or language-nonspecific. Recently, Kroll et al. (2006) have argued for viewing the control of language selection as a dynamic process influenced by factors of the sort tracked in the current study.

The results of Study 1 reveal a within-language SCP effect for the bilinguals with both higher and lower levels of L2 vocabulary knowledge, when they named the target picture in L1 Chinese and a cross-language SCP effect for bilinguals with a lower level of L2 vocabulary knowledge when the language of the target picture was L2 English.

There are two striking differences between the current results and those obtained from the main experiment of Lee and Williams (2001). First, the within-language SCP effect was not present in Lee and Williams (2001). They explained that the use of L2 French, different from the competitor's language on the unrelated intervening trials, could wipe out the head start which the L1 competitor could have enjoyed in the lexical competition during picture naming. They argued that their data show that naming in L2 involves inhibition of L1. However, this is not the case with the bilinguals examined in Study 1. The "selected language bias" of L2 English did not succeed in inhibiting the non-intended L1 Chinese, unlike in Lee and Williams (2001).

This difference may have resulted from a higher level of L2 ability for the participants in the current study. The participants in Lee and Williams (2001) had studied L2 French for 8.79 years on average, whereas the participants in Study 1 had studied L2 English for 14.71 years on average. As a result, it may be that the participants in Study 1 had a higher proficiency level in L2. Furthermore, the participants in the current study were living in a country where L2 was being spoken on a regular basis, whereas the participants in Lee and Williams (2001) were living in an L1 speaking context at the time of testing.

Second, the unbalanced bilinguals in Lee and Williams (2001) demonstrated a cross-language SCP effect, when they named the target picture in L2 French. If we followed Lee and William (2001) in assuming that the presence of a cross-language SCP effect provides evidence for cross-language lemma competition during word naming in a selected language, the SCP effect found in the CCCE condition in our study could reflect the inflexibility of a functional language-specific selection mechanism in the bilinguals in the low CAVT group as "the selection mechanism could not be automatically put into the L2 mode" (ibid, p. 245) when they decided to speak in L2, as shown by the presence of cross-language lexical competition, even when they were cued to switch from L1 to L2. Conversely, the absence of cross-language SCP for the bilinguals in the high CAVT group suggests that they were better able to shift into L2 mode.

The findings of Study 2 provide evidence of a cross-language SCP effect for classroom learners. This suggests that language selection of Chinese-English classroom learners is achieved by means of suppressing lexical items in the non-intended language. For these participants there was also an absence of a within-language SCP effect, as for the bilinguals with study-abroad experience in the low CAVT group in Study 1.

[Insert Figure 1]

Figure 1 illustrates the contrast between the bilinguals in the low CAVT group in Study 1 and the classroom learners in Study 2. For the former group, it is possible that, as their naming in L2 might involve less inhibition of words of the non-intended L1 than the classroom learners, they might resort to the language-specific mechanism, which allowed them to maintain the head start which the Chinese competitor had on the naming of the target picture in L1 Chinese, thus producing within-language competition. For the latter group, it is possible that they might make use of inhibitory control to ensure selection in the intended language by inhibiting candidates from L1 Chinese, thus the absence of such competition.

According to the interactive view of bilingual lexical access, as advanced earlier in this paper, successful selection of the proper candidate of a bilingual speaker can be achieved by creating a differential activation level of words in the intended and non-intended languages. One way to create such a difference is to postulate a mechanism external to the lexicon which constrains the selection by inhibiting words in the non-intended language (Green, 1998). The findings revealed with regard to the Chinese-English classroom learners in Study 2 seem to support such a view.

The findings from Study 2 also suggest a role for learning experience to modulate the language selection mechanism. For L2 classroom learners, their language selection is achieved by means of suppressing lexical items in the non-intended language. For the bilinguals with study-abroad experience, their language-selection does not require a massive inhibition of the non-intended language. The difference, as noted in the foregoing discussion, could arise from a different degree of activity of the two languages. Classroom learners could not enjoy as many authentic communications as those bilinguals could in the target language learning context. So, their L2 could not be as frequently activated as that of their counterparts even though their level of L2 lexical knowledge was similar. According to the Activation Threshold Hypothesis (Paradis, 1987), their L2 activation threshold could be higher, which might demand a larger amount of inhibition of L1 Chinese, thus the elimination of the within-language SCP effect.

Study 3 yields evidence for within- and cross-language SCP for the bilinguals with study-abroad experience as well as for the classroom learners with higher working memory capacity. It is sometimes argued that classroom learners have to learn to suppress L1. So, the advantage in cognitive resources might allow them to maintain the head start which the Chinese competitor had on the primed target picture naming in L1 Chinese. These data suggest that this suppression arises both in classroom learners and in bilinguals with study-abroad experience. However, when we look at the error data from Study 3 along with the latency data, we see that the participants with study-abroad experience had achieved a more flexible control of language selection.

In summary, the findings of the three studies allow us to make a tentative conclusion. For Chinese-English bilinguals, the smooth functioning of the language selection mechanism depends on achieving a high level of L2 lexical knowledge. Language selection is also further facilitated by study-abroad experience and high working memory capacity. Furthermore, for L2 classroom learners, their language selection is achieved by means of suppressing lexical items in the non-intended language, which is also facilitated by high working memory capacity.

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Footnotes:

1. According to Wheeldon and Monsell (1994), this inhibitory effect is called 'competitor priming' in order to distinguish it from the positive priming to which the term 'semantic priming' usually refers.
2. Each run of trials consisted of three definitions trials followed by two picture-naming trials.
3. Pictures were chosen from six categories: 1) animal set; 2) small artifacts set; 3) big artifacts set; 4) clothes set; 5) food set and 6) people set.
4. 1 means completely unrelated, 2 means not related, 3 means somehow related, 4 means related, 5 means highly related.
5. As we were interested in the cross-language lexical competition, language change was involved in each of the four conditions, which means there was a language change from the immediately preceding filler picture trial to the target picture trial.
6. The CAVT is a test developed by Laufer and Nation (1999). Version C was used in this experiment, which had a reliability of .91 (see Laufer and Nation 1999: 44).
7. An answer is correct when it is correct semantically. If it is used in a wrong grammatical form, it is not marked as incorrect. If it is used with a spelling error, which does not distort the meaning of the word, it is not marked as incorrect either. The scoring of this test was the same as that in Laufer and Nation (1999).
8. One indicates the lowest level of proficiency and 10 the highest and the total rating is 40.
9. The instruction of this task was written in Chinese.
10. Data collection lasted 3 weeks. For each participant, the whole testing session lasted about 50 minutes.
11. Target pictures naming data were subjected to the same procedure of data exclusion as described in Lee and Williams (2001).
12. Although there was no significant difference between the mean span scores of the CAVT high and low group, there might be differences within each group as the SD for each group was quite large (12.58 and 8.22 respectively). So, ANCOVA was used for latency and error rate data analyses.

