Cross-Language Priming in Chinese-English Bilinguals with Different Second Language Proficiency Levels

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Abstract

In this paper we describe an experimental study of cross-language priming effects between Chinese and English. The priming effects for both translation equivalents and semantically related word pairs were examined from a developmental aspect, in particular under three different situations according to bilinguals' second language (English) proficiency level measured by CPVT and language history questionnaire, and learning experience determined by whether they have lived in a foreign country. The results match up with previous findings, in terms of the larger effects of priming from L1 to L2 than from L2 to L1 ("priming asymmetry") and the stronger facilitation for translation priming than semantic priming. More importantly, our study demonstrates how such asymmetries in priming change as the bilinguals' L2 learning history changes. These findings are discussed in light of current models of bilingual lexical memory.

Keywords: Bilingualism; cross-language priming; Chinese.

Introduction

Cross-language priming is a widely used experimental paradigm in psycholinguistic research to study bilingual lexical representation and organization. . In this paradigm, cross-language word pairs (semantically related or translation equivalents) are presented to participants sequentially and participants are required to give a timed response (such as lexical decision or word naming). The method tests if bilinguals show response time differences to pairs of prime-target words that differ in their semantic relatedness. A faster reaction time to related pairs across languages (e.g., prime from the first language and target from the second language) is usually explained as a result of facilitation caused by the implicit spreading of activation from the prime word to the target word in bilinguals' mental lexicon, which indicates that the bilingual's two lexicons share a common conceptual memory representation (cf. Pavelnko, 2009).

Many cross-language priming experiments have been conducted in the past decades (see a detailed review in Altarriba & Basnight-Brown, 2007). In most studies researchers have found translation and semantic priming effects across languages, and have observed a number of interesting patterns, for example: (1) facilitation for translation equivalents is usually larger than that for semantically related words (Basnight-Brown & Altarriba, 2007); and (2) priming effects in the L1-L2 direction (from first language primes to second language targets) are often found stronger than those in the L2-L1 direction, which is referred to as "priming asymmetry" (Jiang & Foster, 2001).

Although it is widely accepted that cross-language priming effects are real, the exact nature of this phenomenon has not been studied extensively or systematically, in particular with regard to the bilingual's L2 proficiency from a development point of view. It might be possible to compare results from different studies with participants having varied L2 proficiency levels, but such comparisons must take into consideration the following: (1) different studies use very different experimental settings (see discussion of methodological issues in Altarriba & Basnight-Brown, 2007); and (2) the criteria used to measure participants' L2 proficiency can be quite different. Some attempts have been made to study the development of priming effects across languages with similar writing scripts (i.e. English and Spanish; see Kiran & Lebel, 2007), but not much work has been done with bilinguals from languages of different writing systems (e.g., Chinese and English; but see a recent work of "semantic competitor priming" by Li & MacWhinney, in press).

The current study aims at filling this gap. In particular, we first designed our experiment to control a host of variables which might have influences on priming (such as word length, frequency, relatedness proportion, nonword ratio, etc. Altarriba & Basnight-Brown, 2007; McNamara, 2005). We thenran a lexical decision task on three groups of Chinese-English bilinguals with different L2 (English) proficiency levels and learning history: low L2 proficiency, high L2 proficiency but without study abroad experience, and high L2 proficiency group with at least one year of experience living in US. We examined the priming effects from these three groups of participants with regard to a computational model of bilingual lexical organization.

Methods

Participants

Sixty bilinguals were paid to participate in this study. They were all native speakers of Chinese and had English as their L2. Three participant groups were created according to their L2 proficiency levels and learning history, which were evaluated both subjectively (through a language history questionnaire) and objectively (through an English vocabulary test).

Language History Questionnaire Participants were asked to fill in a language history questionnaire when they participated in the experiment. This comprehensive questionnaire was developed by Li, Sepanski and Zhao (2006) and includes 25 entries covering different aspects of participants' language history and daily language usage. The Chinese version of the questionnaire was used. Particularly important for this study was the participant's self-rating of proficiency level on English reading, writing, speaking and listening skills (on a 7-point scale, from 1 very poor to 7 native-like).

