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Are abstract and concrete concepts organized differently? Evidence from the blocked translation paradigm

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ABSTRACT
Using the blocked-translation paradigm with healthy participants, we examined Crutch and Warrington's hypothesis that concrete and abstract concepts are organized by distinct principles: concrete concepts by semantic similarities and abstract ones by associations. In three experiments we constructed two types of experimental blocking (similar vs. associative) for both abstract and concrete words. In Experiment 1, we first attempted to transfer previous findings observed in patients by Crutch and Warrington with semantic impairment to healthy participants. In Experiment 2 only noun stimuli were used, and we further included two semantically categorical conditions that differed by a degree of semantic similarity (close vs. distant). In Experiment 3, verbs were used exclusively. Consistent results were obtained across all three experiments: Significant interference effects were observed for abstract items that were blocked by an associative relationship and by a semantic similarity, and for concrete items that were blocked by a semantic similarity (category) but not when they were blocked by an association. The effect of similarity-close was greater than that of similarity-distant in the noun experiment. We argue that the results are in conflict with Crutch and Warrington's proposals, and can be accommodated by a theory of cooperating similarity and association connections for concrete and abstract concepts, with the association bearing more weight for abstract concepts.

Most cognitive theories about the conceptual[1] representation are developed on the basis of studies with concrete items and the empirical and theoretical generalizability to abstract items remains controversial. There is the widely documented phenomenon of the concreteness advantage effect, that is, in comparison with abstract words, concrete ones are processed faster, are more resistant to damage, are acquired earlier, and are easier to recall, other things being equal (e.g., Coltheart, Patterson, & Marshall, 1980; Kroll & Merves, 1986; Walker & Hulme, 1999; see Paivio, 1991, for a review). In contrast, the reverse concreteness effect has also been reported. Some patients suffering from brain damage exhibited selective impairment of concrete word processing while abstract word processing skills remained intact (e.g., Bachoud-Lévy & Dupoux, 2003; Breedin, Saffran,

& Coslett, 1994; Cipolotti & Warrington, 1995; Macoir, 2009; Marshall, Pring, Chiat, & Robson, 1996; Mattioli, 2008; Papagno, Capasso, & Miceli, 2009; Sirigu, Duhamel, & Poncet, 1991; Warrington, 1975, 1981; Warrington & Shallice, 1984; Yi, Moore, & Grossman, 2007). In addition, recent neuroimaging studies have found that abstract and concrete word processing led to the activation of distinct cortical regions, although the results are yet inconsistent (e.g., Noppeney & Price, 2004; Sabsevitz, Medler, Seidenberg, & Binder, 2005; Tolentino & Tokowicz, 2009; Zhang, Guo, Ding, & Wang, 2006).

These observations motivated a variety of theories about the conceptual representations of concrete and abstract words. One school assumes common mechanisms for all words/concepts, attributing the concrete/abstract differences to some quantitative differences, including the number of conceptual features (Plaut & Shallice, 1991, 1993) or the extent of contextual support (Schwanenflugel & Shoben, 1983; Schwanenflugel & Stowe, 1989). A related theory (Paivio, 1986) assumes richer coding types for concrete words (verbal and imagery) than abstract words (verbal). Such theories provide a ready account for the concreteness advantage effect but cannot explain the reverse concreteness effect. Theories assuming qualitative differences between the concrete and abstract concepts explain the double dissociation profiles more easily. The first such theory was proposed by Breedin et al. (1994), postulating that the two types of concepts rely on different types of conceptual features, with concrete concepts containing more perceptual features and abstract ones more functional features. This distinction is rooted in the acquisition process, which is different for the two types of concepts. Sensory experience is a key factor for concrete concepts, and language contexts, such as multiple sentence exposure, is essential for abstract concepts.

Besides potential differences in the representational contents of concrete and abstract concepts, a recent influential theory put forward by Crutch and Warrington (CW), which is the target hypothesis of the current article, has proposed fundamental differences between these two types of concepts in terms of organizational principles[2] (Crutch, 2006; Crutch, Connell, & Warrington, 2009; Crutch, Ridha, & Warrington, 2006; Crutch & Warrington, 2005, 2007). This theory assumes that abstract concepts are organized by semantic association and concrete ones by semantic similarity, with concepts belonging to the same semantic category (e.g., animals) being represented closely. Words with intermediate concreteness involve both types of organizational principles.