13. The analysis on the latency data showed a significant main effect of working memory scores [F (1, 21) = 4.677, p <.05] and an interaction between language of the target picture and working memory scores [F (1, 21) = 6.451, p < .05]. So, adjusted mean scores are reported here. But, the analysis on the error rate data did not yield a main effect of working memory scores [F < 1]; and the interaction between competitor priming and working memory scores did not approach the level of significance [F (1, 21) = 3.716, p = .068]. Therefore, raw scores of percentage of error rate are reported here.
14. The language of instruction for those courses was generally L2 English.
15. This was a comprehensive English course.
16. An independent t-test did not reveal a significant difference between the two mean scores (t30) = 1.134, p=.266).
17. The criteria for data to be included in the final analyses were kept the same as described in Study 1.

Table 1. *A sequence of expected responses in one run of trials for four experimental conditions*

Condition	Chinese filler elicited with a definition	Chinese competitor or control elicited with a definition	Chinese filler elicited with a definition	Chinese or English filler elicited with a picture	Chinese or English target elicited with a picture
CCEC-P	啤酒（beer)	骆驼（camel)	钢笔（pen)	rocket	斑马（zebra)
CCEC-U	啤酒（beer)	灯笼（lantern)	钢笔（pen)	rocket	斑马（zebra)
CCCE-P	啤酒（beer)	骆驼（camel)	钢笔（pen)	火箭（rocket)	zebra
CCCE-U	啤酒（beer)	灯笼（lantern)	钢笔（pen)	火箭（rocket)	zebra

Table 2. *Language history survey data for the Chinese-English bilinguals*

Measure	CAVT High n = 12		CAVT Low n = 12	
	Mean	SD	Mean	SD
Age (years)	27.5	4.38	28.12	3.53
Age began L2 learning (years)	11.75	1.48	12	3.19
Time studied L2 (years)	14.42	3.8	15	5.06
L2 study-abroad experience (months)	37.33	18.71	29.08	13.24
L1 proficiency rating	39.42	0.67	38.17	1.64
L2 proficiency rating	31.5	3.68	26.08	7.81

Table 3. *Mean target picture naming latency (in ms) for the Chinese-English bilinguals (Mean percentage of error rate are indicated in square brackets.)* [13]

Groups	CCEC-P	CCEC-U		CCCE-P	CCCE-U	
	Primed	Unprimed	Priming effect (unprimed-primed)	Primed	Unprimed	Priming effect (unprimed-primed)
CAVT high n = 12	1248 [3.27]	1190 [3.87]	-58	1336 [0.6]	1480 [0.89]	144
CAVT low n = 12	1463 [3.57]	1422 [3.27]	-41	1584 [5.36]	1411 [5.06]	-173

Table 4. *Mean target picture naming latency (in ms) for the Chinese-English classroom learners (Mean percentage of error rate are indicated in square brackets.)*

Conditions	**CCEC-P**	**CCEC-U**		**CCCE-P**	**CCCE-U**	
	Primed	unprimed	Priming effect (unprimed-primed)	Primed	Unprimed	Priming effect (unprimed-primed)
n = 24	1266 [2.68]	1273 [1.25]	7	1577 [7.17]	1417 [7.86]	-160

Table 5. *Descriptive data of CAVT scores and working memory span scores for SAE group and CL group*

CAVT groups		**CAVT scores**		**Working memory span scores**	
		Mean	SD	Mean	SD
SAE group					
n = 8	High span	59.57	9.18	27.14	6.41
n = 8	Low span	58.57	10.41	15.57	2.23
CL group					
n = 8	High span	53	3.70	25.43	9.52
n = 8	Low span	51.57	4.04	1.14	1.35

Table 6. *Mean target picture naming latency (in ms) for SAE group and CL group breakdown by the working memory span (Mean percentage of error rate are indicated in square brackets.)*

Conditions	**CCEC-P**	**CCEC-U**		**CCCE-P**	**CCCE-U**	
Groups	Primed	Unprimed	Priming effect (unprimed-primed)	Primed	Unprimed	Priming effect (unprimed-primed)
SAE Group						
High span	1393 [6.12]	1230 [2.04]	- 163	1405 [4.08]	1229 [5.61	- 176
Low span	1483 [3.06]	1532 [4.59]	49	1711 [4.59]	1624 [2.04]	- 87
CL Group						
High span	1333 [2.55]	1291 [1.53]	- 42	1570 [7.65]	1369 [7.05]	- 201
Low span	1153 [2.55]	1231 [0.51]	78	1389 [8.67]	1425 [5.10]	36

Running head: Semantic competitor priming

Semantic competitor priming within and across languages: The interplay of vocabulary knowledge, learning experience and working memory capacity

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Abstract

This paper reports three studies of bilingual lexical processing, using the semantic competitor priming (SCP) method of Lee and Williams (2001). Study 1 found within-language priming for Chinese-English bilinguals with both higher and lower levels of vocabulary knowledge. There was also a cross-language SCP effect, but this was restricted to bilinguals with lower levels of vocabulary knowledge. Study 2 found a cross-language SCP effect for Chinese learning English in the classroom context. Study 3 found both a within- and cross-language SCP effect for bilinguals with study-abroad experience as well as those classroom Chinese learners of English who had a higher working memory capacity. Those findings are interpreted in terms of a dynamic view of bilingual language selection.

When a bilingual intends to speak in one language, translation equivalents and related words in the non-intended language are also activated (Costa, 2005). Given this pattern of co-activation, one would then also like to know whether or not the forms of the non-intended language enter into actual on-line competition with those of the intended language during speech production. Some models of bilingual lexical access (Costa, Miozzo and Caramazza, 1999) assume that cross-language competition "reflects only the flow of activation, not genuine competition for selection" (Kroll, Bobb and Wodniecka 2006, p.121). On this "non-interactive" account, lexical selection is truly competitive only within languages, but not across languages.

In contrast, interactive models assume that the processor considers all activated candidates from both languages. In this framework, successful selection of the proper candidate can be achieved by maintaining a higher level of activation for words from the intended language (see Costa and Santesteban, 2004). Alternatively, the same result can be obtained by inhibiting words in the non-intended language (Green, 1986).

Costa et al. (1999) found cross-language facilitation effects, rather than interference effects, using the picture-word interference paradigm with Catalan–Spanish bilinguals. Naming was facilitated when the distractor was the name of the picture in both same-language and different-language pairs. Moreover, semantically related distractors in the same-language and different-language conditions were similarly interfering. Costa et al. interpreted these results as evidence for the existence of a non-interactive lexical selection mechanism that considers only the activated candidates of the intended language.