Controlled-Production Vocabulary-Levels Test (CPVT) During the study, participants also took a 20-minute test of their productive vocabulary in English under constrained contexts (Laufer & Nation, 1999). They were asked to fill in the missing part of words in each of 90 sentences (e.g. "He was riding a bicycle"). The test words came from five difficulty levels (from 2000 up to 10,000 words levels) and the total number of correct answers was counted as a participant's total score.

Participant Groups Among the 60 participants, 16 were Chinese students/scholars from universities in Boston, Massachusetts who have been studying/working in the US for at least one year (*M*=4.06 years, *SD*=2.82; mean age = 25.56; average age at which L2 learning began: 11.50,*SD*= 1.71). All of them indicated English as the language that they would use in their working/studying environment. They served in our experiment as the group with high L2 proficiency and with study abroad experience.

The other 44 participants were students from Beijing Normal University (BNU), Beijing, China. Most of them do not have experience living in an English speaking country, and only two have temporarily visited an English speaking country before (less than one month). Among them, 19 were in the high proficiency group since they reported themselves as English major or had got high scores in standardized English tests (i.e. TOEFL, GRE, IELTS etc). Their average age of L2 learning began from 10.53 years old (*SD*= 2.12). Another 25 students were in the low proficiency group (average age of L2 learning began: 12.12, *SD*= 1.48).

Table 1 shows the group average of participants' self-rated proficiency levels, along with their mean CPVT score. We found a strong positive correlation between the participants' CPVT scores and their overall self-rating L2 proficiency levels ($r(58)=.70$, $p < .001$). This result verifies the validity and consistency of our two methods used to evaluate bilinguals' L2 proficiency level. In addition, a one-way ANOVA reveals significant differences among the CPVT scores of the three groups, $F(2,57)=60.95$, $p<.001$, and the post-hoc tests showed that low proficiency group's score was significantly lower than the other two groups ($p<.001$) while there was no significant difference between the two high proficiency groups ($p=.35$). Similarly, a 3 (group) x 4 (language skills) mixed ANOVA on participants' self-rating proficiency levels reveals significant main effects on group ($F(2,57)=31.27$, $p<.001$) and skills ($F(3,171)=13.93$, $p<.001$). The overall self-rating proficiency level of the low proficiency group was 3.45 (*SD*=0.87), which was between "poor" and "functional" and was significantly ($p<.001$) lower than the other two groups. Whereas the difference between BNU high proficiency group (*M*=4.91, *SD*=0.64) and the high proficiency group with study abroad experience (*M*=5.27, *SD*=0.83) was not significant ($p=.39$), both groups had rated their proficiency level at around 5.

Table 1: Participants' average CPVT scores (0~90) and self-rating proficiency levels on English (on a 7-point scale). Standard deviations are in parentheses.

	Abroad high proficiency	BNU high proficiency	BNU low proficiency
Reading	5.56(0.63)	5.32(0.58)	4.08(0.58)
Writing	5.13(0.96)	4.95(0.71)	3.60(1.08)
Listening	5.44(1.09)	4.89(0.88)	3.00(1.23)
Speaking	4.94(1.12)	4.47(0.96)	3.12(1.09)
CPVT	46.88(12.69)	51.26(7.67)	22.68(7.69)

Materials

Critical Word Pairs To control for the words' difficulty levels on participants' lexical decision, we used here the vocabulary from CDI (the MacArthur-Bates Communicative Development Inventories; Fenson & Dale, 1996) as the basis of our critical material[1]. In particular, from a list of concrete nouns that English-speaking or Chinese-speaking toddlers can produce, we selected 32 translation equivalents (like *sock* and 袜子 [sock]) and a list of 32 semantically related word pairs (like *nurse* and 大夫 [doctor]). In addition, we created two lists of unrelated word pairs by reshuffling the words in the two related lists so that words that are unrelated are put into a pair. All the 128 word pairs mentioned above contained an English prime and a Chinese target. We then switched the order of the primes and targets to create another 128 critical word pairs with Chinese as primes and English as targets.

In addition, the 256 critical word pairs were split into four versions via a Latin Square to make sure no target or prime

[1] A small portion of words was replaced with other words that were similar in difficulty but more fit to our experiment requirements on length, frequency and semantic relatedness.

words would be presented twice to a same participant. Each experiment version included 16 translation equivalents (TR), 16 unrelated translation pairs (TU), 16 semantic related pairs (SR), and 16 semantic unrelated pairs (SU). In each category, half of the pairs had English words as the target words, and the other half had Chinese as targets.

