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Is Translation Priming Asymmetry Due to Partial Awareness of the Prime?

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Abstract

In the masked cross-script translation priming literature, it is unknown how *aware* bilinguals are of the briefly presented primes of different scripts, given 50ms prime durations. Kouider and Dupoux's (2004) proposal of *partial awareness* suggests that 50ms English primes were sufficient for the lexical processor to make semantic interpretation. It is unclear whether this is the case to process a different script (e.g. Chinese). Experiment 1 is designed to measure the comparable prime durations to make semantic interpretation on Chinese primes, vs. English primes. Experiment 2 tested whether partial awareness of primes would be the cause of priming asymmetry, namely, whether a comparable level of semantic activation in L2 Chinese primes would produce/restore L2-L1 priming in lexical decision. Our findings demonstrate that 50ms prime duration gave rise to different levels of semantic activation in different scripts and L1/L2. However, increasing prime duration in L2 Chinese did not produce/restore L2-L1 priming.

Key Words: Partial Awareness, Cross-script Translation Priming, Priming Asymmetry, Chinese-English Bilinguals

An important question centering on Bilingualism and Second Language Acquisition is how words in one language are cognitively organized and processed in relation to words in the other language. A previously dominant view of the cognitive architecture of the bilingual lexicon is that bilinguals were believed to have two separate lexicons governed by a control mechanism so that bilinguals do not generally experience interference from one language to the other (Macnamara & Kushnir, 1971; Scarborough, Gerard, & Cortese, 1984). However, more recent evidence has shown that bilingual processing is non-selective, not only in the auditory modality (Weber & Cutler, 2004), but also in the visual modality (Dijkstra, Timmermans, & Schriefers, 2000; Duyck, Van Assche, Drieghe, & Hartsuiker, 2007; Van Hell & Dijkstra, 2002; van Heuven, Dijkstra, & Grainger, 1998; van Heuven, Schriefers, Dijkstra, & Hagoort, 2008). Thus, it becomes clear that both languages are active when only one language is being attended in various language tasks (Brysbaert, 2003). This leads to the conclusion that the two linguistic systems are actively interacting with each other as part of the language process and are integrated at some level in the bilingual lexicon.

One way to test the dynamics of cross-language influence is to use the masked priming paradigm where a bilingual is presented with a prime word in one language immediately followed by a target word in the other language and is instructed to respond to the target word. By measuring the effect of the prime on the target, one can interpret the cross-language connections of the bilingual lexicon (Forster & Jiang, 2001). In the masked priming paradigm, the prime is very briefly presented (40-60ms), so that the subject is not aware of the existence of the prime when instructed to make a lexical decision on the target. Previous masked translation priming studies have demonstrated a priming *asymmetry* in processing translation equivalents, in which an L1 prime could facilitate processing of a translation-equivalent L2 target, but not vice versa (Davis et al., 2010; Dimitropoulou, Duñabeitia, & Carreiras, 2011; Finkbeiner, Forster, Nicol, & Nakamura, 2004; Finkbeiner, Gollan, & Caramazza, 2006; Gollan, Forster, & Frost, 1997; N. Jiang, 1999). These findings were usually generated from late bilinguals. This priming effect from L1 to L2 has been interpreted in terms of linkages between translation equivalents at a lexical level. If the translation equivalents are linked at the lexical level, it is logical to think that L2-L1 priming should also be observed (Jiang & Forster, 2001; Finkbeiner et al, 2004). However, L2-L1 priming was not frequently reported in the literature while L1-L2 priming was always robust (Wang, 2013).

Recently, there have been some studies reporting priming effect of similar magnitude in both directions with highly proficient bilinguals in lexical decision (Dunabeitia, Dimitropoulou, Uribe-Etxebarria, Laka, & Carreiras, 2010; Duñabeitia, Perea, & Carreiras, 2010; Perea, Duñabeitia, & Carreiras, 2008) These bilinguals were within-script, namely, their two languages both used an alphabetic script. It is unclear whether the script would be a factor modulating cross-language masked priming. In fact, Nakamura, Dehaene, Jobert, Bihan, & Kouider (2005) suggest that a serial, posterior-to anterior axis of the ventral visual system appears to be structured similarly across readers of different orthographies but is also partially modulated by the specific requirements of scripts. At the functional level, they suggest that masked priming effects could differ due to the different phonological encoding of different scripts. That is, a prime of a logographic script vs. an alphabetic script can generate different priming patterns. In the case of cross-script bilinguals, L1-L2 priming has been consistently observed (Jiang, 1999; Gollan, Forster, & Frost, 1997; Finkbeiner et al., 2004), while L2-L1 priming was only observed in Wang (2013) in lexical decision with highly proficient balanced Chinese-English bilinguals. Importantly, even with translation priming observed in both directions, L1-L2 priming was stronger than L2-L1 priming.