The non-interactive view has also received support from studies using the semantic competitor priming (SCP) paradigm. Studying advanced English learners of French, Lee and Williams (2001) found a within-language SCP effect when their participants named the target picture in English and a cross-language SCP effect from English to French. At the beginning of each trial sequence, participants activated the prime by providing the definition of an object in English. Half of the time, the intervening trials were all in English and half of the time they included one trial in French. Lee and Williams found that the intervening use of English was essential for sustaining the priming interference effect. In fact, the intervening use of French completely wiped out the head start the English competitor could have enjoyed in its lexical competition with the target name during picture naming. They argued that this suppression of L1 through intervening L2 trials indicates that language selection at the lemma level is achieved through inhibition of the non-intended L1.

However, findings from picture-word interference studies provide evidence against the view of language-specific lexical access. Hermans, Bongaerts, de Bot and Schreuder (1998) investigated whether words in L1 were activated during picture naming in L2 by Dutch-English unbalance bilinguals. They reported that the Dutch name of a picture was activated during initial stages of the lexical process in English as a foreign language. They concluded that bilingual speakers cannot suppress activation from their first language while naming pictures in a foreign language.

Costa and Santesteban (2004) suggested that language proficiency may affect a bilingual speaker's language selection during the planning of spoken utterances in each language. They found a striking difference between the performance of highly proficient bilinguals and L2 learners in a language-switching task. Asymmetrical switching costs were observed for both

Spanish learners of Catalan and Korean learners of Spanish (i.e., it was harder to switch from the L2 into the L1 than vice versa.), but these switching costs were not present when highly proficient Spanish-Catalan bilinguals were asked to perform the switching task either in their L1 and L2, or in their L1 and in their L3. They explained that the highly proficiently bilinguals may be able to achieve language selection without actively inhibiting cross-language competing candidates whereas the L2 learners may need to make use of inhibitory control to ensure selection in the intended language. They argued that, for a bilingual speaker, an increase in proficiency might lead to a qualitative change from “the reliance on inhibitory control to the reliance on a language-specific selection mechanism during lexical selection” (ibid, p. 505).

Following the analysis of Kroll et al. (2006), we might be able to understand these contrasting findings by exploring the various factors that promote language selectivity, as opposed to interactivity. In particular, we are interested in exploring the roles of (1) L2 vocabulary knowledge, (2) working memory capacity, and (3) language learning history in promoting or hindering language selectivity.

First, it is possible that bilinguals and advanced learners with higher levels L2 vocabulary knowledge may demonstrate stronger language selectivity. There is abundant evidence that L2 vocabulary knowledge influences L2 semantic processing at the word level (Li, 2003; Li, 2007; Nation, 2001). L2 vocabulary knowledge refers to what a learner knows about a word in the second language, which covers both the size and depth perspectives of word knowledge. Vocabulary size denotes the number of words a learner possesses of the target language. With reference to the depth of vocabulary knowledge, it includes knowledge about the form, position, function, and meaning of a word (Nation, 1990). Li (2003, 2007) examined the role of L2 vocabulary knowledge on semantic processing of Chinese learners of English using a primed lexical decision task. The results showed that learners with high-level English vocabulary knowledge were significantly quicker and more accurate than those with low-level L2 vocabulary knowledge.

Second, it is possible that bilinguals with greater working memory capacity may show strong language selectivity. Modern theories of working memory (Rosen & Engle 1998) view it as a system not only for storing and processing temporary information, but also for suppressing irrelevant information and allocating cognitive resources (e.g. Just and Carpenter, 1992). High working memory capacity has been found to be particularly critical for bilingual tasks that demand the activation of both languages (Tokowicz, Michael, & Kroll, 2004). It is relatively less useful in more automatic bilingual tasks (Li, 2004; Michael, Dijkstra and Kroll, 2002).

Third, it is possible that bilinguals who acquire their knowledge of L2 in more interactive learning contexts may come to acquire greater control over language selection. Tokowicz, Michael and Kroll (2004) examined the effects of study-abroad experience and working memory capacity on the types of errors made in a single-word translation task from the L1 into L2. Their study suggests that study-abroad experience leads individuals to make more meaning-related responses.

Although L2 vocabulary knowledge, working memory capacity, and learning experience have been shown to influence L2 processing, few studies have looked at their effects on the process of lexical selection. The current study seeks to explore these relations. Using the SCP paradigm, we examined the interplay of vocabulary knowledge, learning experience and individual differences in working memory capacity.

In Study 1, we tested the role of L2 vocabulary knowledge on SCP with Chinese-English bilinguals with more than 12 months study-abroad experience as participants. We hypothesized that bilinguals with higher levels of L2 vocabulary knowledge would benefit more from their study-abroad learning experience than their counterparts with lower level of L2 vocabulary knowledge due to richer vocabulary, and that this difference in lexical knowledge would affect how they achieve language selection in spoken word production.

In Study 2, we tested the role of learning experience on SCP with Chinese-speaking learners of English with no study-abroad experience as participants. We hypothesized that learning experience might affect the way how Chinese-English classroom learners might achieve their language selection in spoken word production.

In Study 3, we explored the role of individual differences in working memory capacity and learning experience on SCP by examining the spoken word production process of Chinese-English bilinguals with study-abroad experience and Chinese-speaking classroom learners of English. We hypothesized that individual differences in working memory capacity and learning experience would also influence the way participants achieve language selection.

Study 1

Method

Participants

Twenty-four paid full-time university students participated in this study. They were relatively fluent Chinese-English speakers with more than 12 months study-abroad experience. At the time of the study, they were studying at a university in Pittsburgh, Pennsylvania. Twenty-two of them were graduate students and two of them were undergraduate students. Half of them were male students and half were female students.

Tasks and Materials

Semantic competitor priming task. We used the SCP paradigm, devised by Wheeldon and Monsell (1994) and modified by Lee and Williams (2001). In Wheeldon and Monsell's experiments, a participant was asked to produce a prime word in response to a given definition. Later, the participants named a target pictured object. The time to name the target picture (e.g., zebra) was longer when the prime was a semantic competitor. For example, a participant might produce the prime form "camel" in response to the definition "an animal which a traveler rides on in the desert". The production of this prime then interferes with the later naming of a semantically related target picture such as "horse" as opposed to some unrelated picture. This effect occurs even if the prime is named three or more trials before the target[1].

The finding that the prime interferes with the target name retrieval is thought to be due to the strengthening of a prime's representation in memory over its baseline activation. This strengthening makes it a stronger competitor, when it is activated along with other semantically related competitors in parallel with the target representation. In effect, the competitor receives a head start as a result of its prior production (see Lee and Williams, 2001).