Complexity, Word Length and Frequency All Chinese words in the critical word pairs were two-character words, and their complexity was based on the number of strokes of the two characters combined. The length of an English word was calculated as its phoneme number. For the SR and SU conditions, Chinese words had an average stroke number of 13.03 (*SD*=3.41), and English words on average consisted of 4.63 phonemes (*SD*=1.18). For the TR and TU conditions, Chinese words had an average of 14.69 strokes (*SD*=4.64) while English word length was 4.63 (*SD* =1.36). Word length and character complexity are not the same, but they are intended as rough measures of the surface properties of materials in the experiment.

The frequencies of English words were derived from the WebCELEX database (http://celex.mpi.nl/), and Chinese words' frequencies were derived from MCRC corpus (Modern Chinese Research Corpus; Sun et al., 1996), which is an electronic collection of text material from modern Chinese media. The unit for word frequency was "times per million". For the SR and SU conditions, the mean frequency of Chinese words was 32.98 (*SD*=34.46) while that of English words was 40.38 (*SD*=40.68). For the TR and TU conditions, the mean word frequency was 32.34 (*SD*=31.70) for Chinese and 41.28 (*SD*=32.82) for English. Overall, there was no significant difference between Chinese and English ($t(126)=1.33$, $p=.19$) in word frequency.

Semantic Relatedness To evaluate the validity of the critical material we created, we asked a separate group of 14 undergraduate students from BNU to rate the level of semantic relatedness of the critical word pairs on a 6-point scale (with 1 indicating that the two words were not related at all to 6 for being identical in meaning). The mean relatedness of word pairs in the TR group was 5.84 (*SD*=0.17), which was significantly higher than that for TU group (*M*=1.46, *SD*=0.36), revealed by a paired samples t-test ($t(31)=63.38$, $p<.001$). Similarly, the difference between the SR group (*M*=4.38, *SD*=0.29) and the SU group (*M*=1.51, *SD*= 0.30) was significant ($t(31)=39.30$, $p< .001$).

We also checked the reliability of our critical stimuli according to a free association norm from the University of South Florida (Nelson, McEvoy, & Schreiber, 1998). We found that our semantically related word pairs have average association strength of 0.192 and no two words in an unrelated pair can be associated with each other based on the norm[2]. This result is in consistent with the ratings by the 14 BNU students as discussed above.

[2] The association strength indicates how many percents of the participants of the USF Norm rated two particular words in a word pair as associated.

Relatedness Proportion (RP) & Nonword Ratio (NR) In addition to the critical word pairs, we also created 64 pairs of unrelated word fillers, for which we did not control their length or frequency. Moreover, 96 word-nonword pairs were also created. Again, half of the 160 pairs had English as targets and another half had Chinese targets. The English nonwords were created through the ARC Nonword Database (Rastle, Harrington, & Coltheart, 2002) and with their lengths matched to those of critical word pairs. The Chinese nonwords were all made up of two characters and their stroke numbers were matched to Chinese words in critical material.

In each experimental section, one of the four versions of the critical experiment material (64 pairs) was presented to a participant, along with the 160 common unrelated fillers and word-nonword pairs, which yielded a total of 224 experiment trials and a relatedness proportion (RP) of .25 and a nonword ratio (NR) of .50.[3] We set up the values of these two important parameters following the guideline "low RP" and "neutral NR" from McNamara (2005, p.72) to reduce the chance that participants would develop top-down strategies (e.g., expectancy) during the experiment.

Procedure

The experimental material from different categories mentioned above were first mixed and then blocked by language (English vs. Chinese as target words). Half of the participants were presented with the Chinese target block first and the other half were presented with the English target block first. All the participants were tested individually in a psychology experiment room either at BNU, Beijing, China or at Emmanuel College, Boston, USA. Participants were first asked to finish the lexical decision experiment, and then completed the Language history questionnaire and the CPVT test (see participant section). The entire experiment session lasted about 50 minutes. All the experiment instructions were given in Chinese.

