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Shared and separate meanings in the bilingual mental lexicon*

YANPING DONG
Guangdong University of Foreign Studies, China
SHICHUN GUI
Guangdong University of Foreign Studies, China
BRIAN MACWHINNEY
Department of Psychology, Carnegie Mellon University

This paper proposes a shared, distributed, asymmetrical model for the bilingual mental lexicon. To test the sharing of conceptual relations across translation equivalents, Experiment 1 used the classical priming paradigm with specific methodological innovations, trying to satisfy various constraints that had not been addressed in previous studies. The results suggest shared storage for the conceptual representations of the bilingual's two vocabularies and asymmetrical links between concepts and lexical names in the two languages. Experiment 2 examined the details of meaning separation by eliciting semantic closeness rankings for conceptual relations that are equivalent across language translations and those that are not. The results indicate that bilinguals tend to integrate conceptual differences between translation equivalents, but that they also display a "separatist" tendency to maintain the L1 conceptual system in the representation of L1 words and to adopt the L2 conceptual system in the representation of L2 words.

Shared and separate meanings in the bilingual mental lexicon

What is the conceptual organization of the bilingual mental lexicon? This issue has been under investigation for more than forty years, producing dozens of empirical studies. To account for the results of these experiments, five representational models have been proposed. These models provide different answers to two basic questions. First, do bilinguals use a single common store for the meanings of words in the two languages or do they have two separate stores? Second, if there is evidence for shared storage, do bilinguals access the meanings of L2 words in the same way as L1 words? Although there seems to be a consensus in the literature regarding these questions, the actual empirical demonstrations upon which this consensus rests suffer from certain methodological problems. In our first experiment, we introduced specific methodological innovations to the priming paradigm that helped address these concerns.

The third issue regards the mental representations of the cultural and dynamic aspects of words (Pavlenko, 2000). To address this issue, which has been largely ignored in the literature, we elicited semantic closeness rankings to provide a developmental view of language-specific differences in bilingual lexical memory. Results from these two experiments provide evidence for a shared (distributed) asymmetrical model for the bilingual mental lexicon.

Five models

THE SEPARATE STORAGE MODEL postulates two separate language-specific representational systems. Each of the words in a translation pair has its own conceptual representation. Using questionnaires, recall, or word association, some earlier studies found support for the separate storage model (e.g. Lambert, Ignatow and Krauthamer, 1968). However, recent studies, using semantic categorization, lexical decision, and Stroop tasks, have uncovered limitations in the separate storage model. For example, Jin (1990), testing Korean–English adult bilinguals, obtained a reliable cross-language priming effect for concrete but not abstract words, suggesting that concrete translation equivalents are represented in a single common store, whereas abstract ones are represented in separate language-specific stores. Similarly, de Groot and Nas (1991), testing Dutch–English bilinguals, obtained data suggesting that cognate translations share conceptual representations, but noncognate translations have separate conceptual representations. These effects of concreteness and cognate status are instances of a group of effects that we can call WORD-TYPE effects.

To account for word–type effects, de Groot proposed THE DISTRIBUTED MODEL (e.g. de Groot, Dannenburg and van Hell, 1994; de Groot, 1995; de Groot and Comijs, 1995; de Groot and Hoeks, 1995). In this account, some word types have relatively separate storage, whereas

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Address for correspondence
Yanping Dong, Center for Linguistics and Applied Linguistics, Guangdong University of Foreign Studies, Guangzhou, 510421, China
E-mail: *ypdong@mail.gdufs.edu.cn*

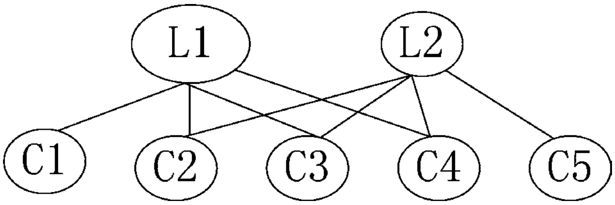

Figure 1. Distributed model of de Groot (1995). The symbols L1 and L2 stand for particular L1 and L2 words. The symbols C1 to C5 stand for an arbitrary set of five conceptual components, some of which are shared and some are not.

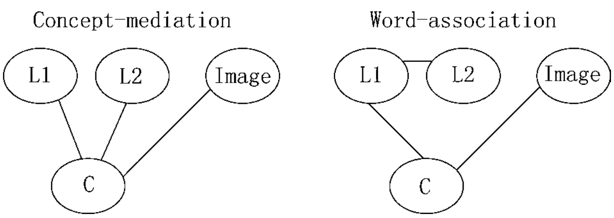

Figure 2. Concept mediation model and word association model (adopted from Kroll and Stewart, 1994).

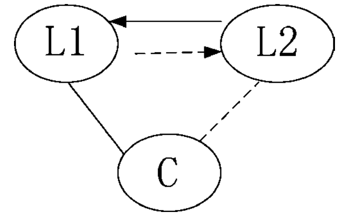

Figure 3. Revised hierarchical model (Kroll and Stewart, 1994).

others have relatively shared storage. The extent of the storage overlap is represented in terms of shared features in a distributed representation (see Figure 1). Concrete words and cognate words may share more conceptual nodes than abstract words and noncognate words.

The separate storage model and the distributed model stand in contrast with three other models that emphasize shared storage. A great deal of work has focused attention on the contrast between two specific shared store models (see Figure 2) that differ in the ways they explain how L2 words access meaning. The CONCEPT-MEDIATION MODEL (Potter, So, von Eckardt and Feldman, 1984) holds that there is a single language – neutral representation for each concept and that L2 words access this representation directly. Translation from one language to the other is mediated by access to this common store. In the WORD-ASSOCIATION MODEL (Potter et al., 1984) on the other hand, speakers access the meanings of L2 words through their L1 translation equivalents.

Potter et al. (1984) compared picture naming in L2 with translation of L1 words into L2 words, and found support for the concept-mediation model. In that study, translation and picture naming were equally fast for two groups of subjects of different proficiency levels. However, recent studies (e.g. Chen and Ho, 1986; Kroll and Curley, 1988; Chen and Leung, 1989; Abunuwara, 1992; de Groot and Hoeks, 1995) suggest that Potter et al.'s conclusion concerning concept mediation requires modification. For example, de Groot and Hoeks (1995) examined Dutch–English–French trilinguals with a higher level of L2 (English) proficiency than L3 (French) proficiency. The task was to translate L1 Dutch words into either L2 or L3. The critical experimental manipulation was word concreteness. The concept-mediation model would predict an effect of this manipulation, whereas the word-association model would not. The results showed a concreteness effect in L1-to-L2 (Dutch-to-English) translation thereby supporting the concept-mediation model. However, the absence of the concreteness effect in L1-to-L3 (Dutch-to-French) translation provided support for a word-association model in that comparison. These results point to a possible developmental shift for adult L2 learners: from reliance on word association in the very early period to concept mediation in a later, more fluent period.

A third type of shared storage model is THE REVISED HIERARCHICAL MODEL (Kroll and Stewart, 1994; Figure 3), which includes aspects of both the word-association and concept-mediation models, along with additional ideas about the asymmetrical relation between L1 and L2. In this model, the link between the shared concept and the L1 name is stronger than the link between the shared concept and the L2 name. At the lexical level, the connection from L2 to L1 is stronger than that from L1 to L2. The weak version of this model makes no asymmetrical assumptions on the lexical level (de Groot and Poot, 1997).

Evidence for or against the revised hierarchical model generally comes from studies of word translation. In Kroll and Stewart (1994), highly fluent Dutch–English bilingual subjects were asked to translate from one language to the other and to name words in either of the two languages. In one condition of the experiment, words were blocked by semantic category, and, in the other condition, they were randomly mixed. If translation relies on concept mediation, there will be interference in the blocked condition. The results showed that only forward translation (from L1 to L2) provided evidence of interference. This suggests that forward translation requires concept mediation, whereas backward translation is mainly based on lexical level links. To put it in another way, an L1 word is more likely to activate its conceptual representation, whereas an L2 word is more likely to activate its L1 corresponding equivalent. Kroll and Stewart took this feature as evidence for the revised hierarchical model.

A series of similar studies ensued, trying to retest or qualify the revised hierarchical model, but this work has not yet yielded a consistent conclusion. La Heij, Hooglander, Kerling and de Velden (1996), for example, found no basis for the lexical level translation route. Similarly, de Groot and Poot (1997) found backward translation slower than forward translation, although the asymmetrical model predicts the opposite. Moreover, comparison of word type variables, such as concreteness and imageability, showed that concept mediation was involved in both directions. However, looking at errors in backward translation and omissions in forward translation, de Groot and Poot found evidence for easier concept activation and word retrieval for L1 words, which is in accord with the weak version of the revised hierarchical model.