Because we wanted to focus on the cross-language SCP effect, we did not manipulate the language change factor. As a result, there were four treatment conditions instead of eight conditions in this task. Each participant was asked to respond orally to three self-paced Chinese definition trials each using a two-character-Chinese-word followed by two picture-naming trials[2]. If a participant did not know the word the definition referred to, he/she was instructed to say "不知道" *(I don't know)*. Before each picture, a cue was displayed on the computer screen, telling the participant what language to use when naming the following picture. Participants were also instructed to name pictures as quickly as possible in either Chinese or English following the language cue before the picture. When they named a picture in Chinese, they were also required to respond with a two-syllable-word. If a participant did not come up with a response, he/she could say “I don’t know” or “不知道” according to the language cue given before the picture.

As to the material selection, 35 target pictures were selected from the pictures provided by the International Picture Naming Project at CRL-UCSD[3]. There are two criteria for this selection: 1) pictures need to be named using two Chinese characters, and 2) percent name agreement on the target pictures should be above 0.8 in both Chinese and English. The selected target pictures were then paired with 35 Chinese two-character words and their definitions were written based on the Contemporary Chinese Dictionary.

Each word pair was accompanied by four additional intervening trials. These included: one unrelated Chinese control definition, two Chinese filler definitions, and one filler picture to be named either in Chinese or English were selected. In order to determine the availability of all the definitions, a pre-test was run among a group of 20 native speakers of Chinese who are full-time graduate students studying at Chongqing University, PR China. After that, a semantic relatedness rating task was administered to another group of 20 Chinese native speakers who were also graduate students studying at the same university. Then, the 32 word pairs were finalized, together with their control definitions and filler definitions, with semantic relatedness rating of 4.29 for the related pairs and 2.11 for the unrelated pairs[4].

A target picture could be named in one of the four conditions: CCEC-P, CCEC-U, CCCE-P and CCCE-U[5]. An example of the sequence of expected responses in one run of trials for each condition is shown in Table 1. Materials were divided into four lists: List A, List B, List C and List

D with eight items in each condition. Participants were assigned randomly to one of the material list with equal number of male and female participants in each list.

[Insert Table 1]

The Controlled Active Vocabulary Test (CAVT). The CAVT[6] was used to measure learners' controlled productive ability to use a word when they are compelled to produce a word in a constrained context. There are 90 sentences and each of them has a word with a missing part, which has to be supplied. The first letter of each item is always provided so that there is only one correct answer for each item. For example: He was riding a bic___. The participants need to understand the meaning of the sentence or activate their knowledge of the missing word before they are able to fill in the blank. A correct answer[7] is scored 1 point in this task, and the highest possible score is 90.

Language history survey. Participants completed a language history survey in which they reported on their L2 learning experiences in L1 Chinese. They all began their English learning in schools in PR China. Some of them began their English learning in a primary school and some in a secondary school. Each participant rated their L1 and L2 reading, writing, speaking and listening proficiency on scales from 1 to 10[8] and indicated their types of L2 language learning exposure as well as the age they began learning the L2 (see Table 2 for more details of the group means for the major measures of the survey).

Working memory span task. We used a modified version of the Conway and Engle (1996) operation span task. In this task[9], 66 mathematical operations were randomly paired with a total of 66 to-be-remembered Chinese words. The mathematical operations were organized into 15 series, and the number of operation-word strings per series varied from two to six, with three series of each length being performed. The order of series length was randomized. Three series of 2 operation-word strings were used for the purpose of practice.

During the task, the participants were presented with operation-word strings, e.g., (6÷2) + 2 = 5? They were instructed to read the operations aloud and decide whether the operations were correct or not by pressing the “Y” or “N” button and at the same time say “dui” (correct) or “cuo” (wrong) aloud. After that, a two-character Chinese word would appear immediately on the screen, and the participants were asked to read aloud the Chinese word presented. Then, the experimenter immediately clicked the mouse, and another operation-word string was presented. This process continued until the recall cue was presented, and then the participants were to recall the Chinese words in order. A mini-recorder was used to record their recall. The instructions for this task were presented in written form in Chinese.

Procedure

Participants were tested individually in the Psylab of Carnegie Mellon University[10]. They were instructed to complete the SCP task first. Then they were asked to take the Controlled Active Vocabulary Test in L2 English. After a short break, the participants were required to complete a language history survey in their L1, and finally, they were asked to take a working memory span task in Chinese.

Results

CAVT data

Participants were grouped on the basis of their CAVT scores. Twelve participants in the CAVT high group had a mean score of 78.17 (SD 6.60) and 12 participants in the CAVT low group had a mean score of 57.17 (SD 9.00). Results of an independent t-test revealed a significant difference between the mean scores of the two groups [t (22) = 6.515, p <.0001].

Language history survey data

We compared the CAVT high and low groups in terms of (1) their age, (2) the age at which they began to learn L2, (3) the number of years they had studied L2, and (4) the number of months of study-abroad experience (see Table 2). There were no reliable group differences on those dimensions (*p*s > .05). We also compared the overall proficiency rating of the two groups for their L1 and L2, and we found that participants in the CAVT high group gave a higher L1 overall proficiency rating than their counterparts [t (22) = 2.442, p < .05], and they also rated their L2 overall proficiency higher than their counterparts [t (22) = 2.173, p < .05].

[Insert Table 2]

Both subgroups rated their L1 proficiency significant higher than their L2 (for the CAVT high group: t (11) = 7.453, p < .01; for the CAVT low group: t (11) = 6.106, p < .01). Thus, we considered Chinese as their L1 dominant language and English as their second language for both groups.

Working memory capacity data

The average working memory capacity (WMC) span score was 21.88 (range = 6 to 49), and the average accuracy rate on the mathematical operations was 84.65% (range = 56.67% to 96.67%). We also compared the mean differences of the span scores in the CAVT high and low groups. The mean span score was 23.25 (SD 12.58) for the former group and 20.5 (SD 8.22) for the latter group. No significant difference was found between these two groups [(t (22) = .634, p=.533].

Semantic competitor priming data

Target picture naming data[11] were excluded, if there was no response after three seconds.

Trials were also excluded if the wrong language was used, if the picture was named incorrectly, if the subject said "I don't know", or if the expected competitor was not elicited as the definition response for the prime. If a target item had more than one third of the data excluded, then it was discarded from further analysis. Using these criteria, four items were discarded from the analyses. If a participant had more than one third of the target naming data discarded, those data were excluded from the final analyses. Target picture naming data for correct responses which fell beyond 2.5 SD of the group means in each condition were also excluded from final analyses. Data from all the 24 participants met this criterion.

Subject analyses of variance (ANCOVA) were conducted in SPSS using a 2 (Language of target pictures: L1 vs. L2) × 2 (SCP: primed vs. unprimed) × 2 (L2 vocabulary knowledge: high vs. low) mixed design, and working memory span scores were treated as a covariate to eliminate potential confounding effects in the analyses[12].