The stimulus presentation and response registration were controlled by DMDX (Forster & Forster, 2003) run on desktop computers with Windows XP as the operating system. The computers' screen resolution was set to be 1024x768 with 16-bit color depth and a refresh rate of 60Hz. Stimulus words were always presented in black color on a white background. English words were all presented on lowercase letters and the font size for all primes and targets was 36 point. In each experimental trial, first a blank screen was shown to participants for 1000 milliseconds, followed by a fixation sign "+" that appeared for 500ms in the center of the screen, which reminded the participants that a trial was about to start. Then a prime word appeared for 150ms and was then immediately replaced by the target. Participants needed to make a lexical decision on the target

[3] According to the definition of McNamara (2005, p. 68), RP is defined as the proportion of related trials (32 here) out of all word prime-word target trials (128 here); NR is the conditional probability that the target is a nonword (96 here) given that the prime and the target are unrelated (192 here).

(Yes/No) by pressing the "j" key or the "f" key respectively. The participants were told to respond as quickly and as accurately as possible. The target remained on the screen for 2500ms or until the participants responded, followed by a new trial. Participants' response and reaction time for each target word were collected. In addition to the 224 experiment trials, there were 10 practice trials at the beginning of the experiment for participants to get familiar with the procedure.

Stimulus Onset Asynchrony (SOA) SOA indicates the time interval between the onset of the prime words and the onset of the target. It is widely accepted that short SOA can prevent participants developing top-down strategies (like expectancies from primes) in a priming experiment. Given our interest in implicit automatic processing of two languages, the SOA of our experiment was set to be 150ms, a number widely accepted as a short SOA in previous literature (McNamara, 2005, p.72; Altarriba & Basnight-Brown, 2007).

Results

Reaction Times

Only the critical word pairs (excluding fillers and nonwords) entered into our statistical analysis. Among them, 2.81% were incorrect responses, therefore discarded. In addition, outliers were trimmed from the data by removing responses more than 2.5 standard deviations below or above each participant's mean (accounting for 3% of the total responses). Such procedure of trimming has been a common practice in the priming literature (Zeelenberg & Pecher, 2003).

ANOVA A participant-based 3x2x2x2 mixed-design ANOVA was conducted on the reaction time (in milliseconds), with Group as the between-subject factor, and Direction (English vs. Chinese as targets), Prime Type (translation vs. semantic) and Relatedness (related vs. unrelated) as the within-subject factors [4]. Significant main effects were found for all the four factors. For Direction, $F(1,57)=46.48$, $p < .001$, and partial $\eta^2=.45$, suggesting that overall our participants responded significantly faster to L1 targets (Chinese: 578.96ms) than to L2 targets (English: 647.28ms). For Prime Type, $F(1,57)=17.56$, $p < .001$, and partial $\eta^2=.24$, showing that overall our bilinguals recognized targets in the translation group (605.09ms) faster than those in the semantic group (621.16ms). Regarding the variable Relatedness, $F(1,57)= 76.40$, $p<.001$, and partial $\eta^2=.57$, indicating that our participants were significantly faster in responding to the related word pairs than to unrelated pairs (594.41ms vs. 631.84ms; i.e., a priming effect). Finally, for Group: $F(2,57)=10.48$, $p < .001$, and partial $\eta^2=.27$, indicating the three groups had significant different mean reaction times, in particular, the BNU high proficiency group had the shortest mean RT (550.62ms) significantly different from the low proficiency group (619.59ms) and the high proficiency group with study abroad experience (669.16ms).

Significant interactions were also observed in our data. For example, the interaction between Direction and Relatedness had an $F(1,57)= 39.88$, $p<.001$, and partial $\eta^2=.41$. This interaction effect shows that the magnitudes of priming effects were not equal for the L1-L2 and L2-L1 directions. The priming from L1 to L2 was significant ($p<.001$) and larger (+67.19ms) than the marginally significant priming effect from L2 to L1 (+7.68ms, $p =.084$).

The interaction between Type and Relatedness had an $F(1,56)= 8.67$, $p = .005$, and partial $\eta^2=.13$. The follow-up comparisons clearly showed that the magnitudes of translation priming effect (+52.02ms) was larger than the semantic priming effect (+22.85ms), though both priming effects were significant ($p<.001$ and $p=.002$ respectively).