It is argued that Chinese-English translation equivalents are interconnected at the semantic/lexical level, which is the source for the translation priming effect (Forster & Jiang, 2001; N. Jiang, 1999; X. Wang & Forster, 2010; Xin Wang, 2007). Given the handful of studies showing priming effects in lexical decision in both language directions, , the majority of studies have consistently reported L1-L2 priming, but not vice versa (e.g., Davis, et al., 2010). To explain the priming asymmetry, several accounts have been offered. One is straightforward: lack of proficiency in L2 results in less automatic processes compared to L1; therefore, there is no L2 effect on L1. However, this does not seem to be the case because within L2 priming was consistently reported in the literature (Gollan et al., 1997; Jiang, 1999). In addition, Dimitropoulou, DuOabeitia, & Carreiras' (2011) demonstrated that L2 proficiency did not modulate priming effects. Another proposal, not so straightforward, is that for late L2 learners, the L2 lexicon is not stored in the same memory system as the L1 lexicon (Nan Jiang & Forster, 2001; Witzel & Forster, 2012). This view is supported by the finding that L2-L1 priming can be obtained in an episodic memory task, but not in lexical decision. A third account, the Sense model account, attributes the asymmetry to the differences in the semantic representations of L1 and L2. According to the Sense Model, the absence of L2-L1 priming is due to the less richly semantically represented L2 compared to L1 (Finkbeiner et al, 2004; Wang & Forster, 2010). This account predicts that bilinguals, given balanced language experiences in L1 and L2, should produce translation priming in both directions. This is consistent with the findings in Wang (2013), where priming was obtained in both directions with proficient balanced bilinguals who had similar language experience in L1 and L2, but only in the L1-L2 direction with proficient unbalanced bilinguals in lexical decision.

One related issue, but never investigated in these studies, is how *aware* bilingual participants are of the briefly presented primes of different scripts. A hotly debated issue in the masked priming literature is to what extent subliminal stimuli can be processed semantically (Dehaene et al., 1998). Kouider and Dupoux's (2004) proposal of *partial awareness* suggests that *awareness* is not an all-or-none notion; rather, there is a state of *partial awareness* in which participants can identify part of the visual stimuli; for instance, they can identify certain letters or fragments of an English word in the masked presentation but are very poor at identifying the entire stimulus. One assumption of this argument is that pictures or words are complex, hierarchically organized stimuli that are represented at several levels of detail (in the case of words the levels would range from features to letters of phonemes, to the whole word) and that particular masking conditions will affect certain levels but not others. *Partial awareness* is opposed to *global awareness*, in which the stimulus is identified at all processing levels. Under the condition of *partial awareness*, participants may use the letters or features that they have perceived to reconstruct what the stimulus is. Once the stimulus has been reconstructed, it can be semantically processed, giving rise to the appearance of unconscious semantic activation. From this point of view, the priming asymmetry may simply reflect the fact that partial awareness of an L2 prime may be much weaker than for an L1 prime.

The variable that directly relates to the unconscious semantic activation is the prime duration. Priming effects have been observed for prime durations as short as 28ms in a semantic categorization task (Frenck-Mestre & Bueno, 1999). In contrast, it has been demonstrated that a semantic priming effect in lexical decision is consistently found for prime durations longer than 50ms, but absent at SOAs of 33ms or 43ms (Perea & Gotor, 1997; Perea & Rosa, 2002; Rastle, Davis, Marslen-Wilson, & Tyler, 2000). Interestingly, the strength of the semantic priming effect does not gradually decrease with a corresponding decrease in prime duration but virtually disappears below 50ms. This might suggest that 50ms may represent some kind of boundary condition that determines whether semantic priming is obtained or not. Furthermore, Kouider and Dupoux (2004) argued that masked cross-modal and semantic priming effects are obtained only with participants who demonstrate partial awareness of the prime, whereas this is not the case when priming is due to similarity of form. Hector's (2005) unpublished dissertation provides strong evidence that semantic activation needs to reach a certain level to obtain a semantic priming effect in lexical decision, and that partial awareness of the prime appears to be relevant in lexical decision but not in semantic categorization. The fact that semantic priming was obtained with prime durations of 55 and 60 ms, but not 42 ms in lexical decision suggests that the critical prime duration for partial awareness of English primes by native speakers may be around 50ms (Hector, 2005).