The target theory, which will be addressed as the organizational hypothesis, was primarily motivated by the behavioral patterns of patients whose cognitive impairments involved conceptual representation. In the first study of this research series, Crutch and Warrington (2005) evaluated the effects of various semantic contexts on the word comprehension performance of a patient (AZ) whose comprehension impairment originated from the semantic access process due to a refractory deficit. The study employed a spoken word to written word matching task, and the target word in each trial was presented with several other words that were either associatively related or semantically similar to the target. For concrete words, in comparison to unrelated conditions, AZ's matching performance was poorer in the semantically similar condition (categorically related, e.g., goose–crow–sparrow–pigeon), but was not influenced by associative blocking (e.g.,

farmer–cow–barn–soil). By contrast, her matching performance of abstract words was hindered in the associatively related condition (e.g., exercise–healthy–fitness–jogging), and not in the semantically similar condition (synonyms, e.g., boil–fry–bake–cook). The pattern that performances on concrete items were influenced by semantically similar (categorical) blocking and abstract items by associative blocking was subsequently replicated with another patient with a similar semantic refractory access deficit (Crutch et al., 2006), a patient with phonological-deep dyslexia (Crutch & Warrington, 2007), and a patient with global aphasia (Crutch & Warrington, 2010). Furthermore, Crutch (2006) carried out post hoc analyses of the reading errors of several deep dyslexia cases and observed that the semantic substitution errors for concrete word targets had a higher percentage of being categorically related to the target, and that those for abstract words were more likely to be associatively related. Finally, in a recent study the group has generalized the findings to healthy participants using a semantic odd one out task, where they observed facilitation effects for similarity-based connections with concrete words and for association-based connections with abstract words (Crutch et al., 2009). Consistent with this line of results for the associative results, Duñabeitia et al. (2009) found greater and earlier effects of associative concrete words for abstract than for concrete words using the visual world paradigm with eye movement measures.

However, there are reasons to be cautious about the generalizability of the results obtained by Crutch and colleagues (Crutch, 2006; Crutch et al., 2006; Crutch & Warrington, 2005, 2007). First, the main results in Crutch and Warrington (2005) were not replicated by a later study with the same paradigm and a patient with the same type of deficit as that of AZ. Hamilton and Coslett (2008) observed that their patient's matching performance for both concrete words and abstract words was significantly influenced by semantically similar blocking and by associative blocking. They speculated that Crutch et al.'s (2006) failure to observe the associative effect for concrete words and the semantic similarity effect for abstract words might be because their patient was already at floor for these items. Furthermore, a recent study (Papagno et al., 2009) reported a semantic dementia patient whose profile could not be explained by the organizational hypothesis. The patient showed the reverse-concreteness effect, that is, an advantage with abstract concepts, but she was not better with associative knowledge than semantically categorical knowledge. Therefore, it remains to be assessed to what extent CW's findings can be generalized to other subjects and other semantically related experimental situations.

There are additional caveats to consider in CW's series of studies. The main issue concerns the confounds of the abstract/concrete manipulation with grammatical class. First, in the main experiments in Crutch and Warrington (2005), the concrete words were predominantly nouns (98%) and the abstract words contained nouns (57%), verbs (36%), and adjectives (7%). Therefore, although the results might be explained by the concreteness dimension, it is equally possible that they were caused by the grammatical class difference. Indeed, there is a rich neuropsychological and neuroimaging literature suggesting that nouns and verbs might be processed differently on the semantic level, the morphosyntactic level and/or the lexical level (e.g., Bedney, Caramazza, Grossman, Pascual-Leone,

& Rebecca, 2008; Caramazza & Hillis, 1991; McCarthy & Warrington, 1985; Rapp & Caramazza, 1998; Shapiro, Shelton, & Caramazza, 2000; see Laiacona & Caramazza, 2004, for a review of patients showing noun/verb dissociations). The interpretation of these dissociations is still a matter of debate, with some theories assuming distinct representations for noun concepts and verb concepts (e.g., Bedney et al., 2008; Huttenlocher & Lui, 1979) and others assuming the same organizational principle for knowledge of all grammatical classes (e.g., Vigliocco, Vinson, Barber, Druks, & Cappa, in press; Vigliocco, Vinson, Lewis, & Garrett, 2004). The point here is simply that the results observed in Crutch & Warrington (2005, 2006) might be explained by a variable orthogonal to the concrete/abstract dimension.

The second issue is more theoretical in nature. For the semantically similar condition in their line of work, concrete items were from the same semantic category (e.g., lemon–banana) and abstract items were near-synonyms (e.g., clean–neat). Different instructions were given in the collection of semantic similarity ratings ("Concrete words, e.g., dog, cat, mouse, horse, sheep—all animals; abstract words, e.g., loud, noisy, blaring, rowdy, deafening—words with a very similar meaning: synonyms or near-synonyms," see Crutch & Warrington, 2007). It is theoretically possible that these two types of semantic relationship are not to be equated, as it has been previously suggested that once the categorical membership was controlled for, the semantic distance (measured by the amount of feature overlap) yields a different type of effect in tasks such as picture naming (Mahon, Costa, Peterson, Vargas, & Caramazza, 2007). Note that this issue can potentially also be applied to the associative variable, although it is less extreme. Associated concrete items may not be "connected" in the same way as associated abstract items.

