Testing processing explanations for the asymmetry in masked cross-language priming*

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Cross-language priming effects using masked primes tend to be asymmetrical. Priming from L1 to L2 is strong, but priming from L2 to L1 is inconsistent and weak. Two kinds of explanations may explain this asymmetry. The representation hypothesis attributes the asymmetry to the different strength of connections between lexical items in the two languages. The processing hypothesis explains the asymmetry by emphasizing differences in processing speed or the general activation level of the two languages. In this study, three versions of the processing hypothesis were examined. Chinese–English bilinguals were tested with a masked priming paradigm on Chinese–English translation pairs in five experiments. Experiments 1 and 2 replicated the asymmetrical pattern of cross-language priming. Experiments 3 to 5 examined three processing-related hypotheses by varying prime and target presentation conditions. The results showed that none of the three processing accounts provides a satisfactory explanation for the asymmetry. The findings are discussed in the context of current models of bilingual memory organization.

Much of the research in bilingual memory organization has focused on the issue of how the two lexical systems of a bilingual are connected. Weinreich (1953) outlined three ways in which they may be related. The two lexical systems may be connected through a common semantic system (compound bilingualism), or have their own distinctive semantic representations (coordinative bilingualism), or the less proficient language may be associated with the dominant language at the lexical level only and thus connected to the semantic representation indirectly (subordinative bilingualism). The compound and subordinative models were later known as the concept-mediation hypothesis and word-association hypothesis, respectively.

In the more recent literature, three additional models or hypotheses have been proposed. They all acknowledge that the two languages may be connected simultaneously at both lexical and conceptual levels in a bilingual. However, they differ from each other in their emphasis on the factors that are believed to determine the patterns of connections in a specific bilingual speaker. The intermediate hypothesis (Chen and Leung, 1989; see also Kroll and Sholl, 1992; Potter, So, Eckardt and Feldman, 1984) postulates that a bilingual's proficiency in the second language may determine how the two lexical systems are connected. Early in the acquisition process, lexical items of the second language (L2) are connected mainly through their translation equivalents in the first language (L1). Thus, less proficient bilinguals may rely on lexical links more than conceptual ones. However, as their L2 proficiency improves, direct connections may develop between the words of the new language and the conceptual system, and play a more important role in language processing.

The dual-route connection hypothesis proposes that, while the two kinds of connections might exist simultaneously in a bilingual, the way in which a particular word is represented depends on the nature of this word. Specifically, it is suggested that concrete or cognate words in the two languages are more likely to be related through a shared semantic (De Groot, 1993; De Groot and Nas, 1991) or imagery

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system (Paivio, 1991; Paivio, Clark and Lambert, 1988) than abstract or noncognate words.

A third model, the revised hierarchical model proposed by Kroll and Stewart (1994), claims that words in the two languages may be directly linked at the lexical level and also indirectly linked through shared conceptual representations. It further postulates that the strength of these links may vary, depending on which language or direction of connection is involved. Specifically, two asymmetries are suggested. At the lexical level, the connection from an L2 word to its equivalent in the first language is hypothesized to be stronger than that from an L1 word to its L2 equivalent. At the same time, the link between a word and its corresponding concept is assumed to be stronger in L1 than in L2.

A great deal of empirical research has been directed towards understanding bilingual lexical organization. Among the various research paradigms, cross-language priming is among the most frequently used (e.g., Chen and Ng, 1989; Jin, 1990; Smith, 1991; De Groot and Nas, 1991; Altarriba, 1992; Sánchez-Casas, Davis, & García-Albea, 1992; Keatley and De Gelder, 1992; Gollan, Forster and Frost, 1997). In a typical cross-language priming study, reaction time and error rate are measured to determine whether words preceded by a translation equivalent or a semantically related word in the other language are responded to faster or more accurately than when they were preceded by an unrelated word.

Of the bilingual priming studies carried out over the last fifteen years, three different types can be distinguished in terms of their experimental designs and procedures. Earlier priming studies typically used a two-phase design. In the study phase, participants were exposed to words in one language. In the test phase, they were asked to perform various tasks, such as lexical decision or naming, which involved either the same words, translation equivalents or semantically related words in the other language (e.g., Kirsner, Smith, Lockhart, King and Jain, 1984, Experiments 1 and 3; Scarborough, Gerard and Cortese, 1984; Durgunoglu and Roediger, 1987; Smith, 1991). A consistent finding from these earlier studies was that mere exposure to a word in one language in the study phase may facilitate the processing of the same word in the test phase, but not its translation equivalent or a semantically related word in the other language.

As has been pointed out by Kirsner et al. (1984), Chen and Ng (1989) and De Groot and Nas (1991), a potential problem with the two-phase design was the long lag between the first and second presentations of the translation or related pair. A lag of 10 to 20 minutes between translation equivalents or semantically related words, which was typical in these studies, may fail to detect any priming effects because meaning-related activation might be very transient, making any effects originated from such activation too short-lived to be detected.

In response to this lag problem, later bilingual priming studies have employed a single-phase design. In these studies (e.g., Mack, 1986; Schwanenflugel and Rey, 1986; Frenck and Pynte, 1987; Grainger and Beauvillain, 1988; Chen and Ng, 1989; Jin, 1990; Altarriba, 1992; Kroll, Sholl, Altarriba, Luppino, Moynihan and Sanders, 1992; Keatley, Spinks and De Gelder, 1994; Fox, 1996), the time interval between the presentations of the prime and the target was usually very short (less than a second in most studies), and the target word was always preceded immediately by the prime word without intervening words. Two consistent patterns of findings emerged from these studies. First, exposure to a word in one language may facilitate the recognition of not only the same word, but also its translation equivalents in the other language. Second, the extent of facilitation depended on the direction of priming. The magnitude of cross-language priming is greater in the L1–L2 direction than the reverse (e.g., Schwanenflugel and Rey, 1986; Frenck and Pynte, 1987; Chen and Ng, 1989; Jin, 1990; Altarriba, 1992; Keatley et al., 1994).

All of these later single-phase bilingual priming studies used a standard priming paradigm where both the prime and the target were visible to participants. A major problem with this paradigm is the potential involvement of strategic effects. When the prime is visible, participants may become consciously aware of the bilingual nature of the task, and the way in which the prime and target are related. This may lead the participants to adopt various strategies. Given an SOA of 1000 ms, for example, participants may translate the prime before the onset of the target, which would facilitate performance on translation pairs. Even with a relatively short SOA (e.g., 250 ms), which is presumably too brief to allow covert translation, the participants' awareness of the prime-target relationship may still affect their performance at the decision stage. That is, they may be more inclined to give "yes" response to a target preceded by a related prime, whether a translation equivalent or a semantically related word, than a target preceded by an unrelated prime, thus resulting in priming effects for related pairs. Such a tendency can be seen in the higher error rates produced on nonwords that are one letter different from a word (e.g., NRUSE) that is semantically related to the prime (e.g., doctor) (e.g., O'Connor and Forster, 1981). (See Forster and Davis, 1984, De Groot and

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Nas, 1991, and Forster, 1998, for more detailed discussion of potential problems associated with the standard priming paradigm).