[Insert Table 3] [13]

To determine the within- and cross-language SCP effect, we calculated the mean naming latencies to target pictures for correct responses and the mean error rate. In the analyses of naming latencies, the main effect of Language was significant [F (1, 21) = 12.675, p < .001]. Target pictures were named about 122 ms more quickly in L1 Chinese than in L2 English. But the interaction between the Language and L2 vocabulary knowledge was not significant [F (1, 21) = 2.626, p = .120]. Neither the main effect of SCP [F (1, 21) = .632, p = .436] nor the interaction of SCP with Language was significant [F (1, 21) = 1.168, p = .292]. However, there was a three-way interaction of the Language, SCP, and L2 vocabulary knowledge [F (1, 21) = 4.619, p < .05]. Bilinguals with higher levels of L2 vocabulary knowledge named primed target pictures more slowly than unprimed target pictures (1248 ms vs. 1190 ms; priming effect is 58 ms) in L1, but they named primed target pictures faster than unprimed target pictures in L2. On the other hand, bilinguals with lower levels of L2 vocabulary knowledge named primed target pictures more slowly than unprimed target pictures both in L1 Chinese (1463 ms vs. 1422 ms; priming effect is 41 ms) and L2 English (1584 ms vs. 1411 ms; priming effect is 173 ms). There was also a main effect of L2 vocabulary knowledge [F (1, 21) = 5.766, p <.05]. The bilinguals in the CAVT high group named the target pictures about 156 ms faster than those in the CAVT low group (1314 ms vs. 1470 ms).

For the error rate data, the analyses did not show a main effect of Language [F (1, 21) = 0.584, p = .453], SCP [F (1, 21) = 3.226, p = .087], or an interaction between the two factors [F (1, 21) = 2.40, p = .135]. Neither did the analysis yield an interaction between Language, SCP and L2 vocabulary knowledge [F (1, 21) = 0.095, p = .760]. However, there was a main effect of L2 vocabulary knowledge [F (1, 21) = 5.545, p <.05] and an interaction between Language and L2 vocabulary knowledge [F (1, 21) = 11.59, p < .01]. The error rate for the bilinguals in the CAVT high group was significantly lower than that in the CAVT low group (2.16% vs. 4.32%). Further, for the bilinguals with a high level of L2 vocabulary knowledge, the error rate in naming target pictures in L2 was significantly lower than that in naming target pictures in L1 (0.79% vs. 3.57%), but for those bilinguals with a lower level of vocabulary knowledge, this reverse pattern was observed, which means that their error rate was higher when they named the target pictures in L2 than in L1 (5.21% vs. 3.42%).

Discussion

Study 1 yielded three important results. One was the three-way interaction of Language, SCP, and L2 vocabulary knowledge in the latency data. For all participants, a within-language SCP effect was observed when the language of the target picture was L1 Chinese. However, the pattern was different when the Language was L2 English. In that case, a cross-language SCP was only observed for bilinguals with lower levels of L2 vocabulary knowledge. The second important result was that L2 vocabulary knowledge had an effect on both naming latencies and the error rate. The bilinguals in the CAVT high group named the target pictures faster than those in the CAVT low group and further their error rate was lower than that of their counterparts in the CAVT low group. The third important result was the interaction between Language and L2 vocabulary knowledge. Bilinguals with a high level of vocabulary knowledge named target pictures in L2 more correctly than target pictures in L1. However, bilinguals with lower L2 vocabulary knowledge named target pictures in L1 more correctly.

The findings of this study provide evidence for a cross-lexical competition when Chinese-English bilinguals with study-abroad experience are engaged in a SCP task. They also point to the possibility that L2 lexical knowledge might constrain language selection during the planning of spoken utterances in each language.

We can also ask whether there is evidence in these data for a language-specific selection mechanism. If so, is this reliance on a language-specific selection mechanism associated more with high levels of L2 vocabulary knowledge or more extensive learning experience? In order to answer those questions, we will examine the role of learning experience on within- and cross-language inhibitory priming using a group of Chinese-English classroom learners with no study-abroad experience using the same SCP task.

Study 2

Method

Participants

The participants were 27 first-year students enrolled in the graduate program of Linguistics and Applied Linguistics at Chongqing University, PR China and 10 first-year graduate students in science and engineering programs at Zhejiang University, PR China. All of them had Chinese as their native language and English as their second language. They had received English classroom instruction since secondary education. At the time of this study, participants from the first group took four or five academic courses[14] in Linguistics and Applied Linguistics, while participants from the second group took the course of College English[15]. None of the participants had any experience of studying or living in English speaking countries.

Procedure

Participants were tested individually in their home institutions and data collection was spread out in a period of two weeks. The general procedure and experimental tasks were the same as those described in Study 1.

Results

CAVT and language history survey data

Participants were measured on their L2 vocabulary knowledge using CAVT. Their scores ranged from 46 to 68 with a mean a mean score of 54.2 (SD = 5.84), and their mean score of CAVT was similar to that of the CAVT low group in Study 1[16]. On average, participants were 24.96 (SD = 3.06) years old and they began their English learning in secondary schools at the age of 12.67 (SD = 0.87) and they studied English in a classroom setting for an average of 11.75 years

(SD = 2.05). Participants gave an average of total rating of 34.92 (SD = 4.54) for their ability in their native language and 28.67 (SD = 4.33) for their ability in L2 English.

Semantic competitor priming task data

Seven participants who were not able to name nine or more of the target pictures were excluded from the analyses[17]. One participant was also excluded, because the recording volume was not aloud enough. In order to keep the number of participants in each material list equal, data were included from 24 participants of the total 29 eligible participants. All subsequent analyses reported are based on this revised set of 24 participants.

Subject analyses of variance were conducted using a 2 (Language: L1 vs. L2) × 2 (SCP: primed vs. unprimed) design. Both mean lexical latencies of target pictures for correct responses and mean error rate were analysed (see Table 4 for the means).

[Insert Table 4]

In the analyses of naming latencies, the effect of Language was significant [$F (1, 23) = 20.154$, $p < .001$]. Target pictures were named about 227 ms more quickly in L1 Chinese than in L2 English. The effect of SCP was not significant [$F (1, 23) = 3.998$, $p = .06$]. Although there was a numerical difference of 76 ms between the mean RT for the primed target pictures and the unprimed ones, the difference was not reliable. However, the interaction between the two factors approached significance [$F (1, 23) = 5.99$, $p < .05$]. The nature of the interaction was just as Lee and Williams (2001) reported: Unbalanced bilinguals demonstrated a cross-language SCP effect when they named the target pictures in L2 rather than in L1.

In the analyses of error rate, the effect of Language was significant, with a higher error rate in naming the target picture in L2 than in L1 (7.49% vs. 1.96%) [$F (1, 23) = 63.175$, $p < .001$].