Finally, a methodological note is that in the rating collections for similarity and association strength, an ~ -3 (extreme associative) ~ 0 (unrelated) $\sim +3$ (similarity—category/synonym) rank was used, forcing the participants to choose between associative or similar relationships (Crutch & Warrington, 2007). Such a rating system may artificially increase the difference between association and similarity, and cannot reflect truthfully cases where word sets were both associatively and semantically related.

In light of these considerations, the current study aims at evaluating the organizational hypothesis about the abstract and concrete conceptual organizations in healthy subjects, taking into consideration the theoretical and methodological issues outlined above. As Crutch (2006) suggested, their hypothesis about the conceptual structure should make similar predictions for any semantically mediated processes across different types of subjects. In doing so, we need a task that involves semantic processing and that can be employed with abstract items. The spoken word to written word matching task is not suitable for healthy subjects because it can be achieved with minimum semantic activation, and a task such as picture naming is not feasible because abstract items cannot be depicted. Crutch et al. (2009) adapted a semantic odd one out judgment task for healthy subjects and observed facilitation effects rather than the interference effects with patients, raising questions whether the same mechanisms apply for both cases. We therefore turned to a paradigm developed by Kroll and Stewart (1994)—the

blocked translation—where semantic relationship produced interference effects. In this paradigm, bilingual subjects translate words into another language, and words are arranged into experimental blocks in similar ways to those in Crutch and Warrington (2005). It has been observed that, at least in the first language (L1) to second language (L2) translation version of the paradigm, when the words in a set were from the same semantic category, the translation latencies were prolonged in comparison to those in unrelated sets (see also La Heij, Dirkz, & Kramer, 1990; La Heij, Hooglander, Kerling, & Van der Veldon, 1996). More recently, a common task called cyclic semantic blocking, in which a set of pictures were named multiple times in different types of blocks, also demonstrated a similar semantic interference effect (Belke, Meyer, & Damian, 2005; Damian, 2003; Damian & Als 2005; Damian et al., 2001; Maess, Friederici, Damian, Meyer, & Levelt, 2002).

Although the exact mechanisms of the translation task and the semantic effects in such blocked settings are still equivocal (e.g., Belke et al., 2005; Biegler, Crowther, & Martin, 2008; Damian, 2003; Damian & Als, 2005; Damian, Vigliocco, & Levelt, 2001; Jefferies & Lambon Ralph, 2006; Maess et al., 2002; Schnur, Schwartz, Brecher, & Hodgson, 2006), the involvement of the conceptual and word retrieval components in this task make it suitable to elucidate the characteristics of the conceptual structure. Specifically, in different blocks, we asked participants to translate into L2 words small sets of L1 words that were semantically similar (similarity block), associatively related (associative block), or unrelated (unrelated block). The types of words (concrete vs. abstract) were also manipulated. We follow the prevailing notion of semantic effects in blocked naming and speculate the following for the mechanisms underlying the potential interference effects. It is commonly assumed that lexical access in production, either when naming a picture or translating a foreign word, is a competitive process, such that the stronger other candidates are activated, the harder it is to select the target lexical node (e.g., Kroll & Stewart, 1994; Levelt, Roelofs, & Meyer, 1999; Roelofs, 1992; but see Mahon et al., 2007), which in our current case is the target L2 lexical node. In experimental blocks where words are closely related in their conceptual space (e.g., semantic category coordinates), activation spreads among the (L2) items more strongly than unrelated blocks, leading to greater competition for (L2) target selection.

Besides transferring CW's results to healthy subjects with the blocked-translation task (Experiment 1) using their stimuli (Crutch & Warrington, 2005, their experiments 4 and 5), we attempted to address the several methodological issues outlined above in their study. We separated the variable concreteness and grammatical class by carrying out separate experiments using only noun stimuli (Experiment 2) or verb stimuli (Experiment 3). In the noun experiment (Experiment 2), we further included additional conditions varying the degree of semantic similarity within the same categorical relationships to assess the effect of a comparable kind of semantic similarity in concrete and abstract items. Finally, throughout the three experiments, we carried out separate ratings for associative and similarity strength independently, and used an identical procedure and instructions to collect rating values (semantic similarity and association) for concrete and abstract words. If the organizational hypothesis were correct, we would predict in all experiments

interference effects for semantic similarity blocking for concrete words but not for abstract words, and associative blocking for abstract words but not for concrete words. The predictions from the alternative theories (e.g., Breedin et al., 1994), which attribute more weights to the association connections for abstract concepts than for concrete concepts, are less straightforward and will depend on the actual weights being given to various types of semantic features/connections for a particular concept.