In response to the problems associated with visible primes, more recent bilingual studies (De Groot and Nas, 1991; Sánchez-Casas et al., 1992; Gollan et al., 1997) have adopted a masked priming paradigm, using the procedures developed by Forster and Davis (1984). Its most important feature is the combination of a very brief presentation of the prime (e.g., 50 ms) with the use of a forward mask. The use of masked prime has the advantage that participants are usually unaware of the presence of the prime and of the bilingual nature of the task. As a result, the strategic effects associated with the standard priming paradigm are minimized.

All of these masked priming studies investigated the role of cognate status in bilingual organization. In De Groot and Nas (1991), Dutch–English bilinguals were tested with both within- and between-language repetition word pairs and semantically related word pairs under masked and nonmasked conditions. Two types of between-language word pairs were used, cognate word pairs and noncognate word pairs. Cognates are translation equivalents that have similar meaning and pronunciation and/or orthography because of a common origin. Both between-language repetition and associative priming effects were observed under nonmasked and masked conditions for the cognate word pairs. For the noncognate word pairs, both between-language repetition and associative priming were found under nonmasked conditions, but under masked conditions, only repetition (translation) priming was found (Experiments 3 and 4). Note that in both of the experiments that produced noncognate translation priming in the masked condition, the participants were tested in the L1–L2 priming direction.

The second study using the masked priming paradigm, reported by Sánchez-Casas et al. (1992), tested Spanish–English bilinguals with a semantic categorization task where the prime was either identical, a translation equivalent or unrelated to the target. The priming direction was from L2 to L1, and only masked primes were considered. As in the De Groot and Nas (1991) study, cognate and noncognate pairs were distinguished. It was found, in line with the findings of the De Groot and Nas study, that cognate translations produced significant priming effects, which were comparable to the priming effects observed for identical word pairs. However, inconsistent with what was found in De Groot and Nas (1991), no priming effects were found for noncognate translation pairs.

The third study, reported by Gollan et al. (1997), tested Hebrew–English bilinguals with cognate and noncognate translation pairs. Unlike the other two masked priming studies, in which only one priming direction was tested, participants in this study were tested in both priming directions, from L1 to L2 and from L2 to L1. One of the most important findings of this study was that noncognate translation pairs produced priming effects only in one priming direction, from the dominant language to the weaker language, but not vice versa. This is important because what seemed to be conflicting results in the other two masked priming studies – that is, translation priming was found for noncognates in De Groot and Nas (1991) but not in Sánchez-Casas et al. (1992) – become consistent in the light of this study, when one takes priming direction into consideration (L1–L2 in De Groot and Nas, 1991, and L2–L1 in Sánchez-Casas et al., 1992).

Together, these three studies produced an important and consistent finding: when noncognate translation pairs are involved, strong and consistent cross-language priming occurred from L1 to L2, but no priming from L2 to L1 was found. As mentioned above, this asymmetry can also be found in most previous nonmasked cross-language priming studies in that the magnitudes of priming effects have been consistently greater from L1 to L2 than from L2 to L1 (Jin, 1990; Altarriba, 1992; Keatley et al., 1994).

What lies behind this asymmetry? Several explanations can be given. First, this asymmetry may reflect some representational features of the bilingual memory. Kroll and Stewart's (1994) revised hierarchical model may offer such an explanation. According to this model, links between L1 words and concepts are stronger than those between L2 words and concepts. Assuming that the cross-language priming effects come from the shared conceptual representation of the translation equivalents, this model would seem to predict that strong priming effects should be observed from L1 to L2 and weaker or no priming effects should be observed from L2 to L1 (this issue will be discussed in more detail later).

In addition to the above representation account, several processing accounts can be given. The first processing account has to do with the amount of time allowed for prime processing in these experiments. According to this temporal constraint hypothesis, the combination of a very short exposure time for the prime and the masking procedure, which has produced priming effects in monolingual studies with native speakers (e.g., Forster and Davis, 1984; Sereno, 1991), may not allow non-native speakers to recognize the L2 primes (e.g., Grainger and Beauvillain, 1988). This may be particularly true when the two languages involved have different scripts, as in

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Gollan et al. (1997). In such a case, due to this script difference and their limited proficiency in the second language, these participants may be disadvantaged at both letter perception and word access levels (see Kempe and MacWhinney, 1996 for example). As a result, they might fail to perceive the letter strings or to recognize a letter string as a word within the time window allowed for the prime word.

The second processing account, the different speed of access account, was proposed in Gollan et al. (1997). Instead of suggesting that the prime word is not recognized under the temporal condition, they argued that the absence of priming from L2 to L1 may be a result of the relative processing speed in the two languages. According to this view, when the prime is an L2 word and the target is an L1 word, the L2 prime will be processed more slowly than the L1 target. Due to the short interval between the prime and the target, the L1 target may be accessed before the L2 prime can affect its processing. That is, the prime word is recognized, but is recognized too late to produce L2–L1 priming. However, when the priming direction is reversed, the L1 prime should always be processed fast enough to affect the processing of the L2 target.

The third processing account, the general activation level hypothesis, is based on the idea that a bilingual's dominant language (usually L1) is basically stronger than the weaker language (L2). This is especially the case for bilinguals who are much more fluent in one language than in the other. This will have an impact on processing such as in cross-language priming experiments in which the prime is masked. In such a situation, the weaker language is less active and it is easier to inhibit than the more dominant language (Green, 1986; 1998). Hence, the different general activation levels of the two languages may be involved differentially in the priming directions. In the L2–L1 priming direction, where the targets are L1 words and the L2 prime is masked and consciously invisible, the L2 prime will normally be less active and therefore less available for processing. On the other hand, in the L1–L2 priming direction, the dominant L1 is generally more active and therefore harder to suppress. This in turn allows L1 primes to affect L2 targets.

The aim of the present study is to test these three processing explanations for the asymmetry in masked cross-language priming. The purpose of the first two experiments was to replicate the asymmetrical pattern of cross-language priming effects. The next three experiments were designed to test the three processing explanations.

Experiment 1

The purpose of this experiment was to replicate the finding of asymmetrical cross-language priming effects found in previous masked and nonmasked cross-language priming studies. Chinese–English bilingual speakers were tested with translation pairs in both priming directions, that is, from their first language, Chinese, to their second language, English (C–E or L1–L2) and from English to Chinese (E–C or L2–L1). According to previous studies, translation priming should occur in the L1–L2 priming direction, and no, or significantly reduced, priming should be found in the L2–L1 direction.

Method

Participants. Fifty-two Chinese–English bilingual speakers participated in the experiment. They were all graduate students or visiting scholars from mainland China studying at the University of Arizona at the time of testing. Most of them had studied English in formal settings for at least eight years. Those who were graduate students all had a TOEFL score of 550 or higher when they were admitted to the university. Their lengths of residence in this country varied from eight months to seven years. Most of them worked as research or teaching assistants. Except for a few volunteers, all of the participants were paid for their participation.