As conventionally claimed, translation priming is semantic across languages with different scripts and phonology, such that the only way to link the two languages is at the conceptual level, as in the case of Chinese-English bilinguals. The aforementioned arguments about the awareness of the masked primes lead us to speculate that translation priming might also depend on whether bilingual participants are partially aware of the masked primes, either in L1 or L2. It seems reasonable to suppose that the threshold of partial awareness for English primes is higher for L2 speakers than for English native speakers, due to different degrees of familiarity of the linguistic stimuli and the script across these two populations. Along the same line of argument, the threshold of partial awareness of L1 Chinese primes could be lower than that of L2 English primes. Previous translation priming studies have employed an SOA of 50ms in both L1-L2 and L2-L1 directions (e.g., Gollan et al, 1997; Jiang, 1999; Finkbeiner et al., 2004). If the threshold of partial awareness of L2 primes is higher than that of L1 primes and the degree of prime awareness is critical, it is clear why L2-L1 priming may be absent in lexical decision. Therefore, it is important to ensure that the prime reaches the same degree of *partial awareness* in either direction, but is not consciously perceived (i.e., is not identifiable).

In the current study, an attempt is made to measure the relation between prime duration and partial awareness in L1 and L2, with the aim of then adjusting the duration of the L2 prime so that it is comparable to an L1 prime. If differential partial awareness is responsible for the priming asymmetry, then it should disappear under these conditions. Obviously, a key issue is how to measure partial awareness comparably in languages with different scripts. The most obvious method would be to use a two-alternative forced-choice technique, in which participants are asked to guess which alternative is more likely to be the prime. The problem here is that performance will depend on how similar the two alternatives are, and any comparison across languages requires that this similarity must be held constant. For example, if the prime is "horse", we might expect poorer performance if the alternatives were orthographically similar (e.g., "horse -house"), phonologically similar (e.g., "horse-course"), or semantically similar (e.g., "horse- pony") compared to alternatives that are quite distinct (e.g., "horse- garden"). But if the prime is 马 (Chinese for "horse"), how could the alternatives be designed so that they are equivalent to the English alternatives?

Semantic Discrimination Task

The solution to this problem of cross-language equivalence is to eliminate orthographic and phonological factors by using alternatives that vary in their semantic overlap with the prime, but neither of which is actually the prime. Thus, the alternatives for the prime "horse" might be "donkey-ocean". If the prime activates the semantic properties for "horse", then the overlap with the properties of "donkey" will be greater than the overlap with the properties of "ocean", and therefore "donkey" would be selected as being more likely to be the prime. Performance now cannot be influenced by the orthographic or phonological similarity of the alternatives. Comparability across languages is now achieved by using the Chinese translations of "donkey" and "ocean" as alternatives. So, if the prime is 马, the alternatives would be "驴一洋". Assuming that these are good translations, then performance in either language will depend on the strength of semantic activation produced by the prime. If L1 and L2 demonstrate different degrees of semantic activation, we can then determine how long the L2 prime needs to be presented in order to generate the same degree of semantic activation as that generated by a 50ms L1 prime.

Experiment 1A Semantic Awareness Measure

The purpose of this experiment was to measure the partial awareness of L1 and L2 primes in Chinese-English bilinguals in a two-alternative forced-choice task, where the participant must identify which alternative is closer in meaning to the prime. If performance in L1 and L2 differ significantly at the prime duration of 50ms, it could be hypothesized that the absence of L2-L1 translation priming might be related to insufficient semantic activation of L2 masked primes.

Method

Participants. Thirty-six Chinese-English undergraduate and graduate bilinguals were recruited from the University of Arizona for this experiment. All of them were native speakers of Chinese and had lived in the USA for at least a year and a half for academic purposes by the time of testing. Participants had received a minimum of 8 years of formal English instruction in China before they came to the USA. All the participants were paid 6$ to participate in the study.

Materials and Design. The experimental items (see Appendix A) were composed of a set of English words and their Chinese translation equivalents adapted from Wang and Forster (2010) and the *Longman dictionary of contemporary English: English-Chinese* (Zhu & Deng, 1998). A total of 240 sets of three Chinese words -- 720 Chinese words total -- were selected for use as high-frequency nouns. The Chinese items are either one-character, two-character or three-character words. Each word had a unique English translation. Correspondingly, a total of 240 sets of 720 English words were used as English stimuli. Within each set of three words, one served as the prime word and the two others as response alternatives. One of the alternatives was semantically related to the prime word; the other was neither semantically related to the prime word nor the response alternative. The semantic relation was either categorical (*magazine* and *novel*) or associative (*black* and *white*). For instance, if the prime was the word "*cat*" then the two response alternatives "*dog- gun*" might have been used. When constructing the Chinese items, it was ensured that the three words within each set (trial) were of the same length (i.e., the same number of characters). Additionally, 10 sets of translation pairs were selected as practice items.