This review has shown that there is a general consensus that bilinguals rely on a single shared conceptual store. This view, which matches up well with people's intuitions, has been taken for granted in most current studies of bilingual lexical memory. However, it would be a mistake to imagine that this issue has been fully resolved and will never resurface. Evidence in favor of separate storage in bilinguals has received support from studies using methodologies, such as electrical stimulation, PET and fMRI (for a review see Paradis, 1995a). For example, Ojemann (1994) has shown that electrical stimulation of the cortex can distinguish between areas eliciting L1 responses and others eliciting L2 responses. According to Gomez-Tortosa et al. (1995), selective impairment in one language after surgery demonstrates that each language has a different anatomical representation within the perisylvian dominant area. Even some recent behavioral studies have presented evidence for at least partial separation between languages. For example, de Groot and Nas (1991) obtained data suggesting that cognate translations share conceptual representations, but that noncognate translations have separate conceptual representations. Together, these neurological and behavioral studies indicate that it would be dangerous to simply dismiss the notion of at least partial lexical separation without making a careful assessment of the detailed predictions of the alternative models.

Operation of the priming paradigm

To investigate bilingual lexical memory, researchers have come to rely increasingly on comparisons arising from the use of semantic priming. It is generally believed that semantically related words in the same language like *doctor* and *nurse* are stored together in the mind (Collins and Loftus 1975). As a result, one word of a semantically related pair will help activate the other in priming experiments, producing within-language priming effects. In the bilingual case, the litmus test for the presence of lexical sharing is the presence of cross-language semantic priming effects. The absence of priming effects supports the separate store view, whereas the presence of priming supports the shared store view. The diagnostic nature of this test provides experimenters with clear inferential power, since there will always be a clear outcome from every experiment. However, if the experiments that use this test have internal flaws, the resultant incorrect conclusions will appear deceptively convincing.

We have learned that priming is likely to trigger strategic allocation of attention (Kroll, 1993) to specific parts of one store or the other. When the semantic relation between all the related pairs in a priming experiment is quite regular, subjects may use this to speed up their responses (e.g. Neely, Keefe and Ross, 1989). Most researchers (e.g. de Groot and Nas, 1991; Fox, 1996) have employed MASKING to minimize such attentional priming. But Gollan, Forster and Frost (1997) made the point that the masked priming paradigm is relatively insensitive to semantic factors. Altarriba (1992) sought to reduce attentional priming due to list regularities by reducing RELATEDNESS PROPORTION and NONWORD RATIO (both to about 33%). The study of Schwanenflugel and Rey (1986) further showed that, at an *SOA* (stimulus-onset asynchrony) of 300 ms or less, there is insufficient time to allow for priming of a target through the corresponding translation equivalent in the other language. Hutchison, Neely and Johnson (2001) also suggested that strategic priming was not operating below 200 ms (no strategic priming at a 167-ms SOA in their experiment).

The presence of cross-language semantic priming has been taken as evidence for the shared view of the conceptual organization of the bilingual's two vocabularies. However, the utility of this diagnostic technique depends on the specific CHOICE OF SEMANTIC RELATIONS. Studies have used either primes that are close associates (like *doctor* as a prime for *nurse*) or primes that are members of the same category (like *furniture* as a prime for *desk*). But findings from Lupker (1984) and Kroll and Sholl (1992) indicate that "word associates may prime lexical level representations whereas category relations may prime conceptual level representations" (Kroll, 1993, p. 58). Although Kroll is talking more about the within-language than the cross-language situation, it is also true of the cross-language situation. For example, in the English–Chinese cross-language semantic priming pair *doctor* and 护士: *hu*(4)*shi*(4), *doctor* may activate *nurse*, which in turn may activate its Chinese equivalent 护士: *hu*(4)*shi*(4), all by the lexical level route with no concept involved. Since we wish to measure conceptual level representations, this means that we should avoid use of associative primes.

On the other hand, category membership appears to be a valid semantic relation for diagnosing conceptual connections. Unfortunately, Schwanenflugel and Rey (1986) showed that it was difficult to compose category membership primes that were matched for baseline reaction times (RT) and which also avoided reuse of primes. Their experiments used eight categories with 12 category members for each category selected from three degrees of category typicality (high, medium and low). *Hand*, *finger* and *hair*, for example, are all members of the category BODY PARTS and prime-target pairs such as *body–hand*, *body–finger* and *body–hair* were included as semantically-related pairs in the experiments. There were 12 pairs that all began with the prime *body* which was exposed visually to subjects for 300 ms. Each of the 12 pairs followed directly in sequence after the others, producing a list of 12 lexical decision items, each beginning with *body* as a prime. It is impossible to avoid attentional priming in this design.

To investigate conceptual level representations, we must ensure that the conceptual level is sufficiently activated. Otherwise, data collected may not reflect what it is supposed to reflect. De Groot and Nas (1991), for example, found cross-language associative priming for cognates (like *rose–roos*) but not for non-cognates (like *bird–vogel*) in the masking condition and suggested that cognates but not non-cognates shared conceptual representation. This suggestion is in contrast with a series of other studies which investigated two languages that have no cognates between them and found associative priming effects (with the same priming paradigm but with other ways instead of masking to fight against confounding factors) (e.g. Fox, 1996). We therefore suspect that, in de Groot and Nas's masking condition, the conceptual level was not sufficiently activated, and that activation remained primarily at the lexical level. This interpretation can explain the pattern of their results and is consistent with the observations of Gollan et al. (1997) that the masked priming paradigm is relatively insensitive to semantic factors.

Associative priming effects may arise from both lexical and conceptual levels. Within a single language, form priming (i.e. priming with prime-target pairs similar in form like *life–lift*) effects can only come from lexical level activation. If we want to argue that priming reflects conceptual activation, we need to demonstrate, at a minimum, that the level of priming we observe in a given experiment exceeds the level found for mere lexical form priming.

In short, to ensure a valid operation of the priming paradigm, we have to satisfy three conditions. First, attentional priming must be ruled out, preferably by techniques such as the use of an appropriate nonword ratio (about 33%), a low relatedness proportion (about 33%) and a proper SOA (lower than 300 ms). Second, appropriate semantic relations should be chosen, so that priming data from a certain specific prime-target relation measures the processes we believe it is measuring. Third, priming must be operationalized in such a way that associative priming is not smaller than form priming.

Research questions

Because previous studies using the priming paradigm to solve the separate-shared contradiction failed in one way or another to satisfy all the necessary conditions, further studies are warranted. The first goal here is to obtain stronger evidence regarding the notion of a shared conceptual store. The second goal is to clarify the possibly shifting relation between word association and concept mediation during the acquisition of bilingual competence. Although most studies emphasize the role of concept mediation, there is also evidence that low-proficiency subjects rely on word association (e.g. de Groot and Hoeks, 1995). Thus, it appears that learners begin with a system that is well-characterized by the revised hierarchical model with its reliance on direct lexical association, and then move on to a system that makes stronger use of concept mediation.

The third question requiring further investigation is the extent of meaning overlap in a partially separated store. For some words, it is reasonable to imagine that there is high meaning overlap between languages. For example, the concept *FOOT* is as important to the English word *kick* as to the Chinese equivalent 踢 *ti(1)*. However, for other words, there are specific linguistic and cultural meaning components that are not equivalent and should be taken into account (e.g. Pavlenko, 2000). The concept *SETTLEMENT*, for example, may be more prominent in the English word *colony* than in the Chinese equivalent 殖民地 zhi(2)min*(2)di(4)*, whereas the concept *EXPLOITATION* may be more prominent in the Chinese equivalent 殖民地 than in the English word *colony*.

In summary, there are three research questions for the present study: 1) Are the bilingual's two vocabularies shared at the conceptual level or are they stored separately? 2) If they are shared, do translation equivalents in the two languages access this shared concept in the same way? 3) If evidence for the shared view has been found, what are the organizational and developmental patterns for those meaning components that are not equivalent between a pair of translation equivalents?

Experiment 1

Experiment 1 addressed the first two questions. This experiment used a series of measures to satisfy constraints not met by previous studies. First, we used a 33% nonword ratio, a 33% relatedness proportion, and an SOA of 200 ms to rule out attentional priming. Second, we used semantic relations that satisfied more constraints than any previous studies. Third, we inserted a monitoring device in the experiment to ensure that activation reached the conceptual level and that the presence or absence of semantic priming effects indicated the true picture at the conceptual level.

Method

Subjects

A class of 17 third-year English majors (21–22 years old) in the Guangdong University of Foreign Studies participated in each of the four language conditions combined from the two languages of English and Chinese. They had learned English for six years in middle school and almost three years in the university. All of them had passed an English test of TEM-4 (Test for English Majors administered to second-year university students in China) three months before our experiment. They were paid for their participation.