None of the other effects were significant.

Discussion

One important result of this study was the Language × SCP interaction yielded from the analyses of target picture naming latencies. We found a cross-language SCP effect when the classroom learners named the target picture in L2 English, which confirms the robustness of cross-language inhibitory priming effect from L1 to L2 as demonstrated by the unbalanced bilingual speakers in Lee and Williams (2001), as well as the bilinguals with study-abroad experience in the CAVT low group in Study 1. As noted earlier, participants in this study had a similar level of vocabulary knowledge as those bilinguals with study-abroad experience in the CAVT low group, so the cross-language SCP effect was obtained regardless of study-abroad learning experience.

When the classroom learners named the target picture in L1 Chinese, the cross-language inhibitory priming was not obtained. This agrees with the result reported in Lee and Williams (2001).

Study 3

Method

Participants

Sixteen bilinguals with study-abroad experience (SAE) and 16 classroom learners (CL) participated in this study. For the SAE group, the CAVT score ranged from 41 to 68 with a mean of 59.42; for the CL group, it ranged from 46 to 59 with a mean score of 51.94.

Results

Participants in the CL group were measured on their working memory span using the same span task as described in Study 1. In general, participants in this group responded correctly to 89.25 % of the mathematical operations (range = 26.70% to 100%). They were then divided into a high span and a low span group, with a mean span of 25.43 for the high span group and 10.33 for the low span group.

The SAE group was also grouped on the basis of their performance in the working memory span task with a correct rate of accuracy of 87.55 % for the mathematical operations (range = 60.67% to 90.67%). The mean span score of the high span group was 27.14 while the mean span score of the low span group was 15.57. The SAE group and CL group did not differ in their CAVT scores [F (3, 28) =1.995; p =. 142] and post-hoc tests did not reveal any significant differences (ps > .2).

[Insert Table 5]

Results from one-way ANOVA yielded a significant between-group difference of working memory span scores [F (3, 28) =13.24, p<.001]. Further, post-hoc tests revealed a significant difference between the mean high and low span scores of the SAE group (p<.01) as well as a significant difference between those of the CL group (p<.001). Moreover, post-hoc tests did not show a difference between the two high span groups (p = .947) or between the two low span groups (p = .333).

To determine the role of working memory capacity (WMC) and learning experience (LE) on within- and cross-language SCP, we used a 2 (Language: L1 vs. L2) × 2 (SCP: primed vs. unprimed) × 2 (WMC: high vs. low) × 2 (LE: SAE vs. CL) mixed ANOVA design. The analyses on the latency data revealed a significant main effect of Language [F (1, 28) = 9.26, p< .01].

Target pictures were named more quickly in L1 Chinese than in L2 English (1331 ms vs. 1465 ms).

The analyses also showed a significant interaction between SCP and WMC [F (1, 28) = 4.571, p<.05] (see Table 6). Primed target pictures were named 146 ms more slowly than unprimed target pictures for the participants of higher WMC in the SAE group and CL group. However, this pattern was not observed with the participants of lower WMC in the two groups. Although there seemed to be a numerical difference of mean naming latency for the primed target pictures and the unprimed target pictures (1711 ms vs. 1624) when the participants with lower WMC in the SAE group named primed target pictures in L2 English, this difference was not reliable (p = .602).

[Insert Table 6]

Furthermore, the analyses yielded a significant interaction between WMC and LE [F (1, 28) = 6.006, p<.05]. The participants of higher WMC in the SAE group named all target pictures more quickly than those of lower capacity (1314 ms vs. 1588 ms), whereas the participants of higher WMC in the CL group named all target pictures more slowly than those of lower span (1391 ms vs. 1299 ms). None of the other effects were significant (ps > .11).

The analyses on error rate data showed a significant main effect of Language, with a lower error rate in naming the target picture in L1 than in L2 (2.87% vs. 5.68%) [F (1, 28) = 15.091, p< .01]. The interaction between Language and LE was also significant, F (1, 28) = 13.747, p< .01. The participants in the CL group named the target pictures in L1 Chinese with a much lower error rate than they did with the pictures in L2 English (1.79% vs. 7.27%), while participants in the SAE group named the pictures in L1 Chinese and L2 English with a similar error rate (3.95% vs. 4.08%).

There was no main effect SCP, but there was a significant three-way interaction of Language, SCP, and WMC [F (1, 28) = 4.266, p< .05]. Participants with higher WMC named primed targets with a higher error rate than unprimed targets (4.34% vs. 1.79%) in L1 Chinese, but they named the primed and unprimed targets with a similar error rate in L2 English (p = .656). However, for the participants with lower capacity, the pattern was reversed. They named primed and unprimed target pictures in L1 Chinese with a similar error rate (p = .818). However, in L2 English they named primed targets with a higher error rate than unprimed targets (6.63% vs. 3.57%).

Discussion

With regard to the error rate data, there were two important results. The first was the interaction between language and learning experience. The participants in the CL group tended to be less skillful when naming targets in L2 English. However, their counterparts in the SAE group showed no difference between the error rates for L1 and L2. As noted earlier, the SAE group and CL group did not differ in their CAVT scores; the interaction effect seems to suggest that study-abroad experience leads to a more accurate L2 naming in a language-switching task of this type.

The second result of importance for the error data was the significant three-way interaction of Language, SCP, and WMC. The fact that the lower WMC participants failed to demonstrate within-language SCP indicates that they may not be keeping the prime active in memory. The fact that higher WMC participants show the SCP effect for L1 indicates that they have the basic verbal processing needed to display the SCP effect for errors as well as latencies, but that their relatively low level of L2 experience makes the effect of SCP relatively weaker in L2 English in terms of error data.

For the latency data, both within- and cross-language SCP effects were observed for the participants with higher WMC. Higher WMC may allow participants to keep the Chinese competitor in mind when naming pictures in both L1 Chinese and L2 English. Although Studies 1 and 2 revealed a robust cross-language SCP effect from L1 to L2 for bilinguals with study-abroad experience and classroom learners with no study-abroad experience, only a weaker trend was demonstrated for the participants with lower WMC in the SAE group. For the participants with lower WMC in the CL group, no such trend was seen at all. It seems that, for the participants with study-abroad experience, their lack of cognitive resources could be compensated for to some extent by their experience in the target language context.

General Discussion

The main goal of the studies presented here was to determine to the extent to which the functioning of the language selection mechanism is influenced by the factors of L2 vocabulary knowledge, learning experience, and individual differences in working memory capacity. As noted earlier in this paper, there is disagreement on whether bilingual language selection mechanism is language-specific or language-nonspecific. Recently, Kroll et al. (2006) have argued for viewing the control of language selection as a dynamic process influenced by factors of the sort tracked in the current study.