Participants were tested with both Chinese and English stimuli presented in blocks, but each translation pair was presented only once either in Chinese or English (within-subject design). During the experiment, participants were presented with a total of 240 trials, half in Chinese and half in English. Care was taken so that no alternatives were semantically related within trials or across trials. Two counterbalanced lists were constructed so that half of the English trials would be in Chinese on the other list and the other half Chinese trials would be in English on the other list. Within each list, English and Chinese blocks were separately presented to participants, with an additional block of practice items either in English or Chinese prior to the testing trials. Within each block, trials were presented at random in either English or Chinese. Because participants were presented with both English and Chinese in the same experiment, in order to control the language switch effect, the order of language presentation was counterbalanced. Taken together, four lists were constructed so that every set of items in both Chinese and English was tested with the same amount of participants. For example, on one list 'cat' was the prime with two alternatives 'dog gun'; on the other list the Chinese translation of 'cat', namely 猫, was the prime with two alternatives that were translations of 'dog gun', namely 狗 枪。

Within each Chinese block there were five conditions that were defined by the masked prime durations: 40ms, 50ms, 60ms, 70ms and 80ms. Every block consisted of an equal number of trials (12) under each condition. Because translation priming was reliably observed from L1 to L2 in lexical decision when the prime duration was 50ms, it was logical to measure participants' semantic awareness starting from the prime duration at 40ms where participants might be able to semantically interpret the L1 Chinese stimuli. The same design was applied to English blocks, except that the trials were presented at prime durations of 50ms, 60ms, 70ms, 80ms and 90ms. 50ms was used as the starting measure for English trials because bilinguals usually failed to produce L2-L1 priming at 50ms in lexical decision (e.g., Gollan et al., 1997; Jiang, 1999, Forster & Jiang, 2001).

Procedure. The presentation conditions in both languages mirrored the conditions used in previous cross-language lexical decision tasks (e.g., Finkbeiner et al., 2004; Gollan et al., 1997; Jiang, 1999). This was done to ensure that the primes in the current experiment would be presented under the same conditions as those in the previous studies. The English trial started with a forward mask '**########**' of 500ms followed by an English word at one of the various prime durations, immediately followed by a backward mask '&&&&&&&&' presented for 150ms, followed by a 500ms blank before the two alternatives (presented for 500ms) appeared on the screen for response. In the Chinese presentation, a different forward mask and backward mask were used to maintain a similar masking effect. Each trial started with a 500ms forward mask of an ancient Chinese character '鼺鼺鼺鼺鼺' immediately followed by a prime word at different prime durations; then the prime was replaced by an English non-word '**BREMOTHE**' for 150ms followed by a 500ms blank before the presentation of the two response alternatives (500ms).

Participants were given written instructions in Chinese about the experimental conditions. They were told to choose which of two words was semantically related to a briefly presented prime word. It was explained that sometimes they might not be able to identify the prime, but it was nevertheless necessary to make the best guess as to which alternative was correct. For example, being presented with an English trial as the following: '######## → magazine → &&&&&&& → novel apple', participants were encouraged to identify the prime word *magazine* as accurately as possible so as to choose the response alternative (*novel*) that was semantically related to *magazine*. The same procedure was applied to Chinese stimuli.

The alternatives were presented side by side, and if the correct alternative appeared on the left side, participants were instructed to press the left key on the button box; if the response word was on the right, they would press the right one. Feedback was not provided after each trial. Within each block, every condition consisted of an equal number of left responses and right ones. Participants could rest in between the blocks if they chose to do so.

Participants were randomly assigned to each list. The presentation of blocks was fixed during the experiment. Trials were randomly ordered within each block.

Upon completion of the experiment, participants were debriefed and reported that they were able to see/identify more Chinese stimuli than English ones. All of them stated that they were able to identify the prime word in English and Chinese if the prime duration was long enough and that identifying English masked primes was more difficult than Chinese ones.

Results and Discussion

Performance was evaluated by analyzing the accuracy rates produced by the bilingual participants at different prime durations in both English and Chinese. If the participants generated well above 50% correct answers at a certain prime duration, it could be claimed that they made good semantic interpretation of the masked primes at that prime duration.