There was also a significant 3-way interaction among Direction, Type and Relatedness, $F(1,56)=5.83$, $p=.019$, and partial $\eta^2=.09$. This finding is important since the follow-up comparisons revealed that, combining the three groups, both translation and semantic priming were not significant from the L2 to L1 (English to Chinese) direction (+12.04ms, $p=.058$ and +3.32ms, $p=.68$ respectively), but significant from the L1 to L2 direction (+92.00ms for translation priming and +42.37ms for semantic priming, both $p <.001$). This revealed a clear "priming asymmetry".

Planned Comparisons We also conducted a series of planned comparisons (paired-samples t-tests) to study individual priming effects across different situations (See Table 2). For the low proficiency group at BNU, there were significant translation-priming effects of +106.07 ms from Chinese (L1) primes to English (L2) targets ($t(24)= 6.03$, $p<.001$) but not from L2 to L1 (+6.76ms; $t(24)= 0.63$, $p=.532$). There were also significant semantic priming effects of +37.32 ms from L1 primes to L2 targets ($t(24)= 2.29$, $p=.031$) but not from L2 to L1 (-0.33ms; $t(24)= 0.03$, $p=.976$).

For the high proficiency group from BNU who had not study abroad experience, there were significant translation priming effects of +74.03 ms from the direction of L1 to L2 ($t(18)= 6.11$, $p<.001$) but only marginally significant translation priming from L2 to L1 (+17.53ms; $t(18)= 1.70$, $p=.106$). Similarly, there were significant semantic priming effects of +28.05 ms from L1 to L2 ($t(18)= 2.62$, $p=.017$) but not from L2 to L1 (1.76 ms; $t(18)= 0.116$, $p=.909$).

Interestingly, for the high proficiency group who had study abroad experience (in Boston), there were significant

[4] Many investigators prefer to report the results from both participant-based and item-based ANOVAs for priming data, but we agree with McNarama (2005, p. 57) that items should not be treated as a random variable given they are often carefully selected and organized by the investigators. Therefore only participant-based results are reported here (an item-based ANOVA did reveal similar patterns on our data).

translation priming effects for both directions (+95.91 ms from L1 to L2, $t(15)= 4.02$, $p=.001$; and +25.35ms from L2 to L1, $t(15)= 2.59$, $p=.02$). But there were only significant semantic priming effects of +61.75 ms from L1 to L2 ($t(15)= 2.22$, $p=.043$) but not from L2 to L1 (7.87 ms; $t(15)= 0.50$, $p=.623$).

Table 2: Priming effects across different groups (unit in milliseconds). Bold numbers indicate significant priming.

	Prime Type	Abroad high proficiency	BNU high proficiency	BNU low proficiency
L1 to L2	Translation	**+95.91** ($p=.001$)	**+74.03** ($p<.001$)	**+106.07** ($p<.001$)
	Semantics	**+61.75** ($p=.043$)	**+28.05** ($p=.017$)	**+37.32** ($p=.031$)
L2 to L1	Translation	**+25.35** ($p=.02$)	+17.53 ($p=.106$)	+6.76 ($p=.532$)
	Semantics	+7.87 ($p=.623$)	+1.76 ($p=.909$)	-0.33 ($p=.976$)

Partial Correlations We also computed the partial correlations between the four priming effects and the CPVT scores with participants' average RT controlled. The results showed that there was a significant positive correlation between CPVT scores and translation priming effect from L2 to L1 ($r(57)=.32$, $p=.014$), but no correlations were found between CPVT and other three priming effects. This result is consistent with the data shown in Table 2 in that participants' translation priming from L2 to L1 increases as their L2 proficiency level increases while the priming from L1 to L2 stays on a stable level.

From Table 2 and above analyses, we can find a clear "priming asymmetry" across all the groups. In addition, it seems that the magnitude of this asymmetry gradually decreases as bilinguals' knowledge and experience of their L2 increases, particularly in terms of the asymmetry of the translation priming effects between L1 to L2 and L2 to L1. The magnitude of the semantic priming from L2 to L1 also increased slightly to 7.87ms for the high proficiency group who had study abroad experience, although this was not statistically significant.

Error Rate

Our critical word pairs contained only 2.81% of responses that were incorrect. Therefore the error rate was not the main target of our study. Nevertheless an ANOVA was applied to the error rate data, which revealed that participants tended to make more errors on English (L2) targets than Chinese (L1) targets (2.88% vs. 1.42%, $F(1,57) = 6.22$, $p = .016$). In addition, a significant main effect on relatedness ($F(1,57) = 8.09$, $p = .006$) indicated that fewer errors were made on related word pairs than unrelated word pairs (1.49% vs. 2.81%). No main effects on Prime Type and Group were found.