Materials

As we wish to investigate the conceptual organization of the bilingual lexicon, we have to choose enough pairs of words that are semantically related, lend themselves easily to the construction of complex balancing conditions, and do not have high associative strength. We relied on Jackendoff's (1990) theory of conceptual structure to provide a systematic characterization of the conceptual relations that a verb may have with another word. These conceptual relations are common to translation equivalents, which is important in the cross-language semantic priming.

(1) The first group is formed by a verb and its conceptual primitives (e.g. *enter–IN*, *export–OUT*). For example, in the conceptual structure of *enter*, $[_{EVENT}$ GO($[_{THING}]_{i,}$ $[_{PATH}$ TO($[_{PLACE}$IN($[_{THING}]$ j)])])], both TO and IN are the conceptual primitives and are essential to the meaning of *enter*. The words of *enter* and *in* are thus conceptually related. However, as there is no universal vocabulary for conceptual primitives that works across all languages, the construction of targets for this group between languages like English and Chinese may be difficult.

(2) The second group is formed by a verb and its conceptual default values (e.g. *kick–FOOT*, *listen–EAR*). FOOT is the default value of *kick*, because it cannot be replaced by any other value. People cannot kick with their hands or eyes or anything else in the normal sense.

(3) The third group is formed by a verb and its preferred conceptual i values (e.g. *sail–SHIP*, *bark–DOG*). The "$[\,]_i$" position in the conceptual structure is generally reserved for the external argument, which may be an actor, or a patient/beneficiary, or a theme. The meaning of a word may prefer a certain specific value to be filled in this position. A typical example is *sail*: [GO ([*SHIP*]$_i$, [ON ([*WATER*])])].

(4) The fourth group is formed by a verb and its preferred conceptual j values (e.g. *taste–FOOD*, *drive–CAR*). Roughly speaking, the [] j position in the conceptual structure is reserved for objects which may be a patient/beneficiary, or a theme, or a source/goal/reference object.

(5) The fifth group is formed by a verb and its trunk values (e.g. *whisper–SPEAK*, *wail–CRY*). *Whisper*, for example, is a special kind of *speak* and the conceptual structure of *whisper* embraces that of *speak*.

(6) The sixth group is formed by a verb and its antonyms (e.g. *take–GIVE*, *love–HATE*). The conceptual structure of *take*, for example, is the same as that of *give* except that one of the most prominent features is changed into its opposite and they form a pair of antonyms. For a comparison, read both structures:

[CAUSE([ ]i, [GO ([ ]$_j$, [AWAY-FROM(POSSESSION)])])]

for *take*

[CAUSE([ ]i, [GO ([ ]$_j$, [TO ([IN(POSSESSION)])])])]

for *give*

Using this framework, we then collected the associative strength for each pair of the words in the above six groups of relations. Given a word of a related pair as the prime (e.g. *kick*), we wanted to know the chances that subjects would give the other word in the pair (e.g. *foot*) as a response. Two classes (24 individuals in each) of first-year English majors in the Guangdong University of Foreign Studies participated. One class used the English version of the materials and the other class used the Chinese version. Table 1 lists ASSOCIATION STRENGTHS (the number of the expected response divided by the total number of collected responses) of the words used in this study.

Although the associative strength for the group of word-antonyms is as large as that for any pair of word associates (e.g. around 50% in de Groot and Nas, 1991), we decided to keep them so that we would have a range of pairs with different associative strength. To connect with previous research, we included a group of repetition pairs. Including the control group, there were altogether eight groups of words for the experiment proper. To ensure that associative priming is not smaller than form priming, we added one group of similar-form pairs and another group of word associates. Including the control group, there were three groups of words for this monitoring part of the experiment. As we used the same control group for both parts of the experiment, there were altogether 10 groups of materials, including 8 groups in the experimental part,

Table 1. *Associative strength for each conceptual relation.*

Conceptual relations	Examples and associative strength: English		Chinese	
1. Word–primitive	grasp–with	4%	抓住–用	0
2. Word–default value	kick–foot	4%	踢–脚	6%
3. Word–preferred i value	sail–ship	8%	航行–轮船	4%
4. Word–preferred j value	taste–food	20%	品尝–食物	25%
5. Word–trunk value	whisper–speak	8%	耳语–说话	4%
6. Word–antonym	take–give	48%	拿走–给予	54%

Table 2. *Mean RT (ms), ER (%), SD and PE (priming effects) for monitoring materials.*

	Language condition: CC				EE			
Prime type	RT	ER	SD	PE	RT	ER	SD	PE
Associated pairs	330	0.65	69	76	401	0.65	97	40
Similar-form pairs	381	3.27	95	25	413	1.96	91	28
Unrelated pairs	406	2.61	97		441	1.31	91	

2 groups plus the shared group of controls in the monitoring part (Appendix A).

The third step was to collect baseline reaction time (RT) data for all the targets so that the baseline RTs for each of the 10 groups of targets in both languages would be as similar as possible. The data in Appendix A show that there were, in fact, no significant differences between any two groups within the same language or any two corresponding groups across languages in baseline RTs. Therefore, any RT differences to the targets when preceded by primes would be attributable to the prime-target relations instead of the targets themselves. Altogether, there were 360 pairs of stimuli, including 81 pairs of related items (Appendix A), 168 unrelated pairs with words as targets (only the 9 pairs from the control group are listed in Appendix A), and 91 pairs with non-word targets. The Relatedness Proportion and Nonword Ratio were both 33%.

Design and procedure

For the experiment proper, priming effects from six classes of conceptual relations and also from repeated pairs of words, with unrelated pairs as their control, were compared in all the within-language and cross-language conditions (i.e. English–Chinese; Chinese–English; English–English; Chinese–Chinese). The experiment used a 4 (language conditions: EC, CE, EE, CC) by 8 (prime types) factorial design. We set 200 ms as the SOA of the experiment in accordance with studies like Altarriba (1992) and Zhou, Marslen-Wilson, Taft and Shu (1999).

Experiment 1 was conducted in a computer room with multiple workstations. Four subjects were tested at the same time with one assigned to each language condition. Subjects did their work independently and we took measures so that no interference would come from the other subjects.

The procedure was quite similar to that in de Groot and Nas (1991)'s unmasking experiments. The instructions, presented to subjects on the screen, were in the language of the targets. In the instructions, subjects were told that pairs of letter strings would appear on the screen one after the other, that the first letter string of each pair would always be a word, but that the second could be either a word or a nonword. Subjects were then asked to determine both as accurately and as quickly as possible, whether the second letter string of each pair was or was not a word. In the case of a word, they were to press, with their left forefinger, the "YES" key on their left hand. In the case of a nonword, they were to press, with their right forefinger, the "NO" key on their right hand. Prior to every prime-target pair, a fixation stimulus (an asterisk) appeared on the screen for one second, slightly to the left of where the prime was to appear. Then there was a blank inter-stimulus interval (ISI) of 20 ms. The prime was presented in the middle of the screen for 160 ms, and following the prime offset there was a blank of 40 ms before the target appeared. The SOA was, therefore, 200 ms. The target remained on the screen until the subjects pressed "YES" or "NO". The experiment was controlled by custom-built software for response monitoring and stimulus ordering on a Windows machine with a CRT display (Zeng and Dong, 1998).

Results

Incorrect responses were excluded, as well as responses that took less than 120 ms or over 1200 ms (less than 0.5%). This trimming means that, for the present experiment, outliers 2.5 SD units above and below the means were excluded. Data for the monitoring part (form priming pairs and associative priming pairs) were then calculated separately from data for the experiment proper.

Results for the monitoring part

Monitoring materials were included in order to guarantee that associative priming was not smaller than form priming. Table 2 lists relevant RT data together with standard

Table 3. *Mean RT (ms), SD, ER (%) and PE (Priming Effects) for all language by prime type conditions (* indicates a significant priming effect).*

	Language conditions															
	EE				CE				EC				CC			
Prime types	RT	ER	SD	PE	RT	ER	SD	PE	RT	ER	SD	PE	RT	ER	SD	PE
PT 1: Verb–primitives	421	0	78	20	429	2.61	98	23	384	0	70	26	389	0.65	78	17
PT 2: Verb–default value	396	1.31	83	45*	395	1.31	90	57*	358	0.65	100	52*	347	1.96	72	59*
PT 3: Verb–preferred i value	409	1.31	95	32*	387	1.96	96	65*	362	0.65	131	48*	348	1.31	83	58*
PT 4: Verb–preferred j value	388	1.96	97	53*	386	0.65	86	66*	344	0	87	66*	344	1.31	87	62*
PT 5: Verb–trunk value	391	1.96	91	50*	368	0.65	94	84*	366	1.31	85	44*	356	1.96	90	50*
PT 6: Verb–antonyms	410	4.58	101	31*	405	1.96	125	47*	358	5.23	91	52*	360	5.23	79	46*
PT 7: Verb–repetition	378	1.96	68	63*	374	0.65	73	78*	364	2.61	80	46*	359	0.65	101	47*
PT 8: Unrelated words	441	1.31	91		452	3.27	125		410	0.65	75		406	2.61	97	

deviations (SD), error rates (ER) and priming effects (PE). Only two language conditions (CC and EE) were relevant, because the totally dissimilar nature of the writing systems of Chinese and English makes form priming impossible in the cross-language conditions.