Materials and design. The critical stimuli included sixty-four pairs of Chinese–English translation equivalent words. They were constructed with the following procedures. A set of 100 English words was selected initially. They were high-frequency nouns that had unique bisyllabic Chinese translations. These words were used as stimuli for several reasons: (i) to make sure that the English words were familiar to all the participants; (ii) to keep the stimuli homogeneous; and (iii) it is easier to find abstract nouns that have unique bisyllabic Chinese translations, as compared with verbs or adjectives. To create the list of translations, the English words were given to three Chinese–English bilingual speakers, all graduate students at the University of Arizona. They were asked to provide the first Chinese translation that came to mind for each word. Those English words that produced a different Chinese translation from each of the three informants were discarded from the list. The Chinese translations were then given to three different informants who were asked to provide the first English translation that came to mind for each word. Chinese words that produced different English translations from the informants were discarded.

This produced seventy English–Chinese translation

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	List 1		List 2		List 3		List 4	
C–E translation	法律	law	方法	method	艺术	art	死亡	death
	law		*method*		*art*		*death*	
control	日子	method	错误	law	日子	death	错误	art
	day		*error*		*day*		*error*	
E–C translation	art	艺术	death	死亡	law	法律	method	方法
control	world	死亡	idea	艺术	world	方法	idea	法律

Figure 1. Construction of presentation lists and examples of Chinese–English translation pairs used in Experiment 1.

pairs each of whose members is a unique translation of the other, as judged by the six informants. The English word *method*, for example, was translated into *fangfa* by all three informants and the other three informants all translated *fangfa* into *method.* Sixty-four such pairs were chosen to serve as stimuli. The mean frequency for the English words was 191 occurrences per million (Kucera and Francis, 1967), and the mean frequency for the Chinese words 157 occurrences per million (Beijing Language Institute, 1986).

In addition, 32 English abstract nouns and 32 Chinese abstract nouns served as control primes. Their mean frequency was 175 and 140 per million respectively. Thirty-two Chinese and 32 English nonwords were also included. The Chinese nonwords were generated by combining two characters such that the combination did not form a word or make sense. The English nonwords, all orthographically legal, were generated by replacing or interchanging one or two letters in real words. (See Appendix A for the stimuli).

Four completely counterbalanced lists of items were constructed such that each translation pair appeared in both L1–L2 and L2–L1 priming directions and each target appeared only once in a presentation list. A target word that was used in the translation condition on one list was used in the unrelated condition on the other. (See Figure 1 for translation examples and the construction of the presentation lists.) Each list had 16 Chinese–English translation pairs, 16 Chinese–English unrelated pairs, 32 Chinese–English nonword pairs, in one block, and 16 English–Chinese translation pairs, 16 English–Chinese unrelated pairs, and 32 English–Chinese nonword pairs the other block. (Note that like word pairs, nonword targets in the nonword pairs were preceded by word primes from the other language.)

The experiment involved a 2 x 2 x 2 design with prime-target relation (translation, unrelated), priming direction (L1–L2, L2–L1) and target lexicality (word, nonword) as within-participant factors.

Procedure. Each trial consisted of a mask for 500 ms, a prime word for 50 ms and a target word or nonword for 500 ms, all presented in the center of the screen, with each member of the triad immediately following the other. The forward mask for English primes consisted of ten hash marks (##########). For Chinese primes, it was a light gray rectangular pattern about the same size as the mask for English primes. The presentation of the items was blocked by target language, with half the participants doing the C–E pairs first and the other half doing the E–C pairs first. The items were presented in a different random order within each block for each participant. Participants were assigned to the presentation lists randomly. They were asked to decide whether the target was a word or not by pressing one of the two buttons, with the favored hand for the YES button and they were asked to respond as quickly and accurately as possible. Instructions and ten practice trials were given before the experimental trials. The instructions were given in Chinese. The experiment was self-paced. Upon the completion of the experiment, an exit interview was given in which the experimenter provided a brief explanation about the method and purpose of the experiment and also asked the participants about their language background and if they could notice or identify the prime.

The stimuli were presented on a computer-controlled monitor. The presentation of stimuli and the collection and analysis of data were carried out using the DMASTR software developed by Kenneth I. Forster and Jonathan C. Forster at the University of Arizona.

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Table 1. *Participants' reaction time (ms) and error rates (%, in parentheses) as a function of priming direction and prime–target relation in Experiment 1*

	L1–L2	L2–L1
Translation	710 (4.9)	568 (1.3)
Unrelated	755 (7.4)	581 (2.3)
Priming	45* (2.5)	13* (1.0)

* significant at .05 level.

Results and discussion

No participants who participated in this and the following experiments reported either noticing or being able to identify the prime in the exit interviews.[1]

The participants' RT and error rates are presented in Table 1. Only correct responses to the real word targets were analyzed. Any RTs more than two standard deviations above or below the same participant's mean RT were trimmed to the values at two standard deviations from the mean. Such trimmed data accounted for 4.4 per cent of all the data in Experiment 1. The same procedure was followed in all the experiments reported in this study and the trimmed data was less than 5 per cent in all experiments. For each participant, four mean RTs were calculated, one for each condition. A two-way ANOVA carried out on the correct RTs for word targets produced a significant main effect of target language in both a participant (F1) and an item (F2) analysis, $F_1(1,48) = 86.1$, $p < .05$; $F_2(1,120) = 411.1$, $p < .05$, and a significant main effect of prime-target relation, $F_1(1,48) = 46.7$, $p < .05$; $F_2(1,120) = 49.4$, $p < .05$. There was also a significant interaction of priming direction and prime-target relatedness in RT, $F_1(1,48) = 11.1$, $p < .05$; $F_2(1,120) = 18.1$, $p < .05$, suggesting that the magnitude of the priming effect in the L1–L2 direction (45 ms) was significantly greater than in the L2–L1 direction (13 ms). Separate analyses of RT for each priming direction indicated that the priming effect for L1–L2 pairs was significant, $F_1(1,48) = 45.23$, $p < .05$; $F_2(1,60) = 47.55$, $p < .05$, as was the 13 ms effect for L2–L1 pairs, $F_1(1,48) = 4.24$, $p < .05$; $F_2(1,60) = 5.81$, $p < .05$.

The analysis of the error rates produced a significant main effect of target language, $F_1(1,48) = 27.94$, $p < .05$; $F_2(1,120) = 28.81$, $p < .05$, a significant main effect of prime-target relation, $F_1(1,48) = 5.26$, $p < .05$; $F_2(1,120) = 5.02$, $p < .05$ but no interaction. The data from all the participants were also analyzed on the basis of which block of items was taken first. Twenty-four participants, six for each list, did the C–E block first and 28 participants, seven for each list, took the E–C block first. The analysis of the data from these two groups produced a similar pattern of results as the overall analysis. There was a priming effect of 47 ms and 44 ms in reaction time for the two groups in the L1–L2 direction, respectively. Both were significant by participant and item analyses (C–E block first: $F_1(1,20) = 41.47$, $p < .05$; $F_2(1,120) = 39.11$, $p < .05$. E–C block first: $F_1(1,24) = 16.95$, $p < .05$; $F_2(1,120) = 12.92$, $p < .05$). The facilitation in the L2–L1 direction was 9 ms and 16 ms for the two groups respectively. The former was significant by participant analysis only, $F_1(1,20) = 6.46$, $p < .05$; $F_2(1,120) = 2.46$, $p > .05$, and the latter only approached significance by item analysis, $F_1(1,24) = 2.59$, $p > .05$; $F_2(1,120) = 3.71$, $p = .058$.