Table 1 and 2 provide the means of the accuracy rates at each prime duration in Chinese and English. As shown in Table 1, as the prime duration increases, accuracy rates increase in both languages. As expected, performance in Chinese (L1) surpassed that in English (L2). Under the same prime duration (50ms, 60ms, 70ms or 80ms), t-tests revealed significant differences between English and Chinese: t (70) = 7.72, $p < .001$ at 50ms; t (70) = 6.71, $p < .001$ at 60ms; t (70) = 5.06, $p < .001$ at 70ms; t (70) = 5.64, $p < .001$ at 80ms. At the prime duration of 50ms, bilinguals were able to perform correctly on 78% of the trials in L1 Chinese, whereas they performed correctly on only 55% in L2 English. This shows a significant difference in performance between Chinese and English when the prime duration was 50ms. However, 55% correct answers in L2 English demonstrate that bilinguals were able to make slightly above chance guess of English primes.

Planned comparisons of 50ms Chinese primes with various prime durations in English showed that the significant difference between Chinese and English started to disappear when English primes were presented for 80ms and 90ms: $t(70) = 1.40$, $p > .05$ for Chinese primes at 50ms compared to English primes at 80ms; and $t(70) = 1.83$, $p > .05$ for Chinese primes at 50ms compared to English primes at 90ms. Therefore, the comparable prime duration based on similar error rates across languages was 80ms for English when the Chinese primes were presented for 50ms.

-------(Table 1 inserted about here)--------

------- (Table 2 inserted about here)---------

The current experiment demonstrates evidence for the different degrees of semantic activation in the early automatic processes of L1 and L2, but confirmed that proficient bilinguals were able to effectively process L2 primes at prime durations of 60ms, 70ms, 80ms and 90ms. However, bilinguals performed very close to chance at 50ms of English L2 primes, suggesting that they were not as effective given that prime duration. Two factors can contribute to this difference: one is that bilinguals' L2 is not as proficient/dominant as their L1 so that they require longer prime durations to make the semantic interpretations; the other is that the duration of a

Chinese word might not require the same exposure duration as an English word to reach the similar/same level of semantic activation. To understand whether language proficiency and the script play a role in the cross-language difference, it is necessary to investigate how native speakers of English perform in this task.

Experiment 1B Semantic Awareness Measure of Monolingual English Speakers

Method

Participants. Eighteen native speakers of English, undergraduates enrolled at the University of Arizona, were recruited for this experiment. All of them received one course credit for participation.

Materials and Design. Only half of the English items used in Experiment 1A were selected for Experiment 1B in order to compare bilingual and monolingual's performance on the same items. Therefore, a total of 120 sets of English trials were used to test English native speakers.

The design was the same as in Experiment 1, except that the native participants were only presented with English stimuli, including 120 randomly presented trials in addition to practice items.

Procedure. The same as in Experiment 1A, except that native participants were given written instructions in English.

Results and Discussion

Performance was evaluated by analyzing the accuracy rates generated by the native English participants at different prime durations (50ms, 60ms, 70ms, 80ms, and 90ms). If participants produced well above 50% correct answers given a prime duration, they were considered effectively making semantic interpretations of the masked primes under that prime duration.

Table 3 and 4 showed the means of the accuracy rates at different prime durations in processing English words by native speakers and Chinese-English bilinguals. Note that the accuracy rates from bilingual participants were calculated only on the items used in Experiment 1B, so that two groups of participants were compared by the performance on the same set of items. Both groups produced more than 50% correct trials under all prime durations and showed decreasing error rates as the prime duration increased. Under each prime duration, the performance significantly differed between the two groups: $t(34) = 2.03$, $p < .001$ at 50ms; $t(34) = 2.03$, $p < .001$ at 60ms; $t(34) = 2.03$, $p < .001$ at 70ms; $t(34) = 2.03$, $p < .001$ at 80ms; $t(34) = 2.03$, $p < .001$ at 90ms, indicating that English native speakers processed the primes more effectively than bilingual participants. At the prime duration of 50ms, bilinguals performed correctly on 54% of the trials, whereas native speakers achieved 68%. These results demonstrated the contrast in language automaticity between proficient L2 speakers and natives of English and suggest that language proficiency is a factor for bilinguals not able to perform as accurately as native speakers.

-------------- (Table 3 inserted about here)-------------------

---------------(Table 4 inserted about here)-------------------

In comparing native Chinese readers and native English readers' performance, Chinese items performed in Experiment 1A were selected to match their English equivalents in Experiment 1B for analysis. Table 5 and 6 demonstrated the means of the accuracy rates at each prime duration in processing Chinese and English words by native speakers. When the prime was presented for 50ms, native readers of Chinese performed better than native English readers, but the difference was not significant: $t(34) = 2.03, p = 0.077 > 0.05$. This similar pattern was observed when the prime was 60ms: $t(34) = 2.03, p = 0.44 > 0.05$; 70ms: $t(34) = 2.03, p = 0.84 > 0.05$ and 80ms: $t(34) = 2.03, p = 0.61 > 0.05$. These results suggest that native speakers of English and Chinese did not perform significantly differently on briefly presented words, regardless of the script difference. This suggests that the difference in performance at 50ms between English L2 readers and native English readers might be caused by less familiarity in L2 stimuli rather than the script itself. The comparable prime duration for bilinguals to process L2 English primes as effectively as native speakers when they process 50ms English primes, measured by error rates, is 70ms or 80ms, according to Table 3.