Associative priming effects were clearly larger than form priming effects. LSD test (Least Significance Difference for with-subject multiple comparisons) showed that, in the CC condition, associative priming was significantly larger than form priming, and in the EE condition this difference was not significant. These results show that the current operationalization of the priming paradigm satisfies our third criterion for valid operation of the priming paradigm.

Results for the experiment proper

Table 3 lists the statistics for the experiment proper. The eight prime types are numbered throughout as PT1, PT2, PT3, PT4, PT5, PT6, PT7, and PT8.

A 4 (language conditions) by 8 (prime types) factorial analysis indicated that the interaction between prime types and languages was not significant ($F(21,512) = 0.483$, $p = 0.976$). The main effect of prime types was significant ($F(7,512) = 11.72$, $p < .001$) and the main effect of language conditions was also significant ($F(3,512) = 21.59$, $p < .001$). Multiple comparisons (Bonferroni with significance level at 0.05) indicated that both the EC and CC conditions were significantly different from the CE and EE conditions. That is, SUBJECTS RESPONDED TO FIRST LANGUAGE TARGETS (I.E. EC AND CC CONDITIONS) FASTER THAN TO SECOND LANGUAGE TARGETS (I.E. CE AND EE CONDITIONS), although the targets were selected so that their translation equivalents were not different in baseline lexical decision times (Appendix A).

The same multiple comparisons failed to find any significant difference either between CC and EC, or between EE and CE. These results indicate that the languages of the primes (i.e. whether English or Chinese) produced no effect on the lexical decisions of the same targets. Multiple comparisons (LSD with significance level at 0.05) for the eight prime types showed that in all the four language conditions priming effects were significant for the semantically related groups of PT2, PT3, PT4, PT5, PT6, PT7, and that there was no priming effect for PT1. To put it another way, FOR ANY SEMANTICALLY-RELATED PRIME TYPE, IF THERE WAS ANY SIGNIFICANT PRIMING EFFECT IN THE WITHIN-LANGUAGE CONDITIONS (CC AND EE), THERE WAS SIGNIFICANT PRIMING EFFECT IN THE CROSS-LANGUAGE CONDITIONS (EC AND CE).

The same LSD multiple comparisons also showed that there was no significant difference between any two of the six groups of prime types PT2-PT7. This finding indicates that, in the present operation of the priming paradigm, there was no significant difference between all the six different semantic relations, although they had quite different associative strengths (Table 1). This provides further support for our confidence that priming effects mainly came from conceptual level relations.

Discussion

The first important finding is that, whenever there were significant priming effects in the within-language conditions, there were also significant priming effects in the corresponding cross-language conditions. The within-language priming effects indicate that the semantic relations were close enough to show up in priming tasks. The corresponding cross-language priming effects indicate that THAT THERE WAS A SHARED CONCEPTUAL SYSTEM FOR THE TWO VOCABULARIES IN THE BILINGUAL'S MIND. If there had been two separate systems, there would not have been any corresponding cross-language priming effects.

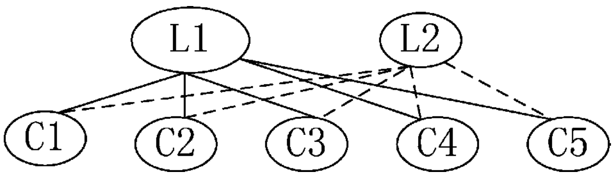

Figure 4. Asymmetry within a shared conceptual store.

The second finding is that subjects responded to L1 targets (i.e. EC and CC conditions) faster than to L2 targets (i.e. CE and EE conditions), although there was no difference in baseline RTs for targets across the languages. De Groot and Nas (1991, Table 2) reported similar findings. The most probable interpretation for this finding is the representational asymmetry. That is, links between the L1 word and the individual components of the concept in the distributed model (Figure 1) are stronger than the links between the L2 word and the conceptual components. Figure 4 illustrates how an asymmetry of activation on the lexical level arises within a shared conceptual store. Because we used equivalent conceptual relations in the experiment, the (arbitrary) five nodes in Figure 4 are all shared across the two languages.

Additional evidence for this representational asymmetry comes from the comparison of repetitive priming (PT7) in the CE and EC conditions. In this cross-language translational priming, the larger priming effect from the CE (L1–L2) condition than from the EC (L2–L1) condition (78 vs. 46) is consistent with many previous studies (for a review see Jiang, 1999). Excluding the possibility of three popular processing accounts for this priming asymmetry, Jiang (1999) inferred that the most probable interpretation is the representational asymmetry, as shown in Figure 4.

The third finding is that we obtained significant priming for all of the conceptual relations except for the PT1 relation between a verb and its primitives (i.e. "kick" priming "with"). The absence of priming here reflects the fact that the primitives, as independent words, are not associated with the primes. In Jackendoff's (1990) conceptual structure, primitives serve as the links between other more substantive values. Because of their status as links, they receive less specific activation from the primes. The other six relations between non-linking concepts all showed significant priming.

Thus far, our data suggested a shared conceptual system with asymmetrical links between the lexical representations of the two languages and their shared concepts. Evidence for asymmetry in the present study is not as direct as that provided in some other studies in the literature (Kroll and Stewart, 1994; Talamas, Kroll and Dufour, 1999). However, the evidence for the shared view provided here is direct and strong. The specific contribution lies primarily in the methodological innovations that satisfy a wider set of constraints not satisfied in previous studies. Because of the diagnostic nature of the priming paradigm, it is crucial that studies satisfy this full range of constraints.

Experiment 2

Experiment 2 addressed the third question: If evidence for the shared view has been found, what are the organizational and developmental patterns for those meaning components that are not equivalent across a translation pair? As it is hard to operationalize these language-specific differences in meaning using semantic priming, this experiment relied instead on a ranking task in which different groups of subjects were asked to rank the closeness of certain carefully selected words to a head word.

Method

Subjects

Four groups of subjects with different language backgrounds participated in the experiment. The first two groups consisted of two (randomly selected) classes of first-year English majors (18–19 years old) and two (randomly selected) classes of third-year English majors (21–22 years old) in the Guangdong University of Foreign Studies. The third-year students were much more advanced in English than the first-year students, because third-year students had two more years of experience as English majors and had passed TEM-4 tests (Test for English Majors in China). The third group of subjects (at the average age of 32) included monolingual adult Chinese who were working in the same university. The great majority of them had finished middle school, but had learned little English. The fourth group (at the average age of 30) consisted of native speakers of English who were either teaching English or studying Chinese in the same university. As some of them had acquired some knowledge about the Chinese culture and the Chinese language, they were not "pure" enough as native English-speaking controls. Therefore, if we fail to find any difference between Chinese monolinguals and native English-speaking subjects in the present study, it does not necessarily mean there is no difference between them. If, however, we do find some difference, it is likely that this difference is real.

Materials

There were altogether 16 groups of words (see Appendix B). In each group, there was a head word (e.g. *red*) and eight other words, seven of which were more or less related to the head word and one of which was not related in any way. Subjects were asked to rank the closeness of the eight words to the head word.

The seven related critical words for each group were selected from free associations of five Chinese learners of English and two native speakers of English. In the selection of the eight words in each group, we followed four principles:

(1) Only common and high frequency words were selected so that all the subjects could understand them without much effort. Any differences resulted from the ranking could then be attributed primarily to linguistic and cultural differences involving meaning components.
(2) We selected words that reflected both the shared core concepts of the head word in the two languages (e.g. *COLOR* to the head word *red*) and concepts that were not equivalent across the two languages. A pair of translation equivalents may be different in either their associative meaning, or their collocational meaning. The Chinese 新娘 (*xin(1)liang(2)* "bride", for example, is more closely associated with the Chinese word 红色 *hong(2)se(4)* "red" than the English equivalent *bride* with *red*, because brides wear red in China. The English word *jealousy*, on the other hand, is more closely associated with the English word *green* than its Chinese equivalent, since English speakers talk about turning *green with jealousy*. This principle in the selection of the materials ensured that there would be differences in the semantic rankings in the two languages.
(3) For each head word, the seven related words were selected so that the degrees of closeness to the head word could be distinguished. In fact, we first selected 20 groups of words and then discarded four groups that subjects found hard to rank.
(4) One or two words were selected that were not in any way related to the head word in each group. We used these words as monitors to see whether the subjects had been serious in doing the experiment. If they gave a high ranking to these words, they were considered not serious enough and their data were not entered into the statistical analysis. Among the 144 students that participated, 12 subjects gave two or more such monitors a ranking higher than 3 and their data did not enter into the following statistics.