The results indicate that participants took less time and made fewer errors when making lexical decisions about words in their first language, which is consistent with the results of many previous studies (e.g., Chen and Ng, 1989) and also confirms the participants' relative proficiency in the two languages. More importantly, it was found that the participants' performance on the L2 targets was facilitated when these targets were preceded by their L1 translation equivalents, compared with their RT on targets preceded by unrelated L1 words. L2 primes also produced significant priming on the L1 targets. However, the effect was greatly reduced.

It should be noted that this experiment provided a more valid and reliable test of the asymmetry in cross-language priming than previous studies for two reasons. First, in previous masked bilingual priming studies, the asymmetrical pattern of cross-language priming was obtained with different groups of participants tested in different priming directions. Given the potential variations among bilinguals in terms of such factors as L2 proficiency, it is important that priming asymmetry is tested and confirmed with a design in which priming direction is a within-participant variable. The present experiment provided such a test and confirmation.

Second, the two members of a translation pair may not always be unique translations of each other in both directions. For example, the English word *practice* may always be translated into *lianxi* in Chinese, but *lianxi* may be translated into *exercise* as well as *practice* in English. This constitutes a potential problem for interpreting an asymmetry in cross-

[1] After being told there was a prime word between the mask and the target, some curious participants asked or were invited to do part of the test again. This time, almost all of them noticed something flashing between the mask and the target and some of them were able to identify the language, but none of them was able to identify the prime word.

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language priming because the asymmetry may be a result of using translation pairs whose members may be unique translation equivalents in one direction but not the other. However, in previous cross-language studies, translation pairs were often assumed to be equally translatable in both directions and little information was given as to how the translation pairs used in an experiment were constructed. Given the way the translation pairs used in this experiment were constructed, ensuring that the two members of each translation pair are the unique translation equivalents of each other, the asymmetry observed is less likely to be a result of a particular set of translation pairs used.

The asymmetry obtained in this experiment, however, is slightly different from what was found in previous studies. While no significant L2–L1 priming was found in the earlier masked priming studies (Sánchez-Casas et al., 1992; Gollan et al., 1997), the priming effect in the present experiment was significant. However, the asymmetry was still present, in that L2–L1 priming was much weaker than L1–L2 priming. The presence of a small but significant L2–L1 priming effect raises the question about the status of L2–L1 priming. Is the L2–L1 priming effect obtained in the present experiment an effect just specific to this experiment, or is L2–L1 priming a consistent and reliable effect failed to show up in previous studies for methodological reasons? It is possible, for example, that L2–L1 priming will materialize only in an experiment with a certain level of power in its design. Consistent with this view, Gollan et al. (1997) did produce a priming effect of 9 ms for noncognates (Experiment 3), but as the experiment involved only half as many items as the present experiment, the effect was not significant. When the noncognate data were collapsed with the cognate data which also showed a 9 ms priming effect, the effect became significant (p. 1132).

To find out whether a consistent L2–L1 priming effect could be replicated, a different set of stimuli and different participants were tested with the same procedure as in Experiment 1. If L2–L1 priming is a consistent effect, we would expect a small but significant effect in Experiment 2 as well.

Experiment 2

Method

Participants. A group of 44 different Chinese–English bilingual speakers participated in the experiment. They were all graduate students studying at the University of Arizona at the time of testing. Like the subjects in the previous experiment, they all had a TOEFL score of 550 or higher when they were admitted to the university. None of them participated in the previous experiment. They were all paid for their participation.

Materials and design. A different set of 64 English-Chinese translation pairs were generated following the same procedure as described in Experiment 1. They had the same characteristics as the stimuli in Experiment 1 except that (i) they were all concrete nouns, and (ii) they were of lower frequency relative to the stimuli in Experiment 1, as many high-frequency concrete nouns in Chinese are single-character words. The mean frequency for the English words was 39 occurrences per million, and the mean frequency for the Chinese words was 34 per million. The stimuli also included 32 English and 32 Chinese prime words. They were all concrete nouns, with a mean frequency of 95 per million for English prime words and 16 per million for Chinese prime words (see Appendix B). The nonwords were from Experiment 1. The design of this experiment the same as in Experiment 1.

Procedure. The procedure was the same as in Experiment 1.

Results and discussion

The reaction time and error rate from Experiment 2 are presented in Table 2. The analysis of the data was performed in the same way as in Experiment 1. Analysis of participants' RT data produced a significant main effect of target language, $F_1(1, 40) = 49.47$, $p < .05$; $F_2(1,120) = 135.91$, $p < .05$, a significant main effect of prime–target relation, $F_1(1,40) = 38.51$, $p < .05$; $F_2(1,120) = 43.73$, $p < .05$, and a significant interaction of the two, $F_1(1, 40) = 22.03$, $p < .05$; $F_2(1,120) = 37.52$, $p < .05$. Separate analyses of the RT data in the two priming directions showed that the 68 ms difference between the translation and unrelated conditions in the L1–L2 direction was significant, $F_1(1,40) = 37.69$, $p < .05$; $F_2(1,60) = 64.49$, $p < .05$. The 3 ms difference in the L2–L1 direction was not significant, both Fs < 1.

The error data showed similar patterns. There was a significant main effect of target language, $F_1(1,40) = 27.91$, $p < .05$; $F_2(1,120) = 25.78$, $p < .05$, a significant main effect of prime–target relation, $F_1(1,40) = 10.62$, $p < .05$; $F_2(1,120) = 14.67$, $p < .05$, and a significant interaction of the two, $F_1(1,40) = 9.27$, $p < .05$; $F_2(1,120) = 12.58$, $p < .05$. Separate analyses of the error data in the two priming directions produced a significant priming effect in the L1–L2 direction, $F_1(1,40) = 12.29$, $p < .05$; $F_2(1,60) = 17.80$, $p < .05$, but the difference in the L2–L1 direction was not significant, both Fs < 1.

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Table 2. *Participants' reaction time (ms) and error rates (%, in parentheses) as a function of priming direction and prime–target relation in Experiment 2*

	L1–L2	L2–L1
Translation	746 (7.4)	632 (3.4)
Unrelated	814 (14.8)	635 (3.7)
Priming	68* (7.4)	3 (0.3)

* significant at .05 level.

The results of the present experiment replicated the robust priming effects in the L1–L2 direction that were found in previous studies. However, in contrast to Experiment 1, no significant L2–L1 priming was found. This suggests that L2–L1 priming is an elusive effect that cannot be readily replicated across experiments, and the absence of such an effect cannot be attributed to the power of the experiment. This view finds further support in the results from Gollan et al. (1997, Experiment 4) and Sánchez-Casas et al. (1992, Experiment 1). If the absence of L2–L1 priming had to do with the power of the experiment, we would at least expect a small but positive effect when a small number of stimuli and participants were involved. However, both of the above-mentioned studies produced negative, non-significant effects.