Discussions

In this study we have found both translation and semantic priming effects across languages, and also observed a number of patterns consistent with previous findings, such as "priming asymmetry" and the stronger facilitation for translation priming than semantic priming. More interestingly, considering a developmental perspective, we observed a pattern of increasing priming effects from L2 to L1, which mirrors a decrement of the levels of priming asymmetry, as bilinguals' L2 proficiency and experience increases.

Several theoretical frameworks of bilingual mental lexicon have been proposed, including the Revised Hierarchical Model (RHM, Kroll & Stewart, 1994), and more recently, the Sense model (Finkbeiner, et al, 2004), to account for bilingual lexical representation and processing. Our data are in general consistent with the RHM model in that increasing L2 to L1 priming suggests stronger lexical to semantic/conceptual links as L2 proficiency increases. Few computational models, however, have been proposed to account for the underlying mechanisms in bilingual lexical processing. Recently, we introduced a neural network model, DevLex-II, to study how bilingual mental representations of two languages can emerge, develop, and interact with each other as a function of the learning history (see details in Zhao & Li, 2010). The results from our simulations suggest that the representational structure is highly dependent on the onset time of L2 learning. L2 representation becomes "parasitic" on the representation of L1 when the learning of L2 occurs late; in particular, comparing with large and well-organized L1 representations, L2 lexical representations were dispersed and fragmented on the semantic map of our model (See Figure 2 in Zhao & Li, 2010). L2 words were often densely distributed in small chunks, and their locations depended on how similar they were to the L1 words in meaning.

One possible source of the discussed cross-languages priming patterns, based on Zhao and Li's (2010) simulation results, could be due to the nature of the L2 representation in late bilinguals' mental space. L2 words are often projected close to their translation equivalents, thus also close to the L1 words which are semantically related. Such close distribution in semantic representation allows spreading activation to occur more easily from words in one language to their semantically-related words in the other language, which in turn causes the cross-language priming effects. Since there is more overlap in meaning between translation equivalents than between semantically related words, translation priming is often larger than semantic priming.

Regarding the "priming asymmetry" along different priming directions, there might be two interrelated sources. On the one hand, lexical items in L2 are represented in more dense neighborhoods and hence in a more confusable fashion due to increased lexical competition from their nearby items (as demonstrated by the higher error rate for recognizing L2 words in our experiment). When they serve

as primes, a very brief exposure to them may not trigger activations strong enough to spread to the target L1 items not directly adjacent in mental representation. In contrast, activations of L1 items could be stronger given that they are more sparsely represented (thus having less competition). On the other hand, the dispersed and fragmented L2 representations imply that late bilingual's mental representation of L2 words may be relatively "impoverished" (i.e. bilinguals are aware of fewer features and semantic associations of words) in contrast to the better organization and richer relations of L1 items. In addition, bilingual's knowledge of an L2 word relies heavily ("parasitic") on their understanding of those features shared with its L1 equivalent. Therefore, when a L1 word serves as a prime, all the features and associations that the word lends to its L2 equivalent get activated, therefore causing the L2 equivalent easier to be recognized if it is a target.

When late bilinguals' L2 knowledge and proficiency gradually increase, their mental representations of L2 will become less dense and more organized. In other words, less confusion and better organization of semantic associations for L2 will occur. Such changes may cause the priming effects from L2 to L1 stronger and the "priming asymmetry" less salient as found in our experiment.

Finally, age of acquisition (AoA) is a very important factor in bilinguals' second language development, and how AoA and proficiency individually or jointly affect language representation and processing has been a matter of recent debate (see Hernanderz & Li 2007 for a review). It is worth noting that all of our participants are late bilinguals (with an average starting age of learning L2 around 11 years old), but they have different levels of proficiency. Our previous simulations of early versus late L2 learning showed the development of different patterns of representations for the two lexicons. To what extent these distinct patterns can be generalized to different proficiency levels remains to be investigated. Some of our preliminary simulations suggest that lateral connections between semantic representations within the same map/network may serve to model spreading activation for bilinguals (Zhao & Li, 2009).

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