Design and procedure

Omitting subjects whose data were later considered invalid, the matching of the subjects and the two language versions of materials is depicted in Table 4. For each of these six groups, a "mean ranking" of each of the eight words for each head word was calculated. The independent variables are the two language conditions and the subjects' three proficiency levels of English (first-year English majors, third-year English majors and native speakers of English). The dependent variable is the mean ranking of each of the eight words for each head word from each of the six combinations of subjects and languages.

Table 4. *Matching of subjects and language conditions of materials.*

Code	Subjects	Materials
CHN	23 monolingual Chinese knowing little English	Chinese
ENG	13 native speakers of English knowing (a) little Chinese	English
G1CHN	21 first-year English majors	Chinese
G1ENG	21 first-year English majors	English
G3CHN	28 third-year English majors	Chinese
G3ENG	26 third-year English majors	English

Materials were handed out as booklets with instructions in the same language of the test words (see Appendix B). We allowed the subjects to take these booklets home to finish them at their convenience.

Results

The mean ranking of each group of words for each of the six combinations of subjects and languages was calculated. Here are two examples for the group headed by "fruit" and for the group headed by "colony". The complete set of tables is available at <http://talkbank.org/norms/ranking>.

FRUIT	lamp	apple	water-melon	chest-nut	date	tomato	flower	bean
CHN	1.00	7.90	7.00	4.30	4.80	5.50	2.90	2.70
ENG	1.00	8.00	6.90	3.80	4.90	5.50	2.80	2.90
G1CHN	1.00	7.50	7.40	3.90	4.80	5.70	2.90	2.80
G1ENG	1.20	7.80	7.00	4.50	5.00	5.20	2.40	3.10
G3CHN	1.00	7.80	7.20	4.20	5.00	5.40	2.60	2.70
G3ENG	1.10	8.00	7.00	4.30	4.30	5.60	2.60	3.10

COLONY	land	exploit-ation	wealth	en-slave	bee	settle-ment	water	pioneer
CHN	6.60	6.80	4.10	6.50	1.20	4.00	2.50	4.30
ENG	6.80	4.40	4.00	3.30	1.90	7.20	2.50	5.90
G1CHN	6.20	6.80	4.70	6.70	1.20	3.80	2.40	4.30
G1ENG	6.50	6.60	3.30	6.80	1.50	4.80	1.90	4.60
G3CHN	6.20	6.50	4.30	6.60	1.20	4.10	2.10	5.00
G3ENG	6.80	6.00	4.50	6.10	1.30	5.40	2.00	3.80

For each of the 16 groups of words, correlations were then computed between all the six combinations of subjects and languages. The results indicate that the correlation between CHN and ENG may be very high (e.g. 0.98 for the group of words headed by the word *fruit*) or may be low (e.g. 0.48 for the group headed by *colony*), depending on the choice of the materials. However, the correlation

Table 5. *Overall average correlation matrix.*

CHN	1					
ENG	0.81	1				
G1CHN	0.96	0.83	1			
G1ENG	0.94	0.84	0.93	1		
G3CHN	0.95	0.82	0.95	0.93	1	
G3ENG	0.92	0.90	0.92	0.95	0.94	1
	CHN	ENG	G1CHN	G1ENG	G3CHN	G3ENG

Table 6. *Overall average dissimilarity matrix.*

CHN	0.00					
ENG	2.73	0.00				
G1CHN	1.11	2.96	0.00			
G1ENG	1.38	2.51	1.40	0.00		
G3CHN	1.19	2.86	1.13	1.44	0.00	
G3ENG	1.77	2.23	1.73	1.41	1.69	0.00
	CHN	ENG	G1CHN	G1ENG	G3CHN	G3ENG

between G1CHN and G1ENG and the correlation between G3CHN and G3ENG remained high across groups (more than 0.80). The average correlation matrix for all 16 cases in Table 5 shows the general tendency.

As we were more concerned about the dissimilarities rather than correlation's between different combinations of subjects and language conditions, we would need a dissimilarity matrix to compute cluster analysis, multidimensional scaling (MDS) and confirmatory factor analysis. CORRELATIONAL ANALYSIS was used to test how close any two groups of "mean rankings" were to each other; CLUSTER ANALYSIS was used to show which groups formed a cluster on what dissimilarity or similarity level; *MDS* was used to indicate how the different groups could be mapped on what dimensions; and CONFIRMATORY FACTOR ANALYSIS was used to test how well a presupposed model with latent factors could account for the collected data (see chapter 7 in Leary, 2001). We used the *STATISTICA* software package (see <http://www.statsoft.com>) for all these analyses.

For each of the 16 groups of words, we derived a dissimilarity matrix from their mean rankings by STATISTICA, displaying how the six combinations of subjects and languages were different from each other. All the 16 dissimilarity matrixes, when averaged, resulted in an overall average dissimilarity matrix (Table 6). Figure 5 is an attempt to illustrate the matrix by a dendrogram performed by cluster analysis. This figure makes it clear that different groups formed clusters on different dissimilarity levels. CHN, G1CHN and G3CHN were the three closest groups (dissimilarity ≈ 1.13), which also formed a cluster with G1ENG and G3ENG on the dissimilarity level of about 1.42. The most distant group was ENG, which could only be drawn into a cluster with the rest of the data at the dissimilarity level of about 2.23.

This result seems to suggest that the higher the bilingual subjects' English proficiency level, the more similar their rankings of the English version of materials (i.e. G1ENG, G3ENG) are to the ranking of native speakers of English (i.e. ENG), and the more dissimilar these rankings are to the ranking of monolingual Chinese (i.e. CHN*)*.

In order to further clarify these results, an MDS analysis was carried out on the dissimilarity matrix of Table 6. Figure 6 gives the two-dimensional scaling solution. In this figure, the results for CHN, G1CHN, and G3CHN

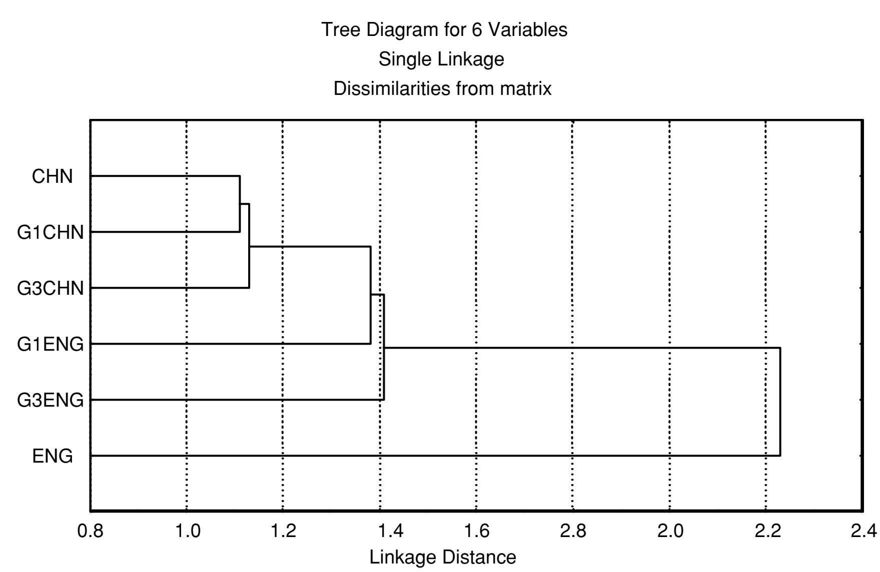

Figure 5. Cluster analysis of the six groups of subjects.