The next three experiments were intended to test the three processing accounts of asymmetrical cross-language priming discussed in the introduction. According to one of the processing accounts, less reliable priming effects from L2 to L1 may be attributed to the temporal conditions of the experiment. Specifically, extremely short exposure time (50 ms) plus immediate forward and backward masking might have prevented the L2 prime from being perceived and accessed by participants who were non-native speakers. Experiment 3 was designed to test this hypothesis.

Experiment 3

This experiment was intended to test whether L2–L1 priming could be observed when the L2 prime was given additional processing time. There are three differences between this experiment and the previous two in terms of method. First, since the purpose of the present experiment is to answer the question of why less reliable priming effects were observed from L2 to L1, only L2–L1 priming direction was tested. No L1–L2 items were included. Second, in order to increase the chance of the L2 primes being processed, a 50-ms blank interval was added between the prime and the target, which allows more processing time for the primes. Third, an L2–L2 within-language condition was added in order to test whether the L2 primes are accessed at all. If within-language repetition priming is found, we can reasonably conclude that the L2 primes were perceived and accessed.

Method

Participants. Sixteen different Chinese-English bilingual speakers from the same population as in Experiments 1 and 2 participated in this experiment. Three of them were employed in local companies in Tucson after completing their degrees in an American institution and the rest of them were all graduate students from mainland China studying at the University of Arizona at the time of testing. None of them participated in the previous experiments. They were paid for their participation.

Materials and design. The stimuli for the cross-language conditions came from the first experiment. The first half of the 64 English-Chinese translation pairs was used in this experiment. The mean frequency for the 32 English words was 178 occurrences per million and the mean frequency for their Chinese translations was 171 per million. The 16 unrelated prime words came from the set of 32 control prime words used in Experiment 1 and were matched for frequency with translation primes. The Chinese nonwords came from Experiment 1 too. The stimuli for the within-language conditions were generated specifically for this experiment. They included 32 English abstract nouns to be used both as primes and as targets for the repetition condition and as targets for the unrelated condition.[2] Another 16 English abstract nouns of similar frequencies served as control primes. The 32 English nonwords were also taken from Experiment 1.

In the case of English–English pairs, both the prime and target words were in lower case letters because many Chinese–English bilingual participants reported difficulty in efficiently recognizing words in upper-case letters. The use of lower case letters for both prime and target made it necessary to introduce some physical change between the prime and target. Otherwise, they would constitute a single stimulus. The changes in physical form were achieved by using different fonts; the prime and target also differed slightly in the size of the font and location on the screen. The prime was smaller than the target by

[2] Semantically related pairs for the L2–L2 condition were initially used, but repetition pairs were eventually chosen because semantically related pairs failed to produce any priming effects.

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approximately $\frac{1}{7}$ in height and $\frac{1}{5}$ in width and was presented one letter space to the left of the center of the screen. For the English nonword items, half were repeated and the other half were not. This manipulation of prime–target relation of nonword items allows one to determine whether any observed repetition effects for word targets comes from the sublexical level, such as visual similarity. If facilitation is substantially sublexical, we should be able to observe repetition effects for both words and nonwords. If we observe repetition effects only for words, we may interpret the facilitation as coming from the lexical level.

Two completely counterbalanced presentation lists were constructed, each containing 16 English–Chinese translation word pairs, 16 English–Chinese unrelated word pairs, 32 English–Chinese nonword in the first block, and 16 English–English repeated word pairs, 16 English–English unrepeated and unrelated word pairs, 16 English–English repeated nonword and 16 English–English unrepeated nonword pair in the second block. Each target item appeared only once within a list.

This experiment followed a 2 x 2 x 2 design, with prime–target relation (translation/repeated, unrelated/unrepeated), type of priming (cross-language, within-language) and lexicality (word, nonword) as factors.

Procedure. The procedure was the same as in the first experiment, except that a 50-ms blank interval was added between the prime and the target. Thus, each trial consisted of a mask for 500 ms, a prime for 50 ms, a blank interval of 50 ms and then the target for 500 ms. The 50 ms was chosen as a result of a pretest in which several non-native speakers were tested to determine a maximum duration of the blank interval that could still keep the prime unavailable for conscious report. The presentation of items was blocked by target language. The English–Chinese trials were always presented first for both lists and for all participants, as no difference was found between the two groups that received different block orders in Experiment 1. The participants were randomly assigned to the two presentation lists.

Results and discussion

The results of Experiment 3 are presented in Table 3. Consistent with the previous experiments, a two-way ANOVA on participants' correct RTs produced a main effect of target language. The participants' RTs were significantly shorter in their first language (581 ms) than in the second language (739 ms), $F_1(1,14) = 34.55$, $p < .05$; $F_2(1,60) = 141.22$, $p < .05$. There was also a main effect of prime-target relation for word targets by both participant and item analysis. The items in the repetition/translation conditions were responded to faster than unrelated items by 38 ms and the difference was significant, $F_1(1,14) = 16.59$, $p < .05$; $F_2(1,60) = 20.81$, $p < .05$. At the same time, there was also a significant interaction between prime–target relation and type of priming, $F_1(1,14) = 19.65$, $p < .05$; $F_2(1,60) = 16.28$, $p < .05$, indicating that the priming effect comes from English–English word trials. Separate analyses of RTs were done for each priming type. The 4-ms priming for cross-language word trials failed to yield a significant difference, both Fs < 1. However, the 72-ms difference between the repeated and unrepeated conditions of English–English word items was highly significant, $F_1(1,14) = 20.58$, $p < .05$; $F_2(1,30) = 27.67$, $p < .05$. In contrast, no significant repetition effect was observed for English nonword items, both Fs < 1.

Table 3. *Participants' reaction time (ms) and error rates (%, in parentheses) as a function of priming direction, prime–target relation and target lexicality in Experiment 3*

	L2–L1	L2–L2	
	words	Words	Nonwords
Repetition	579 (2.0)	704 (7.0)	823 (13.7)
Unrelated	583 (3.2)	776 (9.3)	830 (15.6)
Priming	4 (1.2)	72* (2.3)	7 (1.9)

* significant at .05 level.

The analysis of the error rates produced only one significant difference, a significant main effect of target language $F_1(1,14) = 8.58$, $p < .05$; $F_2(1,60) = 14.75$, $p < .05$.

The robust priming effect observed in the English–English repetition condition suggests that under the temporal conditions of this experiment, the participants were able to access the L2 prime words in time to affect their decision on the L2 target. Similar L2–L2 repetition effects have also been found under the masked condition in Gollan et al. (1997). This facilitation does not come from the sublexical level since no comparable facilitation was found for nonwords.[3] In contrast to the within-language condition,

[3] It is assumed in this paper that within-language repetition effects obtained under the masked condition are lexical in nature. However, it has to be pointed out that whether repetition or form priming effects obtained under the masked condition are lexical or sublexical is a controversial issue in itself. See Forster (1992) and Masson (1991) for arguments and evidence regarding this issue.

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no cross-language priming was obtained. The presence of within-language repetition priming effects and the absence of cross-language priming effects under the same temporal conditions together suggest that the weak and inconsistent L2–L1 priming effects in the first two experiments cannot be attributed to participants' inability to access the L2 primes.