------(Table 5 inserted about here)---------

-------(Table 6 inserted about here)-----------

Does an increased L2 prime duration restore the L2-L1 priming effect in lexical decision?

Experiments 1A and 1B present evidence showing that the degrees of automaticity in processing primes not only differed between bilinguals and native speakers but also between the two languages used by bilinguals. These results encourage us to think that the asymmetry in lexical decision might be due to the less automaticity of L2 than L1. A direct test of the hypothesis is to equate the prime duration across languages on the basis of their performance in the semantic discrimination task and investigate whether L2-L1 priming is restored by increasing the prime duration accordingly in a lexical decision task. The following experiment serves this purpose.

Experiment 2 Lexical Decision in both L1-L2 and L2-L1

The purpose of this experiment is to investigate whether both L1-L2 and L2-L1 priming could be obtained by adjusting the prime durations so that the prime awareness in each language was comparable. Specifically, the research question is that whether both 50ms L1 primes and 80ms L2 primes could effectively produce cross-language priming.

Method

Participants. Twenty-four Chinese-English bilinguals from the same subject pool as in Experiment 1 were recruited for this experiment. All the participants were paid to participate in the study.

Materials and Design. The experimental items (see Appendix B) were selected from Jiang's (1998) and Wang & Forster (2010), given that the translation equivalence was established among similar subject pools. Among the selected items, 60 translation pairs were abstract nouns, while the other 60 were concrete ones. In order to test the priming effects in both L1-L2 and L2-L1 directions, a between-item comparison procedure was adopted. Therefore, 30 pairs of abstract nouns and 30 pairs of concrete nouns were randomly selected in L1 recognition preceded by masked L2 primes in lexical decision (L2-L1), while the rest were tested from L1 to L2. This gave rise to 60 word items in each test of different priming directions. To balance the *YES* and *NO* responses in lexical decision, 60 Chinese non-words and 60 English non-words were selected in the L2-L1 and L1-L2 direction respectively. The Chinese non-words were illegal combinations of two Chinese characters. All of the Chinese words and non-words were two-characters long and all the characters were orthographically distinct from each other. The English non-words were illegal and pronounceable letter strings, matching the word items in length. In addition, 120 English words were selected from CELEX (Baayen, Piepenbrock & Gulikers, 1995) as unrelated primes for Chinese word targets or primes for Chinese non-word targets. They were matched with the English translation primes for frequency, concreteness and length. Similarly, 120 two-character Chinese words were selected from an online frequency list of Chinese characters (McEnery & Xiao, 2005) as unrelated primes for English word targets or primes for English non-word targets, matching with the Chinese translation primes for frequency, concreteness and length.

Half of the critical targets per list were preceded by their translation equivalents and half were preceded by an unrelated prime. Two counterbalanced lists were constructed in each direction, such that if a target was preceded by its translation prime on List A, it was preceded by its unrelated prime on List B and vice versa. No target word or prime word was repeated within lists. Within each list, there were 10 practice trials, including 5 *YES* responses and 5 *NO* responses, prior to the experimental trials that were evenly divided into 2 blocks. Thus each block consisted of 30 word and 30 non-word trials, which were randomly presented. The presentation of each trial in both directions was consistent with the standard masking procedure used in previous studies (e.g., Forster & Davis, 1984; Gollan et al., 1997; Jiang, 1999). Please see the following for a better illustration:

L1-L2 direction

齉齉齉齉齉 (500ms) → 50ms primes → 500ms targets

L2-L1 direction

########## (500ms)→ 80ms primes → 500ms targets

A Chinese character 齉 was selected from ancient Chinese texts to better mask Chinese primes. Critically, an increased prime duration of 80ms was adopted in the presentation from L2-L1. The Chinese targets were presented in SimSun font, Size 12, while the English targets were in Courier New, Size 13.5. It was ensured that the forward mask was no shorter than the primes.

To summarize, this is a 2x2x2 within-subject factorial design, with Language Direction (L1-L2 vs. L2-L1), Word Concreteness, and Prime (translation vs. unrelated) as interested variables.