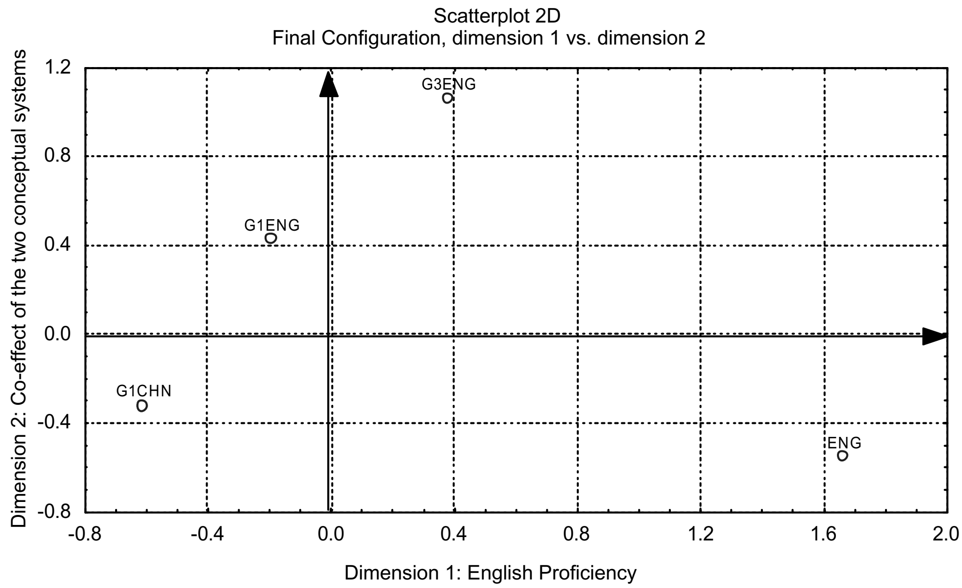

Figure 6. MDS analysis for the six groups of subjects.

were indistinguishable and all occupied a single point in the bottom left quadrant. From the relative positions of the six groups (CHN, ENG, G1CHN, G1ENG, G3CHN, G3ENG), the two dimensions can be identified as ENGLISH PROFICIENCY and CO-EFFECT OF THE TWO CONCEPTUAL SYSTEMS. One of the two systems is the conceptual system in the mind of Chinese monolinguals when interpreting Chinese. The other is the conceptual system in the mind of English monolinguals when interpreting English.

Figure 6 indicates that as the bilingual subjects of G3ENG were more proficient in English than those subjects of G1ENG, the position of G3ENG was closer to ENG and more distant from CHN than G1ENG on the horizontal dimension in the graph. In fact, the horizontal dimension values of G3ENG and ENG were positive and those for G1ENG and CHN were negative. The co-effect of the two conceptual systems (measured by the vertical dimension) was more evident in G3ENG and G1ENG (positive values) than for G3CHN and G1CHN (negative values). To put it simply, G3ENG and G1ENG were influenced by both conceptual systems.

G1CHN and G3CHN, however, were almost indistinguishable from CHN in the graph, which seems to mean that the English conceptual system did not produce any effect on G1CHN and G3CHN. The problem may lie in the extremely high correlation coefficients between all the six groups of subjects for some of the materials (like the case of the *fruit* group). A closer look at the correlation matrix for each group of materials shows that groups of materials headed respectively by *fruit*, *love*, *life*, *mother*, *bamboo*, *student*, *kick* displayed exceptionally high correlation coefficients.

Table 7. *Average dissimilarity matrix for culturally loaded materials.*

CHN	0.00					
ENG	12.49	0.00				
G1CHN	8.49	14.34	0.00			
G1ENG	8.38	13.56	7.44	0.00		
G3CHN	9.02	13.64	7.93	7.72	0.00	
G3ENG	10.54	12.20	10.02	9.97	8.76	0.00
	CHN	ENG	G1CHN	G1ENG	G3CHN	G3ENG

Correlation coefficients for the other 9 groups are not so uniformly high. Therefore, we computed a second analysis based on this set of 9 more distinguishable groups. Table 7 is the AVERAGE dissimilarity matrix for these 9 groups of materials (to be referred to as culturally loaded materials), on which MDS was performed (Figure 7). Unlike Figure 6, Figure 7 shows that G1CHN and G3CHN were distinguishable from CHN. Both G3CHN and G3ENG were influenced by the co-effect of the two conceptual systems (positive values in the vertical dimension). However, G1CHN and G1ENG were relatively more dominated by the Chinese conceptual system. It seems that as the bilinguals' L2 proficiency progressed, the influence of the L2 conceptual system became stronger, even in the representation of L1 words. The shorter distances between G1CHN and G1ENG, and between G3CHN and G3ENG (than that between CHN and ENG) found in cluster analysis was, therefore, due to a CONVERGENCE MOVEMENT. That is, when learning an L2, learners' understanding of the L2 words are inevitably influenced by the L1, and

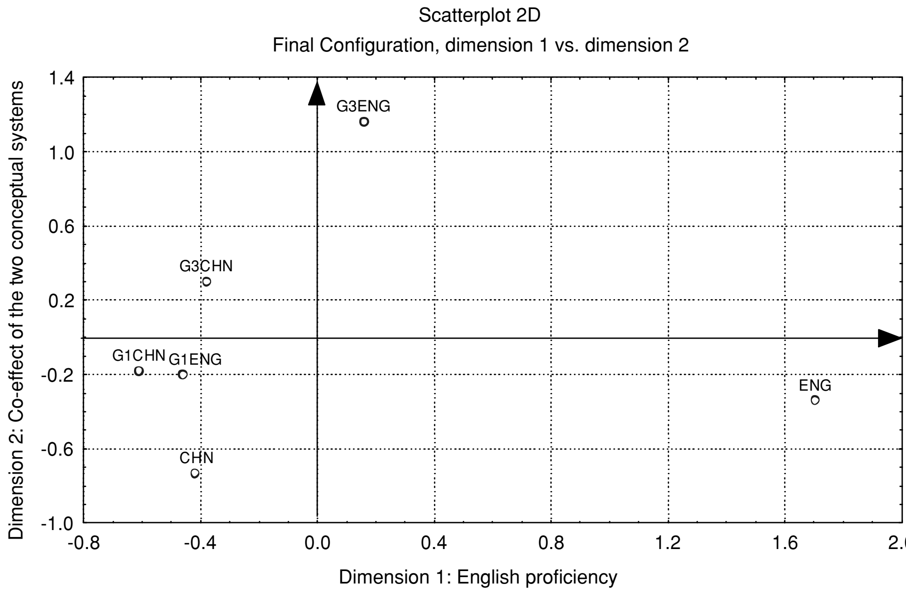

Figure 7. MDS analysis of the culturally loaded materials.

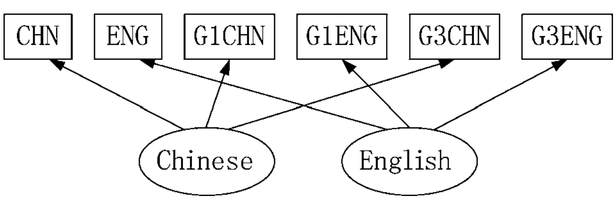

Figure 8. Path diagram for the six groups of subjects.

their L1 conceptual system is reciprocally influenced by the L2.

A confirmatory factor analysis was used to confirm the latent factors underlying these data. Based on the above cluster and MDS analyses, the most probable latent factors were CHINESE CONCEPTUAL SYSTEM and ENGLISH CONCEPTUAL SYSTEM, to be simplified as CHINESE and ENGLISH. Figure 8 is the corresponding path diagram.

On the basis of the path diagram, confirmatory factor analysis was run on the overall average correlation matrix of Table 5. Table 8 gives the T-statistics for each path. It shows that each path was significant. The underlying latent factor for CHN, G1CHN, and G3CHN was THE CHINESE CONCEPTUAL SYSTEM and the underlying latent factor for ENG, G1ENG and G3ENG was THE ENGLISH CONCEPTUAL SYSTEM. The two systems themselves are significantly correlated.

Discussion

The above analysis displays two tendencies for L2 learners, one displayed in the correlations, the cluster and MDS analyses, and the other displayed in the cluster analysis, the MDS analysis and the confirmatory factor analysis.

The first tendency is that CONCEPTUAL DIFFERENCES BETWEEN A PAIR OF TRANSLATION EQUIVALENTS TEND TO CONVERGE IN THE MIND OF L2 LEARNERS. THE MORE ADVANCED THE L2 IS, THE GREATER CO-EFFECTS THE TWO LANGUAGES PRODUCE ON THE CONCEPTUAL REPRESENTATIONS OF THE TWO LANGUAGES. This convergence does not mean that

Table 8. *T-statistics for each path in the confirmatory factor analysis.*

Path	Parameter estimate	Standard error	T-statistics	Probability level
(CHINESE) - 1 → [CHN]	0.978	0.005	202.930	0.000
(CHINESE) - 2 → [G1CHN]	0.977	0.005	199.169	0.000
(CHINESE) - 3 → [G3CHN]	0.974	0.005	182.640	0.000
(ENGLISH) - 4 → [ENG]	0.890	0.019	46.933	0.000
(ENGLISH) - 5 → [G1ENG]	0.970	0.006	152.126	0.000
(ENGLISH) - 6 → [G3ENG]	0.982	0.005	199.814	0.000
(ENGLISH) - 13 → [CHINESE]	0.971	0.007	137.292	0.000

at the very beginning of L2 learning there exists an L2 conceptual system in the bilinguals' mind. On the contrary, it means that at the very early stage of learning an L2 word, L2 learners are more dependent on their L1. Gradually the conceptual representation for the L2 word approaches the conceptual system of monolingual L2 speakers, and the conceptual representation for even the corresponding L1 word is influenced by the L2 conceptual system. CONVERGENCE, therefore, means that conceptual language differences become smaller in the mind of L2 learners. Evidence for this conclusion is distributed among correlation analysis (higher correlations for G3CHN–G3ENG and G1CHN–G1ENG than for CHN–ENG), cluster analysis (lower dissimilarity levels) and MDS (shorter distances).