Experiment 4

The purpose of this experiment is to test whether different rates of access in L1 versus L2 contributed to the observed asymmetry in cross-language priming. As suggested by Gollan et al. (1997), if more time is needed to access an L2 word, then the processing of an L1 target may be well under way before the L2 prime is accessed in a masked priming experiment. This could be what happened in the first three experiments. There was a difference of about 150 ms in the participants' reaction time on L1 and L2 targets in these experiments. If this difference approximately reflects the difference in their lexical access rates in the two languages, an SOA of 50 ms (Experiments 1 and 2) or 100 ms (Experiment 3) was not long enough to allow the L2 prime to be processed before the L1 target. In Experiment 4, Chinese–English bilinguals were tested on L2–L1 translation pairs with a longer SOA to explore this possibility. In consideration of the above RT difference on L1 and L2 targets, an SOA of 250 ms was adopted in this experiment by inserting a backward mask of 150 ms between the blank interval and the target. If the lack of strong priming effects from L2 to L1 was due to the different speed of lexical access in the two languages, we should be able to observe L2–L1 priming effects comparable to L1–L2 priming after we increase the SOA enough to overcome the difference. If there is still no L2–L1 priming, different speed of access is not a likely explanation for the priming asymmetry.

Method

Participants. Eighteen Chinese–English bilingual speakers from the same population as that of previous experiments participated in this experiment. They were all graduate students from mainland China with a TOEFL score of 550 or higher when they were admitted to the University of Arizona. None of them participated in the previous experiments. They were paid for their participation.

Materials and design. Thirty-two translation pairs, 16 English unrelated primes and 32 Chinese nonwords, all from Experiment 3, were used in this experiment. Two counterbalanced presentation lists were constructed, each consisting of 16 English-Chinese translation pairs, 16 English–Chinese unrelated pairs, and 32 Chinese nonword pairs. Each translation pair appeared only once on a presentation list. A target word preceded by a translation prime on one list was preceded by an unrelated prime on the other and vice versa.

This experiment involved a 2 x 2 design with prime–target relation (translation, unrelated) and lexicality (word, nonword) as within-participant variables.

The procedure was the same as in Experiment 3 except that a backward mask consisting of ten hash marks (##########) was presented immediately after the blank interval and before the target. It appeared for 150 ms, thus increasing the SOA from 100 ms in Experiment 3 to 250 ms in the present experiment.

Results and discussion

As in Experiment 1, only correct responses to the word targets were analyzed. Any RTs two standard deviations above or below the same participant's mean RT were trimmed to the appropriate cutoff. The average RT from the eighteen participants was 534 ms for Chinese targets preceded by their English translation equivalents and 541 ms for Chinese targets preceded by unrelated English words. The average error rates for the two conditions were 2.3 per cent and 1.9 per cent respectively. The 7-ms difference in RT between the two conditions was not significant (both Fs < 1), neither was the difference in the error rate.

The failure to obtain L2–L1 priming when increasing the time available for processing of the prime suggests that differential rates of processing in the two languages are not responsible for the weak and inconsistent L2–L1 priming in the first three experiments and elsewhere.

A potential problem with the above interpretation of the results may arise with the inclusion of the backward mask intervening between the prime and target. While the backward mask may have the effect of increasing the SOA between the prime and target, it may actually have interfered in some way with the processing of the L2 prime, or with the priming effect itself. Since no L2–L2 conditions were included in this experiment, we cannot guarantee that the L2 primes were accessed.

However, Forster et al. (1987) obtained strong priming effects with an intervening word between the prime and target, as have Forster and Davis (1984), and so the presumption is that priming is not automatically canceled by an intervening stimulus. More

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importantly, in a series of experiments in which the same stimuli were used as here, but the task was switched from lexical decision to episodic recognition, the same procedure produced strong translation priming from L2 to L1 (Jiang and Forster, 1998). This suggests that the backward mask did not interfere with the processing of the L2 prime.

Experiment 5

The purpose of Experiment 5 is to find out whether a change in the general activation level of the bilingual's weaker language can produce a priming effect from L2 to L1. According to this hypothesis, the lack of strong and consistent L2–L1 priming effects may be a result of the lower level of activation of L2 primes which are available for processing. In order to increase this level, and hence to see whether this would create an L2 to L1 effect, the presentation of targets in this experiment was mixed in terms of language, that is, Chinese and English targets were presented in a single block. An English target might be followed immediately by a Chinese target and vice versa. This way, both of the languages had to be strongly activated to perform the task efficiently and this in turn might produce the L2–L1 effect.

Method

Participants. Eighteen Chinese–English bilinguals from the same population as in the previous experiments participated in the experiment. They were all graduate students from mainland China studying at the University of Arizona at the time of testing. They all had a TOEFL score of 550 or higher when they were admitted into the University. None of them participated in the previous experiments. They were paid for their participation.

Materials and design. The same stimuli used in Experiment 3 were used in this experiment. They included thirty-two English–Chinese translation pairs along with their unrelated primes, thirty-two English repeated pairs and their unrelated primes and thirty-two Chinese and thirty-two English nonwords. Two counterbalanced presentation lists were constructed, each consisting of sixteen English–Chinese translation pairs, sixteen English–Chinese unrelated pairs, sixteen English–English repeated pairs, sixteen English–English unrelated pairs, thirty-two Chinese nonword and thirty-two English nonword pairs.

This experiment involved a 2 x 2 x 2 design. The factors were priming type (between-language, within-language), prime–target relation (translation/repeated, unrelated), and lexicality (word, nonword).

The procedure was the same as in Experiment 3 with two exceptions. First, following the logic of Experiment 4, a backward mask of ten hash marks was inserted for 150 ms between the blank interval and the target to increase SOA. Second, items of different target languages were presented randomly in a single block with the intent to increase the activation level of participants' L2.

Table 4. *Participants' reaction time (ms) and error rates (%, in parentheses) as a function of priming direction, prime–target relation and target lexicality in Experiment 5*

	L2–L1	L2–L2	
	word	Word	Nonword
Repeated	627 (3.5)	697 (4.9)	804 (11.5)
Unrelated	625 (3.1)	751 (11.8)	797 (12.5)
Priming	−2 (0.4)	54* (6.9)	−7 (1.0)

* significant at .05 level.

Results and discussion

The results of Experiment 5 are presented in Table 4. Two separate ANOVAs were carried out on correct RTs and error rates, one for L2–L1 items, the other for L2–L2 items.

L2–L1 items. As can been seen in Table 4, the mixed list procedure did not produce priming with L2–L1 items. There was a 2-ms difference in the wrong direction. Neither the difference in RT nor the difference in error rate between the translation and unrelated conditions was significant.