Procedure. *25* Participants were randomly assigned to each list and tested in both directions. Before each test, they were given a written instruction in the language to be tested as targets. They were told to make a *YES* or *NO* response about the visual stimulus on the computer screen. With the English targets, they were asked to decide whether the letter string formed a word (e.g., house) or a non-word (e.g., roolter). When making a lexical decision in Chinese, they were asked to decide between a word (a meaningful character combination, like *苹果*) and a non-word (a meaningless character combination, like *晓托*). If the presented stimulus was a word, they ought to press the *YES* button, but press the *NO* button if it was a non-word. They were encouraged to make decision as accurately and quickly as possible, but not so quickly as to make lots of errors. They could rest in between the blocks if they wished.

Upon completion of the experiment, participants were debriefed and only two of them reported that they were able to see or identify some primes during the experiment.

Results and Discussion

Subjects who made errors on more than 25% of the trials and those who reported seeing some primes were excluded from analysis. Twenty out of 25 subjects were included in the final analysis. Trials of more than 1500ms or less than 300ms in reaction times were excluded as well, which counted as 1.14% of the total test trials. Data from trials on which an error occurred were discarded and counted as 5.04% of the total trials. Mean response times and error rates for Chinese targets and English targets under each condition are presented in Table 7.

Analyses. Statistical analyses were performed using a linear mixed-effects model (Baayen, 2008; Baayen, Davidson, & Bates, 2008). Unlike more traditional ANOVAs, mixed-effects models take raw unaveraged data as input and incorporate both random effects of participants and items within a single analysis. The fixed-effect factors were Prime Type (translation primes vs. unrelated primes), and Word Type (concrete words vs. abstract words) in each language direction (L1-L2 vs. L2-L1). Subjects and items were random effects. Prior to fitting a mixed-effects model, the data (RTs) were transformed using a reciprocal transformation in order to minimize the effects of positive skew. Models were fitted using a restricted maximum likelihood technique. The lmer function from the lme4 package in R was used (version 2.15.3; CRAN project; The R Foundation for Statistical Computing, 2008).

In the L1-L2 direction with SOA of 50ms, mixed-effects analysis of the RTs showed that there were significant effects of translation priming ($t=3.70$) and word type ($t=3.42$). There was no interaction ($t=0.48$). Therefore, robust L1-L2 priming was observed for both abstract and concrete words with a 50ms prime, which is consistent with the literature. In addition, the concrete words produced more priming than the abstract words, which could reflect greater semantic overlap for concrete translation pairs, but this difference was not significant. Contrary to the hypothesized awareness account, there was no significant L2-L1 priming for either abstract or concrete words when the prime duration was increased to 80ms (t=0.5 for Prime Type in mixed-effects analysis). The critical result is that the asymmetry in lexical decision was observed again even with a duration of 80ms for L2 primes, which indicates that the absence of L2-L1 priming is not due to the limited duration of the L2 prime. Additional analysis across language direction showed that the bilingual participants responded to L1 Chinese targets much faster than L2 English targets (t=5.88) and made fewer errors in their L1 than L2.

------(Table 7 inserted about here)-------

General Discussion

To summarize, Experiments 1 and 2 were designed to determine whether the absence of L2-L1 priming in unbalanced cross-script bilinguals was due to differential partial awareness of the prime. Translation priming is clearly semantic in nature, and it has been suggested that masked semantic priming requires partial awareness of the prime. A prime duration of 50 ms may be sufficient to achieve partial awareness in L1, but not in L2. The procedure we followed was to use a semantic discrimination task that would allow a systematic comparison of semantic awareness across languages. Not surprisingly, Experiment 1A found that performance improved as the prime duration increased in both languages and that performance was significantly better in L1 than in L2 at every prime duration (50ms, 60ms, 70ms and 80ms). These results indicate that it takes bilinguals more time and effort to process L2 masked primes than their L1 counterparts. Parallel to this finding, Experiment 1B showed that native English speakers performed significantly better than proficient L2 bilinguals at each prime duration. At the prime duration of 50ms, which most translation priming studies used, bilinguals were able to make a little over 50% correct trials. This suggests that L2 semantic information was activated, but it is still questionable whether the semantic information was successfully interpreted. According to the accuracy rates, their performance in Chinese at 50ms was comparable to that at 80ms in English. It is thus logical to think that an 80ms prime duration should be used in order to get a similar semantic activation on L2 to that on L1. Therefore, Experiment 2 was designed to test whether an increased prime duration in L2 (80ms), namely increased prime awareness, could increase the effectiveness of L2-L1 priming in lexical decision. The results showed robust L1-L2 priming, but null L2-L1 priming with the same participants.