The results of Study 1 reveal a within-language SCP effect for the bilinguals with both higher and lower levels of L2 vocabulary knowledge, when they named the target picture in L1 Chinese and a cross-language SCP effect for bilinguals with a lower level of L2 vocabulary knowledge when the language of the target picture was L2 English.

There are two striking differences between the current results and those obtained from the main experiment of Lee and Williams (2001). First, the within-language SCP effect was not present in Lee and Williams (2001). They explained that the use of L2 French, different from the competitor's language on the unrelated intervening trials, could wipe out the head start which the L1 competitor could have enjoyed in the lexical competition during picture naming. They argued that their data show that naming in L2 involves inhibition of L1. However, this is not the case with the bilinguals examined in Study 1. The "selected language bias" of L2 English did not succeed in inhibiting the non-intended L1 Chinese, unlike in Lee and Williams (2001).

This difference may have resulted from a higher level of L2 ability for the participants in the current study. The participants in Lee and Williams (2001) had studied L2 French for 8.79 years on average, whereas the participants in Study 1 had studied L2 English for 14.71 years on average. As a result, it may be that the participants in Study 1 had a higher proficiency level in L2. Furthermore, the participants in the current study were living in a country where L2 was being spoken on a regular basis, whereas the participants in Lee and Williams (2001) were living in an L1 speaking context at the time of testing.

Second, the unbalanced bilinguals in Lee and Williams (2001) demonstrated a cross-language SCP effect, when they named the target picture in L2 French. If we followed Lee and William (2001) in assuming that the presence of a cross-language SCP effect provides evidence for cross-language lemma competition during word naming in a selected language, the SCP effect found in the CCCE condition in our study could reflect the inflexibility of a functional language-specific selection mechanism in the bilinguals in the low CAVT group as "the selection mechanism could not be automatically put into the L2 mode" (ibid, p. 245) when they decided to speak in L2, as shown by the presence of cross-language lexical competition, even when they were cued to switch from L1 to L2. Conversely, the absence of cross-language SCP for the bilinguals in the high CAVT group suggests that they were better able to shift into L2 mode.

The findings of Study 2 provide evidence of a cross-language SCP effect for classroom learners. This suggests that language selection of Chinese-English classroom learners is achieved by means of suppressing lexical items in the non-intended language. For these participants there was also an absence of a within-language SCP effect, as for the bilinguals with study-abroad experience in the low CAVT group in Study 1.

[Insert Figure 1]

Figure 1 illustrates the contrast between the bilinguals in the low CAVT group in Study 1 and the classroom learners in Study 2. For the former group, it is possible that, as their naming in L2 might involve less inhibition of words of the non-intended L1 than the classroom learners, they might resort to the language-specific mechanism, which allowed them to maintain the head start which the Chinese competitor had on the naming of the target picture in L1 Chinese, thus producing within-language competition. For the latter group, it is possible that they might make use of inhibitory control to ensure selection in the intended language by inhibiting candidates from L1 Chinese, thus the absence of such competition.

According to the interactive view of bilingual lexical access, as advanced earlier in this paper, successful selection of the proper candidate of a bilingual speaker can be achieved by creating a differential activation level of words in the intended and non-intended languages. One way to create such a difference is to postulate a mechanism external to the lexicon which constrains the selection by inhibiting words in the non-intended language (Green, 1998). The findings revealed with regard to the Chinese-English classroom learners in Study 2 seem to support such a view.

The findings from Study 2 also suggest a role for learning experience to modulate the language selection mechanism. For L2 classroom learners, their language selection is achieved by means of suppressing lexical items in the non-intended language. For the bilinguals with study-abroad experience, their language-selection does not require a massive inhibition of the non-intended language. The difference, as noted in the foregoing discussion, could arise from a different degree of activity of the two languages. Classroom learners could not enjoy as many authentic communications as those bilinguals could in the target language learning context. So, their L2 could not be as frequently activated as that of their counterparts even though their level of L2 lexical knowledge was similar. According to the Activation Threshold Hypothesis (Paradis, 1987), their L2 activation threshold could be higher, which might demand a larger amount of inhibition of L1 Chinese, thus the elimination of the within-language SCP effect.

Study 3 yields evidence for within- and cross-language SCP for the bilinguals with study-abroad experience as well as for the classroom learners with higher working memory capacity. It is sometimes argued that classroom learners have to learn to suppress L1. So, the advantage in cognitive resources might allow them to maintain the head start which the Chinese competitor had on the primed target picture naming in L1 Chinese. These data suggest that this suppression arises both in classroom learners and in bilinguals with study-abroad experience. However, when we look at the error data from Study 3 along with the latency data, we see that the participants with study-abroad experience had achieved a more flexible control of language selection.

In summary, the findings of the three studies allow us to make a tentative conclusion. For Chinese-English bilinguals, the smooth functioning of the language selection mechanism depends on achieving a high level of L2 lexical knowledge. Language selection is also further facilitated by study-abroad experience and high working memory capacity. Furthermore, for L2 classroom learners, their language selection is achieved by means of suppressing lexical items in the non-intended language, which is also facilitated by high working memory capacity.

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Footnotes:

1. According to Wheeldon and Monsell (1994), this inhibitory effect is called ‘competitor priming’ in order to distinguish it from the positive priming to which the term ‘semantic priming’ usually refers.
2. Each run of trials consisted of three definitions trials followed by two picture-naming trials.
3. Pictures were chosen from six categories: 1) animal set; 2) small artifacts set; 3) big artifacts set; 4) clothes set; 5) food set and 6) people set.
4. 1 means completely unrelated, 2 means not related, 3 means somehow related, 4 means related, 5 means highly related.
5. As we were interested in the cross-language lexical competition, language change was involved in each of the four conditions, which means there was a language change from the immediately preceding filler picture trial to the target picture trial.
6. The CAVT is a test developed by Laufer and Nation (1999). Version C was used in this experiment, which had a reliability of .91 (see Laufer and Nation 1999: 44).
7. An answer is correct when it is correct semantically. If it is used in a wrong grammatical form, it is not marked as incorrect. If it is used with a spelling error, which does not distort the meaning of the word, it is not marked as incorrect either. The scoring of this test was the same as that in Laufer and Nation (1999).
8. One indicates the lowest level of proficiency and 10 the highest and the total rating is 40.
9. The instruction of this task was written in Chinese.
10. Data collection lasted 3 weeks. For each participant, the whole testing session lasted about 50 minutes.
11. Target pictures naming data were subjected to the same procedure of data exclusion as described in Lee and Williams (2001).
12. Although there was no significant difference between the mean span scores of the CAVT high and low group, there might be differences within each group as the SD for each group was quite large (12.58 and 8.22 respectively). So, ANCOVA was used for latency and error rate data analyses.