The second tendency is A SEPARATIST TENDENCY, I.E. THE TENDENCY TO MAINTAIN THE L1 CONCEPTUAL SYSTEM IN THE REPRESENTATION OF THE L1 WORD AND TO ADOPT THE L2 CONCEPTUAL SYSTEM IN THE REPRESENTATION OF THE L2 WORD. Conceptual differences between translation equivalents do not disappear. Cluster analysis showed that CHN, G1CHN, G2CHN were the closest cluster. One dimension of MDS was the co-effect of the two conceptual systems, assuming the existence of the two systems. The result of confirmatory factor analysis indicated that when presented the Chinese version of materials, Chinese learners of English tended to keep their Chinese conceptual system; and when presented the English version, they tended to have a system closer to that for native speakers of English.

It seems that when one is learning an L2, one is inevitably influenced in some way by the conceptual system of the L2. However, generally speaking, L2 learners are able to maintain some of these conceptual differences in the two languages, to some extent at least. That is our reply to the discussions initiated by Pavlenko (2000) and to our third research question.

General discussion

Our hypothesis regarding the organization of the bilingual mental lexicon is that it is best characterized by the shared (distributed) asymmetrical model. Experiment 1 tested for the sharing of meanings using the priming paradigm. It showed that the conceptual representations of translation equivalents are shared and the links between L1 names and concepts are stronger than the links between L2 names and concepts. Experiment 2 tested for the details of meaning separation in translation equivalents. There are two major findings in Experiment 2. One is that the process of learning an L2 is a process of integrating the conceptual differences of the two languages. This process of convergence involves a DYNAMIC coordination of shared and separate conceptual representations. The other major finding in Experiment 2 is that L2 learners tend to

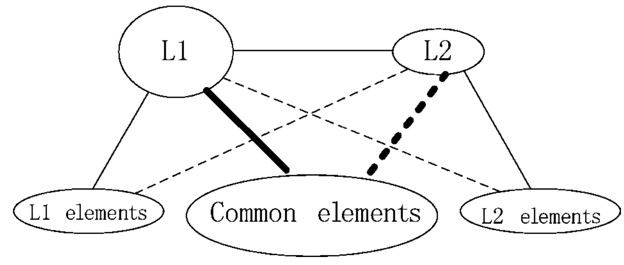

Figure 9. The shared (distributed) asymmetrical model.

preserve their L1 conceptual system in the representation of L1 words and to adopt the L2 conceptual system in the representation of L2 words. This SEPARATIST tendency, under the shared view in Experiment 1 and under the competing trend of convergence, implies an asymmetrical representation of those meaning components that are not equivalent across translation pairs. The assumptions of the shared (distributed) asymmetrical model can be summarized in a diagram (see Figure 9). This diagram emphasizes both the asymmetrical nature of L1 and L2 access to meanings and the extent to which meanings are both shared and partially separate for L1 and L2.

Three types of conceptual elements are distinguished in this figure. COMMON ELEMENTS are conceptual components that are equivalent across translations in the two languages (e.g. the concept *COLOR* in translation equivalents of *red* and 红色 *(hong(2)se(4))*. L1 ELEMENTS and L2 ELEMENTS are language and cultural specific conceptual components (e.g. the concept of *DANGER* being more salient in *red* than in 红色 *hong(2)se(4)* and *BRIDE* closer to 红色 *hong(2)se(4)* than to *red*). For the great majority of translation equivalents, the MAGNITUDE of their common conceptual elements is much greater than their language or cultural specific elements (and that is exactly why they are referred to as "equivalents"). This difference of magnitude is displayed in the figure by a larger circle of "common elements" at the conceptual level in Figure 9. Since "common elements" are usually the key concepts in a lexical word, we assume that the link between lexical names (i.e. "L1" or "L2" in Figure 9) and "common elements" is stronger than the link between lexical names and language-specific elements. This difference is represented by the thickness of the lines.

Experiment 1 indicates that the link between L1 lexical names and "common elements" is stronger than the link between L2 lexical names and "common elements". Experiment 2 indicates that, during the initial stages of L2 acquisition, both L1 specific elements and common elements are associated with the new L2 word. With the advancement of L2 proficiency, the initial link between "L2" and "L1 elements" gradually weakens as the link between "L2" and "L2 elements" strengthens. Experiment 2 also shows that the across-language link between "L1" and "L2 elements" becomes stronger, although it is never as strong as the within-language link between "L2" and "L2 elements".

For these language-specific conceptual elements, Figure 9 illustrates the representational state of ADVANCED bilinguals. That is, the within-language links between lexical names and language specific concepts (i.e. between "L1" and "L1 Elements" or "L2" and "L2 Elements") are stronger than the cross-language links (i.e. links between "L1" and "L2 Elements" or between "L2" and "L1 Elements"). If these cross-language links become weak enough and if the L2 link to "common elements" becomes strong enough, Figure 9 will be the representational state of ideal balanced bilinguals. The advancement of the L2 is accompanied by the weakening of the L2 to "L1 elements" link and the strengthening of the L2 to "L2 elements" and "common elements" links. This dynamic nature of the bilingual lexicon is depicted in Figure 9 by the relative strengths of the links. For simplicity's sake, we do not present different figures for different L2 proficiency stages.

The characterization of shared storage in our model is consistent with many recent findings from brain imaging of bilinguals (Kim, Relkin, Lee and Hirsch 1997): vocabulary is stored in almost the same area for both languages for both early and late bilinguals (around Area 22, roughly Wernicke's area). Syntactic skills, however, may be mapped onto partially separate neural areas. Adults who grow up bilingual use virtually the same areas for both languages (around Area 44, roughly Broca's area). Those who became bilingual as adults, however, show markedly separated brain areas for the two languages. These initial neuropsychological findings offer promise that we will eventually obtain detailed neurological evidence regarding the extent of shared conceptual storage in bilinguals. However, methodological limitations of current techniques, problems with the design of appropriate studies, and concerns with the interpretation of imaging results will have to be overcome before we can rely solidly on neuroimaging to provide a definitive picture of the extent of shared conceptual storage (Paradis, 1995b, 1996).

The shared (distributed) asymmetrical model diagrammed in Figure 9 is consistent with various aspects of each of the five models reviewed at the beginning of the paper: the distributed model, the revised hierarchical model, the separate storage model, the word-association model and the conceptual mediation model. The model combines features of the distributed model and the revised hierarchical model (the weak version). The distributed aspect of the present model can account for word-type effects that have often been used as evidence for separate storage.

The present model also incorporates features from the last two models: word-association and concept-mediation. The developmental shift between these two models has been used to represent the changes that occur as novice bilinguals become fluent bilinguals (e.g. Chen and Ho, 1986; Kroll and Curley, 1988; Chen and Leung, 1989; Abunuwara, 1992; de Groot and Hoeks, 1995). The model in Figure 9 can also portray this developmental shift. For L2 learners, L2 Name–Concept links are weaker than L1 Name–Concept links. Initially, they may be so weak that learners have to rely on lexical-level links from L2 to L1 to achieve activation of concepts (Kroll and Stewart, 1994). The developmental shift is, therefore, implied in the gradual strengthening of L2 Name–Concept links. As L2 develops, the direct links between L2 and concepts strengthen.

A comparison of the studies of La Heij et al. (1996) and Kroll and Stewart (1994) can illuminate aspects of this transition. Kroll and Stewart found that L2–L1 backward translation employed the direct L2–L1 lexical route without involving the conceptual level (i.e. evidence for word-association and part of their revised hierarchical model). But La Heij et al. found that L2–L1 backward translation also involved the conceptual level (i.e. evidence for concept-mediation). A closer look at both studies shows that the two studies used quite different test materials. La Heij et al. used high frequency words and salient semantic context (bright colors or concrete objects like the drawing of a dog). Kroll and Stewart used words that were much lower in frequency (e.g. "bayonet", "cauliflower" and "rocker") and their semantic context is much more implicit (i.e. semantic categorization like "weapon", "vegetables" and "furniture"). The differing results of these two studies arose from the fact that, the more familiar an L2 learner is with an L2 word, the higher the probability of a shift from word association to concept mediation.