EXPERIMENT 1

In this experiment we aimed at assessing whether the findings in Crutch and Warrington (2005) can be generalized to healthy subjects by adapting their stimuli and design to the blocked translation paradigm, incorporating four related experimental conditions (abstract–associative [AA], abstract–semantically similar [AS], concrete–associative [CA], concrete–semantically similar [CS]) and their corresponding unrelated conditions.

Method

Participants. Twenty-four students at Beijing Normal University participated in the experiment and received a small payment. All participants were native Mandarin speakers and had normal or corrected to normal vision. They had English language learning experience beyond 10 years and passed the College English Examination of Grade 6 with a score above 500 out of 710 ($M = 500$, $SD = 70$). The test assesses the English language skills comprehensively including the written and spoken comprehension, writing, grammar, and translation.

Design. Combining Experiments 4 and 5 in Crutch & Warrington (2005), our experiment had a design of 2 (Concreteness: Abstract vs. Concrete) × 2 (Semantic Relationship Type: Similar vs. Associative) × 2 (Relatedness: Related vs. Unrelated). The four related conditions were CS, AS, CA, and AA. For each related condition, an unrelated condition was constructed by regrouping items within the related condition. In CS, each array had four concrete words that were semantically similar, that is, they were within the same semantic category (e.g., goose–crow–sparrow–pigeon). In AS, the four words in each array were abstract words that are semantically similar, that is, they are synonyms or near synonyms (e.g., look–peak–glance–see). Each array in CA had four concrete words that are associatively related (e.g., farm–cow–tractor–barn). In AA case, the four abstract words in array were associatively related (e.g., exercise–healthy–fitness–jogging).

Materials. The stimuli from Crutch and Warrington (2005; Experiments 4 and 5) were adapted to Chinese by direct translation, and the task was to orally translate the Chinese words into English (see Appendix A). There were eight arrays in each of the eight conditions (except for the AS and AS-control, which had nine arrays). For each array, the 4 words were repeated four times to form a 16-word set in a pseudorandom order with no identical word on consecutive trials. Therefore, in each condition (block) there were 128 trials (except for the AS and AS-control:

144), leading to a total of 1056 trials to be completed by each participant. The order of the eight conditions (blocks) was counterbalanced across participants using an incomplete Latin square method. An additional array of four words was selected for practice and warm-up purposes.

To verify the validity of the concreteness and relationship type manipulation we collected corresponding ratings from eight participants who did not take part in the main experiments. They were required to complete three 7-point scale questionnaires. In the first questionnaire, the subject was asked to rate how concrete each experimental word was, with 7 being the most concrete (items that are tangible, can be directly perceived, e.g., banana) and 1 being the most abstract (items that cannot be directly perceived, e.g., ideas). In the other two questionnaires, all stimuli arrays of four Chinese words were presented individually to be rated about how semantically similar and how associative the words were in the array, respectively. For semantically similarity ratings, 7 denoted the most similar, such that the items share a great proportion of conceptual features (e.g., leader–boss–head–senior) and one denoted completely unrelated, where the items do not share almost any semantic features. For association ratings, seven indicated that the items co-occur extremely commonly in the real world and language contexts without sharing conceptual features (e.g., barbecue–charcoal–sauce–smoke) and 1 indicated that the items co-occur extremely rarely in real world and language contexts. Table 1 shows the results of ratings in related conditions. We further considered the usage of more objective measures for semantic relatedness such as the latent semantic analysis (LSA; Landauer & Dumais, 1997; http://lsa.colorado.edu). However, this measure is sensitive to the language context (see Vigliocco, Meteyard, Andrews, & Kousta, 2009), to which both semantic similarity and association may be relevant. The LSA values (highest possible value being 1) of our English targets were high for all related cells: the respective values for AA, AS, CA, and CS (CC) were 0.53, 0.48, 0.52, and 0.45 for Experiment 1; 0.42, 0.42, 0.43, and 0.51 (0.42) for Experiment 2; and 0.46, 0.49, 0.47, and 0.50 for Experiment 3. The values for unrelated arrays were all less than 0.2. Therefore, only our rating data are considered in subsequent analyses. Frequency counts for both English (Kucera & Francis, 1967) and Chinese words (Yu, Zhu, Wang, & Zhang, 1998) are also listed in Table 1, and there were no significant differences across four conditions: Chinese, $F\,(3, 128) = 0.76$; $p = .52$; English: $F\,(3, 128) = 1.76$; $p = .16$.