13. The analysis on the latency data showed a significant main effect of working memory scores [*F* (1, 21) = 4.677, *p* <.05] and an interaction between language of the target picture and working memory scores [*F* (1, 21) = 6.451, *p* < .05]. So, adjusted mean scores are reported here. But, the analysis on the error rate data did not yield a main effect of working memory scores [*F* < 1]; and the interaction between competitor priming and working memory scores did not approach the level of significance [*F* (1, 21) = 3.716, *p* = .068]. Therefore, raw scores of percentage of error rate are reported here.
14. The language of instruction for those courses was generally L2 English.
15. This was a comprehensive English course.
16. An independent t-test did not reveal a significant difference between the two mean scores (t30) = 1.134, p=.266).
17. The criteria for data to be included in the final analyses were kept the same as described in Study 1.

Table 1. *A sequence of expected responses in one run of trials for four experimental conditions*

Condition	Chinese filler elicited with a definition	Chinese competitor or control elicited with a definition	Chinese filler elicited with a definition	Chinese or English filler elicited with a picture	Chinese or English target elicited with a picture
CCEC-P	啤酒 (beer)	骆驼 (camel)	钢笔 (pen)	rocket	斑马 (zebra)
CCEC-U	啤酒 (beer)	灯笼 (lantern)	钢笔 (pen)	rocket	斑马 (zebra)
CCCE-P	啤酒 (beer)	骆驼 (camel)	钢笔 (pen)	火箭 (rocket)	zebra
CCCE-U	啤酒 (beer)	灯笼 (lantern)	钢笔 (pen)	火箭 (rocket)	zebra

Table 2. *Language history survey data for the Chinese-English bilinguals*

Measure	CAVT High n = 12		CAVT Low n = 12	
	Mean	SD	Mean	SD
Age (years)	27.5	4.38	28.12	3.53
Age began L2 learning (years)	11.75	1.48	12	3.19
Time studied L2 (years)	14.42	3.8	15	5.06
L2 study-abroad experience (months)	37.33	18.71	29.08	13.24
L1 proficiency rating	39.42	0.67	38.17	1.64
L2 proficiency rating	31.5	3.68	26.08	7.81

Table 3. *Mean target picture naming latency (in ms) for the Chinese-English bilinguals (Mean percentage of error rate are indicated in square brackets.)* [13]

Groups	CCEC-P	CCEC-U		CCCE-P	CCCE-U	
	Primed	Unprimed	Priming effect (unprimed-primed)	Primed	Unprimed	Priming effect (unprimed-primed)
CAVT high n = 12	1248 [3.27]	1190 [3.87]	-58	1336 [0.6]	1480 [0.89]	144
CAVT low n = 12	1463 [3.57]	1422 [3.27]	-41	1584 [5.36]	1411 [5.06]	-173

Table 4. *Mean target picture naming latency (in ms) for the Chinese-English classroom learners (Mean percentage of error rate are indicated in square brackets.)*

Conditions	**CCEC-P**	**CCEC-U**		**CCCE-P**	**CCCE-U**	
	Primed	unprimed	Priming effect (unprimed-primed)	Primed	Unprimed	Priming effect (unprimed-primed)
n = 24	1266 [2.68]	1273 [1.25]	7	1577 [7.17]	1417 [7.86]	-160

Table 5. *Descriptive data of CAVT scores and working memory span scores for SAE group and CL group*

CAVT groups		**CAVT scores**		**Working memory span scores**	
		Mean	SD	Mean	SD
SAE group					
n = 8	High span	59.57	9.18	27.14	6.41
n = 8	Low span	58.57	10.41	15.57	2.23
CL group					
n = 8	High span	53	3.70	25.43	9.52
n = 8	Low span	51.57	4.04	1.14	1.35

Table 6. *Mean target picture naming latency (in ms) for SAE group and CL group breakdown by the working memory span (Mean percentage of error rate are indicated in square brackets.)*

Conditions	**CCEC-P**	**CCEC-U**		**CCCE-P**	**CCCE-U**	
Groups	Primed	Unprimed	Priming effect (unprimed-primed)	Primed	Unprimed	Priming effect (unprimed-primed)
SAE Group						
High span	1393 [6.12]	1230 [2.04]	- 163	1405 [4.08]	1229 [5.61	- 176
Low span	1483 [3.06]	1532 [4.59]	49	1711 [4.59]	1624 [2.04]	- 87
CL Group						
High span	1333 [2.55]	1291 [1.53]	- 42	1570 [7.65]	1369 [7.05]	- 201
Low span	1153 [2.55]	1231 [0.51]	78	1389 [8.67]	1425 [5.10]	36

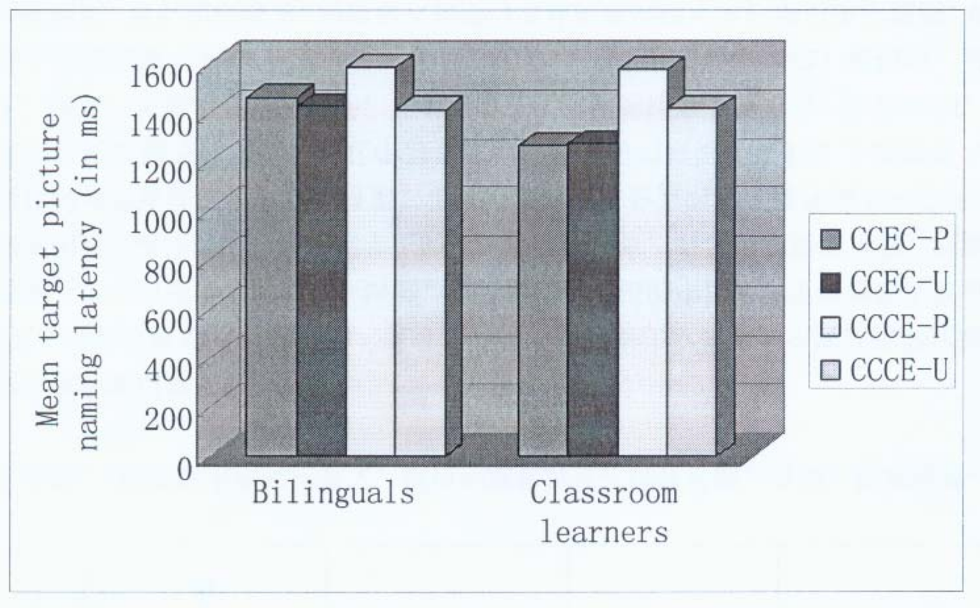
Mean target picture naming latency (in ms)
1600
1400
1200
1000
800
600
400
200
0
Bilinguals
Classroom learners
CCEC-P
CCEC-U
CCCE-P
CCCE-U

Figure 1. *Mean target picture naming latency in four conditions for the Chinese-English bilinguals in CAVT low group in Study 1 and Chinese-English classroom learners in Study 2.*