L2–L2 items. The analysis of the RT data from the within-language items produced a main effect of prime–target relation, $F_1(1,16) = 8.92$, $p < .05$; $F_2(1,60) = 6.07$, $p < .05$, and a significant interaction between prime–target relation and lexicality, $F_1(1,16) = 6.04$, $p < .05$; $F_2(1,60) = 8.44$, $p < .05$, which indicates that repetition effects were limited to word items. Separate analyses of the word and nonword RT data from the within-language condition also showed that the 54-ms difference between repeated and nonrepeated word items is significant, $F_1(1,16) = 26.90$, $p < .05$; $F_2(1,30) = 11.97$, $p < .05$ while the 7-ms difference between repeated and nonrepeated nonword items is not (both Fs < 1). In addition, the participants made significantly fewer errors on repeated word pairs than unrepeated word pairs, $F_1(1,16) = 12.97$, $p < .05$; $F_2(1,30) = 6.52$, $p < .05$. The difference between error rates for repeated and unrepeated nonword pairs is not significant, both Fs < 1.

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Several points can be made on the basis of the above results. First, the within-language repetition effects again suggest that the English primes were capable of being processed under the conditions used in the earlier experiments. Absence of such repetition effects for nonword pairs indicates that the facilitation is lexical in nature. More importantly, encouraging participants to increase the general activation level of their L2 by presenting the Chinese and English targets in a single block did not lead to priming from L2 to L1.

General discussion

The major findings of the present study can be summarized as follows. First, with the primes being masked, and thus perceived by our participants without their conscious awareness, strong translation priming effects were found in the L1–L2 priming direction, but much reduced or no priming was found in the L2–L1 direction (Experiments 1 and 2). Second, no translation priming effects were found from L2 to L1 when the experimental conditions were varied in the following three ways: a blank interval of 50 ms was inserted between the prime and the target to allow more processing time for the prime (Experiment 3), the SOA between the prime and target was increased to 250 ms to delay the processing of the L1 target (Experiment 4), and the test items with L1 and L2 targets were presented in a single, mixed block to encourage the participants to increase the general level of activation of their weaker language (Experiment 5). These findings provide further evidence for the asymmetrical pattern of cross-language priming effects. They also suggest that the three processing-related accounts of asymmetrical cross-language priming discussed earlier cannot provide a satisfactory explanation for the asymmetry.

A methodological question may be raised as to whether the design of Experiments 3–5 had enough power to provide a genuine test for these processing explanations. One may notice that the number of participants and test items was reduced by approximately 50 per cent in Experiments 3–5, as compared with Experiments 1 and 2. It may be argued that if the same number of participants and items were used, these experiments might have produced significant L2–L1 priming. However, there are several reasons to suggest that the absence of L2–L1 priming in Experiments 3–5 cannot be attributed to a lack of statistical power in these experiments.

First, no significant L2–L1 priming was observed in Experiment 2, which involved a number of test items and participants comparable to those in Experiment 1. This suggests that increasing the number of test items and participants will not necessarily bring about a significant L2–L1 priming effect. Furthermore, L2 translation primes did not always produce a positive priming effect. Nonsignificant priming effects in the wrong direction were observed in both this study (Experiment 5) and previous studies (Gollan et al.,1997, Experiment 4; Sánchez-Casas et al., 1992, Experiment 1). One is unlikely to obtain a significant positive priming effect by increasing the power of the experiment under such circumstances.

Second, the data in Experiments 3 to 5 suggest that these experiments were powerful enough to produce a number of effects. In both Experiment 3 and Experiment 5, where an L2–L2 condition was included, a robust within-language priming effect was observed. Furthermore, a post hoc reanalysis of the data for the English targets in Experiment 5 produced a significant frequency effect. The English–English items in Experiment 5 were divided into two halves based on their target frequency. The high-frequency targets had a mean frequency of 282 occurrences per million and the low-frequency targets, 90 occurrences per million. The analysis showed that the higher-frequency items were responded to 44 ms faster (705 ms) than the lower-frequency targets (749 ms). The difference was significant by subject analysis, $F_1(1,16) = 13.07$, $p < .05$, and approached significance by item analysis, $F_2(1,30) = 3.19$, $p = .08$.

Finally, in a recent study that was carried out to investigate the episodic nature of L2–L1 connections, we tested a group of bilingual speakers with the same set of stimuli in two different tasks, one of which was lexical decision and the other episodic recognition. In the latter task, the subjects were first asked to remember a list of L1 words in the study phase. In the test phase, L1 words were presented to the subjects who were asked to decide if they had been on the study list. These L1 words were preceded by either their L2 translations or unrelated L2 words. The same masking procedure was adopted in both tasks. The numbers of test items and participants were comparable with those in Experiments 3–5. As in the present study, significant L1–L2 priming was found in lexical decision and no such effect was found in the L2–L1 direction. However, when the task was switched to episodic recognition, strong and consistent L2–L1 priming was found (Jiang and Forster, 1998). The findings from this study suggest that the lack of L2–L1 priming in Experiments 3–5 has little to do with the power of the experiments.

Another more general methodological issue can also be raised about cross-language priming under masked and nonmasked conditions. As was pointed out earlier, masked priming has become a favored

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Table 5. *Magnitudes of translation priming effects under masked and nonmasked condition: a summary of the published data*

	L1–L2	L2–L1
Masked		
De Groot & Nas (1991)	35, 40, 22	
Sanchez-Casas et al. (1992)		−8
Gollan et al. (1997)	36, 52	9, −3
Present study	45, 6	13, 3, 4, 7, −2
Nonmasked		
Chen & Ng (1989)*	150	165
Jin (1990)	150	36
De Groot & Nas (1991)	113	
Altarriba (1992)**	70, 76	17, 52
Keatley et al. (1994)	66	34

* Values estimated from a graph.

** Preference of language determined from background report and RT in the two languages.

research paradigm over the conventional nonmasked priming procedures, because the results obtained with the former may be less contaminated by strategic effects. The results from a number of cross-language priming studies carried out in recent years using these two paradigms seem to be consistent with such a view. One can find a clear pattern of differences when one compares the results of masked and nonmasked cross-language priming studies. Where very weak or null effects of cross-language priming were observed under masked conditions (L2–L1), significant priming effects were almost always obtained under nonmasked conditions. Where small but significant cross-language priming effects were clearly observed under masked conditions (L1–L2), nonmasked studies often produced considerably larger effects. a summary of translation priming data under masked and nonmasked conditions.

The finding of inflated priming effects under nonmasked conditions is consistent with the idea that non-automatic processes may be involved in nonmasked priming. The involvement of strategic effects in the nonmasked priming condition can also be seen in the finding that cross-language priming effects under nonmasked conditions disappeared when the proportion of related prime–target pairs decreased from large to small (Keatley et al., 1994), suggesting that participants' conscious awareness of the prime–target relation was critical for nonmasked priming effects to materialize.

A more theoretical issue related to this study is to what extent the findings of this study may help invalidate the processing explanations for the asymmetry in cross-language priming and substantiate the representational explanations. While the results from Experiments 3–5 suggest that none of the processing explanations examined provides a satisfactory account of the asymmetry, we are in no position to abandon the processing explanations entirely, because there may be other processing accounts that are not considered in this study. One such candidate is Green's inhibitory control model (Green, 1986, 1998). This model seems to be able to accommodate some research findings in bilingual language processing in terms of a processing, rather than a representational explanation. For example, it accounts for a translation asymmetry in terms of reactive inhibition, not in terms of strength or route of connections involved, as Kroll and Stewart's (1994) model does. That is, in forward (L1–L2) translation, to make sure the weaker L2 is chosen as the output language, or to adopt an L2 output schema in the terms of the model, the L1 system must be inhibited to a greater degree than the L2 system in backward (L2–L1) translation. In the latter case, the output language, L1, is the dominant language and thus, there is less of a need to inhibit L2 to produce L1. The greater inhibition applied to the input language, L1, in forward translation may lead to a longer translation latency in forward translation than backward translation.