The present model provides a dynamic view for bilingual lexical memory, which is often ignored in the literature. The process of learning a second language involves processes that lead to conceptual convergence between L1 and L2 and processes that maintain conceptual differences. Initially, L1 meanings are transferred wholesale to L2 forms (Kroll and Tokowicz, 2001). In addition, early learning tends to ignore L2 specific meanings (Ijaz, 1986). Our current study emphasizes both these effects and the reciprocal effects of L2 on L1. This two-way convergence has also been reported in recent studies of bilingual grammatical convergence (Bullock and Toribio, 2004). Convergence is seen as involving the collapsing of differences in areas of the linguistic systems where the two languages already had similar features; that is, a bilingual's two languages become uniform with respect to a property that was initially merely similar. Ideal balanced bilinguals should maintain the differences between two similar items across the two languages. But it seems that the human mind needs much harder work to maintain those fine differences between similar items.

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Appendix A. *Stimulus materials for Experiment 1*

1. Monitoring materials

1) Words with similar forms

lace/地貌 – face/面貌	call/文体 – ball/球体
plane/计算 – plan/计划	hear/中心 – heart/心脏
space/程度 – speed/速度	mail/结尾 – tail/尾巴
peach/和气 – peace/和平	lock/钟点 – clock/时钟
meddle/中午 – middle/中间	

For targets in English:
RT = 385 ms; ER = 1.85%; SD = 103
For targets in Chinese:
RT = 399 ms; ER = 2.22%; SD = 91

2) Word associates

father/父亲 – mother/母亲	summer/夏天 – winter/冬天
sister/姐妹– brother/兄弟	night/夜晚 – day/白天
girl/女孩 – boy/男孩	tree/树木 – leaf/树叶
clock/时针 – time/时间	crown/皇冠 – king/国王
tea/茶叶 – coffee/咖啡	

For targets in English:
RT = 386 ms; ER = 1.85%; SD = 96
For targets in Chinese:
RT = 384 ms; ER = 2.22%; SD = 108

3) Control group: unrelated words

suggest/提议 – season/季节	chance/机会 – shop/商店
pipe/管道 – action/行动	fry/油炸 – field/田地
learn/学习 – bread/面包	salt/盐 – head/头脑
movie/电影 – master/主人	jade/玉石 – husband/丈夫
history/历史 – street/街道	

For targets in English:
RT = 391 ms; ER = 3.09%; SD = 82
For targets in Chinese:
RT = 388 ms; ER = 1.67%; SD = 96

2. Materials for the experiment proper

1) Words and their primitive concepts

export/出口 – out/外面	dress/穿衣 – in/里面
sink/沉 – down/下面	rise/升起 – up/上面
grasp/抓住 – with/用	return/返回 – back/回来
wash/洗衣 – from/从	approach/接近 – toward/向着
reduce/减少 – cause/使得	

For targets in English:
RT = 400 ms; ER = 3.09%; SD = 110
For targets in Chinese:
RT = 392 ms; ER = 0.56%; SD = 96

2) Words and their default values

kick/踢 – foot/脚	look/看 – eye/眼睛
clap/鼓掌 – hand/手掌	listen/听 – ear/耳朵
buy/买 – money/金钱	hug/拥抱 – arm/手臂
walk/步行 – leg/腿	eat/吃 – mouth/嘴巴
bite/咬 – tooth/牙齿	

For targets in English:
RT = 377 ms; ER = 3.09%; SD = 103
For targets in Chinese:
RT = 379 ms; ER = 1.67%; SD = 88

3) Words and their preferred i values

shine/照耀 – sun/太阳	die/死亡 – life/生命
sail/航行 – ship/轮船	cure/治疗 – doctor/医生
boil/沸腾 – water/水	bark/犬吠 – dog/狗
bloom/开花 – flower/花朵	fly/飞翔 – bird/小鸟
hum/嗡叫 – bee/蜜蜂	

For targets in English:
RT = 392 ms ; ER = 0.69%; SD = 92
For targets in Chinese:
RT = 381 ms; ER = 3.33%; SD = 102

4) Words and their preferred j values

breathe/呼吸 – air/空气
drive/开车 – car/小车
drink/喝 – wine/啤酒
sweep/打扫 – floor/地板
import/进口 – goods/货物
taste/品尝 – food/食物
enter/进入 – room/房间
raise/抬高 – price/价格
comb/梳理 – hair/头发

For targets in English:
RT = 387 ms; ER = 1.24%; SD = 88
For targets in Chinese:
RT = 392 ms; ER = 3.33%; SD = 98

5) Words and their trunk values

creep/爬行 – go/走
slap/掌击 – hit/打
wail/号哭 – cry/哭泣
roll/滚动 – move/移动
whisper/耳语 – speak/说话
jog/慢跑 – run/跑步
shatter/击碎 – break/打破
detect/发现 – find/找到
yell/尖叫 – shout/喊叫

For targets in English:
RT = 391 ms; ER = 2.47%; SD = 128
For targets in Chinese:
RT = 389 ms; ER = 2.22%; SD = 86

6) Antonymic words

take/拿走 – give/给予
close/关闭 – open/打开
succeed/成功 – fail/失败
pull/拉 – push/推
lose/失去 – gain/得到
go/去 – come/来
ask/提问 – answer/回答
love/热爱 – hate/憎恨
forget/忘记 – remember/记得

For targets in English:
RT = 388 ms; ER = 0.62%; SD = 107
For targets in Chinese:
RT = 409 ms; ER = 2.78%; SD = 114

7) Repeated words

read/阅读 – read/阅读
write/书写 – write/书写
shut/关闭 – shut/关闭
regret/后悔 – regret/后悔
fill/填入 – fill填入
lay/放置 – lay放置
float/漂浮 – float/漂浮
laugh/大笑 – laugh大笑
punish/惩罚 – punish/惩罚

For targets in English:
RT = 388 ms; ER = 3.71%; SD = 81
For targets in Chinese:
RT = 409 ms; ER = 3.33%; SD = 102

8) Control group: unrelated words

The same as the control group for monitoring materials.

Appendix B. ***Materials presented as booklets for Experiment 2 (the English version)***

(The Chinese version, which is an exact translation of the English version, is omitted here.)

This is an experiment to test the closeness of word meanings. In the following example, a head word (like *cat*) is given together with eight other words, which are related to the head word in some way. You are required to fill in the eight boxes according to their closeness of meaning. So if you think *mouse* is the closest in meaning to *cat*, put its label *B* in the box under 8; and *D* under 7, if you think *dog* comes next.

cat *(A): pig* *(B): mouse* *(C): tiger* *(D): dog*
(E): lovely *(F): bite* *(G): fish* *(H): plant*

8	7	6	5	4	3	2	1
B	D	G	E	C	F	A	H

In the experiment there are 20 items similar to the above example. After each item is a set of eight words with their labels. Please fill in the eight boxes just the labels of words according to their closeness of meaning to the head word, like the example given above. You must make your decisions and match the eight labels with the eight degrees of closeness.

---

1) **desk** A): television B): chair C): bed D): book
E): furniture F): spoon G): social H): table

2) **car** A): wealth B): house C): river D): highway
E): truck F): alcohol G): driver H): forest

3) **love** A): head B): heart C): eye D): butterfly
E): tears F): rose G): insect H): hand

4) **tea** A): medicine B): art C): silk D): coffee
E): wall F): biscuit G): water H): salt

5) **religion**	A): superstition	B): love	C): ear	D): ignorance
	E): breakfast	F): song	G): God	H): computer
6) **fruit**	A): lamp	B): apple	C): watermelon	D): chestnut
	E): date	F): tomato	G): flower	H): bean
7) **life**	A): classroom	B): family	C): money	D): stone
	E): bedroom	F): kitchen	G): office	G): shirt
8) **red**	A): future	B): late	C): danger	D): bride
	E): moon	F): revolution	G): color	H): debt
9) **kick**	A): foot	B): hand	C): ball	D): football
	E): bucket	F): laugh	G): jump	H): water
10) **colony**	A): land	B): exploitation	C): wealth	D): enslave
	E): bee	F): settlement	G): water	H): pioneer
11) **mother**	A): king	B): needlework	C): son	D): father
	E): woman	F): daughter	G): love	H): book
12) **bread**	A): money	B): bun	C): knife	D): butter
	E): wheat	F): metal	G): vegetable	H): coffee
13) **crane**	A): bird	B): leaf	C): sky	D): neck
	E): longevity	F): pine	G): ant	H): carry
14) **bamboo**	A): flute	B): green	C): upright	D): rock
	E): plant	F): cool	G): ridiculous	H): rainy
15) **student**	A): plane	B): car	C): bicycle	D): young
	E): library	F): book	G): short-sighted	H): study
16) **green**	A): yellow	B): light	C): speak	D): silly
	E): young	F): tree	G): color	H): jealousy