There is a reason to think that L1 Chinese and L2 English primes under the same duration could rise to different degrees of semantic activation because of the script difference and the relative proficiency of L2 to L1. The current findings provide evidence that semantic activation occurs with L1 primes, but less so with L2 primes at the 50ms duration.. In addition, bilinguals' L2 prime semantic activation was lower than native speakers under the same prime durations. Importantly, the results show that increasing L2 prime duration could lead to higher degree of semantic activation as demonstrated in the semantic discrimination tasks, but it did not lead to L2-L1 priming in lexical decision. In other words, translation priming does not depend on partial awareness of primes. Clearly, in the situation of translation priming with Chinese-English speakers, priming has to be semantic, as Chinese and English do not relate to each other either in phonology or orthography. The current findings suggest that translation priming is semantic, but might employ a different mechanism from semantic priming occurring within languages. If semantic priming depends on partial awareness of masked primes, as proposed by Kouider & Dupoux (2004), the underlying mechanism should be attributed to the degree to which the results of semantic processing of the prime reach consciousness. This is consistent with Neely & Keefe's (1989) retrospective account of semantic priming, as priming depends on whether the target word is perceived to be related in meaning to the prime. That is, for the lexical processor to interpret the prime-target relationship in meaning can depend on how 'aware' it is of the prime. If translation priming is a retrospective effect, we should be able to observe priming given a longer L2 prime duration, because the way we measured semantic activation in L1 and L2 was a retrospective process, in which participants made their choices in the 2-AFC task by selecting the target that was semantically related to the prime. This analysis is consistent with the argument proposed by Midgley, Holcomb & Grainger (2009) and Hoshino, Midgley, Holcomb & Grainger (2010) in explaining the nature of translation priming. In their ERP studies, both N250 and N400 components were found to be modulated by L1-L2 translation priming, which was taken to demonstrate that the semantic activation of L1 primes influenced the activation of form-level representations in recognizing L2 targets. Therefore, our results can be taken to suggest that translation priming is different from semantic priming due to the special relation between L1 and L2. Alternatively, we can speculate that translation priming is prospective, rather than retrospective. The mechanism of translation priming is more like automatic spreading activation (Neely, 1977; Posner & Snyder, 1975): the prime activation alters the status of the lexical representation of its counterpart in the other language as the target, so that it is recognized faster. This is an automatic process based on the visual input, but not dependent on partial awareness. Therefore, increasing partial awareness of the prime doesn’t help in the cross-language case.

So why is there no L2-L1 priming? One possible explanation is provided by the Sense Model. The L2 prime is processed adequately in both LD and SC tasks, but priming depends on the proportion of the target word's senses that are primed. This proportion is low in LD, but high in SC (Finkbeiner et al, 2004; Wang & Forster, 2010; Wang 2013). The other possibility is the Episodic L2 hypothesis, which argues that the L2 prime activates episodic memory, not lexical memory, and hence the target needs to be represented in episodic memory to produce priming (Jiang & Forster, 2001; Witzel & Forster, 2012). It is also important to note that these two explanations are built upon one assumption, which is, L2 is learned later in a bilingual's life. Late L2 learners tend to rely on L1 senses to build L2 semantics, especially if language learning occurs in foreign/second language classrooms. This could be different from early L2 bilinguals or simultaneous bilinguals as these bilinguals tend to have equal access to L1and L2 in the same environment and can develop L2 semantics quite independently.

To date, some studies have reported within-script L2-L1 translation priming with highly proficient bilinguals (e.g., Dunabeitia, Perea, & Carreiras, 2010; Perea, Dunabeitia, & Carreiras, 2008). In addition, there is only one reported study (Wang, 2013), demonstrating cross-script L2-L1 priming in lexical decision with balanced simultaneous bilinguals. As pointed out by Hoshino et al (2010), the change in script creates optimal conditions for prime word processing due to less orthographic interference from the target word, compared to within-script primes, and the more salient cues to language membership. This is supported by their ERP findings with Japanese-English bilinguals showing that the emergence of L1-L2 translation effects occurred about 100 ms earlier compared to the French-English bilinguals in Midgley et al. (2009). Following this, the important question to ask is whether L2-L1 cross-script priming is non-existent in lexical decision, or whether it is simply weaker than L1-L2 priming with late bilinguals. In the current experiments, we used the prime duration manipulation to amplify any possible L2-L1 priming effect, but we still found no priming. So it is unlikely that L2-L1 priming was simply too weak to detect, namely, the absolute view is supported. That is, L2-L1 priming either exists or not with late bilinguals, depending on the effectiveness of L2 primes.

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