However, the same mechanism of reactive inhibition doesn't seem to be able to apply to cross-language priming data. Under a nonmasked priming condition, if reactive inhibition determines the activation level of the prime word, one would expect an L1 prime to be more inhibited (to allow the L2 schema to work efficiently), thus producing less priming in the L1–L2 direction than in the reverse direction. This prediction contradicts the nonmasked priming findings summarized in Table 5. It is not clear in this model whether the same mechanism may apply to the masked priming paradigm where the prime is not consciously visible to the participants. If the selection of a schema is determined by a supervisory attentional system on a conscious basis, then reactive inhibition is likely to play a very limited role in masked cross-language priming and in the asymmetry obtained under those circumstances. As a processing-oriented model, the inhibitory control model may be eventually brought to bear on the asymmetry in masked translation priming, but at this point the connection between the two is speculative.

While the asymmetry in cross-language priming cannot easily be accounted for in terms of processing differences associated with L1 and L2, a representa-

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tion-oriented approach seems to be in a better position to explain the asymmetry. It may be argued that the asymmetry is a result of the way the two lexical systems are established and connected in the bilingual lexicon. Between the two lexical systems in a bilingual speaker, both the L1 itself and its connections with the rest of the mental representations may be better established than L2 and the asymmetry in translation priming may reflect such differences between L1 and L2.

This said, it has to be pointed out that there are questions to be answered within the representation-oriented approach as well. One such question, for example, is the locus of the asymmetrical priming. As discussed earlier, the two lexical systems may be linked directly at the lexical level and indirectly through the shared conceptual system. The locus of the asymmetrical priming will depend on one's view as to which route of connections, the indirect conceptual route or the direct lexical route, is involved in translation priming. Two different approaches have been adopted in the literature. According to the conceptual approach, cross-language priming is conceptual in nature and the effects originate from the shared conceptual system (Potter et al., 1984; Kroll, 1993; Kroll and Stewart, 1994; De Groot, 1993). Specifically, when the prime word is presented, it activates this shared conceptual node which in turn preactivates the target word when the target word is a translation equivalent of the prime, thus facilitating its recognition. The asymmetry in translation priming can be attributed to the different strengths of connections between the languages and the conceptual system.

However, a very different approach has also been adopted in the literature. It attributes cross-language priming to the spreading of activation along the direct lexical links between translation equivalents (De Groot and Nas, 1991; Keatley et al., 1994; Gollan et al., 1997). It has been argued by Keatley et al. (1994), for example, that translation equivalents are connected through one-to-one lexical links which are responsible for translation priming. According to this model, the L1 system not only has stronger and richer interconnections within L1, but also stronger and richer connections across systems than the L2 system. The asymmetrical priming effects can be attributed to the difference in the strength of connections across the two language memory systems. Stronger lexical connections from L1 to L2 produce stronger L1–L2 priming.

It is not the purpose of this paper to resolve the issue of whether cross-language priming is conceptually mediated or lexical in nature. However, it is an issue that must be resolved ultimately if one is to adopt a representational explanation for the asymmetry in cross-language priming.

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Appendix A

Stimuli used in Experiments 1, 3, 4 and 5

A. Translation pairs

rest	休息	function	功能	country	国家	direction	方向
effort	努力	question	问题	thought	思想	company	公司
center	中心	method	方法	product	产品	yesterday	昨天
condition	条件	law	法律	art	艺术	future	将来
education	教育	report	报告	death	死亡	spring	春天
balance	平衡	market	市场	winter	冬天	autumn	秋天
language	语言	purpose	目的	summer	夏天	member	成员
music	音乐	service	服务	English	英语	chemistry	化学
change	变化	industry	工业	physics	物理	animal	动物
energy	能量	result	结果	discussion	讨论	television	电视
speed	速度	ability	能力	time	时间	season	季节
reason	原因	record	记录	weight	重量	help	帮助
history	历史	importance	重要	support	支持	freedom	自由
science	科学	war	战争	enemy	敌人	century	世纪
structure	结构	control	控制	average	平均	news	新闻
success	成功	knowledge	知识	color	颜色	need	需要

B. Unrelated Chinese primes

爱情	安静	半夜	保证	长征	沉默	程度	出身
本质	代表	单位	党员	道路	斗争	独立	队伍
感觉	高度	革命	根本	工程	工夫	故事	管理
破坏	气象	情况	缺点	热量	生命	声音	时代

C. Unrelated English primes

life	today	standard	trouble	business	unit
meaning	guess	value	element	difference	activity
type	experience	situation	progress	system	idea
matter	appearance	degree	style	game	force
length	half	ending	plenty	journey	variety
court	event				

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Appendix B

Stimuli used in Experiment 2

A. Translation pairs

cup	杯子	railway	铁路	shirt	衬衫	house	房子
window	窗子	dictionary	字典	glove	手套	watermelon	西瓜
fox	狐狸	magazine	杂志	newspaper	报纸	hair	头发
swallow	燕子	ear	耳朵	grape	葡萄	trousers	裤子
soap	肥皂	egg	鸡蛋	chalk	粉笔	orange	桔子
shoe	鞋子	flag	旗帜	snail	蜗牛	scissors	剪刀
monkey	猴子	mirrow	镜子	eye	眼睛	ink	墨水
skirt	裙子	map	地图	ladder	梯子	mushroom	蘑菇
bread	面包	nose	鼻子	truck	卡车	toothbrush	牙刷
tea	茶叶	pencil	铅笔	towel	毛巾	sun	太阳
blackboard	黑板	bee	蜜蜂	basketball	篮球	cotton	棉花
beer	啤酒	basket	篮子	necklace	项链	textbook	课本
balloon	气球	box	盒子	tooth	牙齿	butterfly	蝴蝶
cake	蛋糕	banana	香蕉	rose	玫瑰	table	桌子
chair	椅子	envelope	信封	tiger	老虎	stamp	邮票
piano	钢琴	cigarette	香烟	tail	尾巴	apple	苹果

B. Unrelated Chinese primes

砖头	飞机	大炮	楼梯	名片	吊车	柜台	灯泡
面粉	大米	皮夹	钱包	水壶	地毯	毛线	镜框
开关	心脏	电筒	对联	哨子	相机	冰棍	花生
鞭炮	脸盆	浴缸	炉子	药片	地板	发票	电影

C. Unrelated English primes

water	wall	sheep	ball	flower	star
peach	head	hand	bowl	tree	lion
elephant	computer	bird	telephone	foot	spoon
ring	floor	door	clock	watch	oven
sky	moon	mop	key	milk	wine
shelf	paper				

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