Procedure and apparatus. The DMDX program (Forster & Forster, 2003) was used to present the stimuli and to collect reaction times and error rates. For the practice block and the experimental blocks, each array had a familiarization phase preceding the actual experimental trials. In the familiarization phase, each written Chinese word in the array was visually presented on the computer screen, with its corresponding English word presented through the headphone. The visual word stayed on the screen until the participants pressed the space bar. The spoken English words were retrieved through the Smart Read software, which generates an audio file for the corresponding English word given a Chinese word input. In the actual experimental blocks, each trial began with a fixation point (+) at the center of the screen for 500 ms, followed by a written Chinese word. Participants were asked to translate the word into English as fast and accurately as possible.

Table 1. *Examples and characteristics of the stimuli in Experiments 1–3: Average rating results and average frequency of each condition*

Condition	Example	Concreteness	Similarity	Association	Chinese Word Freq.	English Word Freq.
		Experiment 1				
Abstract–associative	锻炼 健康 健美 跑步 (exercise healthy fitness jogging)	4.1	4.0 (1.4)	6.3 (1.5)	109	73
Abstract–similar	煮沸 加热 烹调 油炸 (boil heat cook fry)	4.0	5.4 (1.8)	4.6 (1.7)	117	64
Concrete–associative	烤炉 围裙 厨房 烫 (oven apron kitchen soup)	6.7	2.6 (1.4)	6.7 (1.8)	72	55
Concrete–similar	乌鸦 麻雀 鸽子 鹅 (goose crow sparrow pigeon)	6.9	5.1 (1.3)	4.7 (1.4)	12	12
		Experiment 2				
Abstract–associative	宗教 上帝 虔诚 教条 (religion god piety dogma)	3.5	2.3 (1.4)	6.2 (1.8)	61	88
Abstract–similar	焦虑 紧张 害怕 恐惧 (anxiety nerves fear scare)	3.1	6.0 (1.6)	3.9 (2.3)	77	96
Concrete–associative	农民 黄牛 土地 庄稼 (farmer cattle soil crops)	6.7	1.7 (1.5)	6.3 (2.0)	42	39
Concrete–similar–close	长椅 凳子 椅子 沙发 (bench stool chair sofa)	6.8	5.8 (1.7)	3.7 (1.8)	15	47
Concrete–similar–distant	老虎 蜻蜓 青蛙 蛇 (tiger dragonfly snake frog)	6.8	4.8 (1.3)	3.8 (1.4)	64	42

		Experiment 3				
Abstract–associative	犯罪 诉讼 辩护 (commit charge defend)	3.6	2.3 (1.1)	6.2 (1.6)	122	44
Abstract–similar	积累 聚集 增加 (accumulate gather add)	3.6	5.9 (1.1)	3.2 (2.1)	131	49
Concrete–associative	播种 施肥 收割 (sow fertilize harvest)	5.9	2.1 (1.1)	6.3 (2.1)	30	59
Concrete–similar	步行 闲逛 行进 (walk stroll march)	5.6	5.6 (1.1)	3.1 (1.7)	38	46

Note: The similarity and association ratings for corresponding unrelated conditions are listed in parentheses.

The word disappeared once the participant's response triggered the voice key or after a 3-s deadline. The intertrial interval was 1 s. After all trials in an array were completed, the participants initiated the next array by pressing the space bar. The whole experiment lasted for about 1.5 hr by each participant, in two sessions over 2 consecutive days.

Results and discussion

The following types of responses were considered as errors: (a) the responses that differed from those designated by the experimenter, (b) verbal dysfluencies such as stuttering and utterance repairs, (c) recording failures, and (d) reaction times (RTs) that were <200 and >2000 ms. The responses beyond 3 standard deviations of the subject mean were treated as outliers and were eliminated from data analyses along with the errors, which accounted for 4.6% (4.3% errors, 0.3% outliers) of all data points.

Given that in the first repetition the relationship among the words of an array may not be obviously formed (see Belke et al., 2005; Damian et al., 2001) and/or that a short-lived semantic facilitation at the beginning of each block may exist (Damian & Als, 2005; Wheeldon & Monsell, 1994), we analyzed responses collapsing the remaining three repetitions. The mean RTs and error rates of the last three repetitions are shown in Figure 1. The figure also displays RTs of each of the last three repetitions, showing that the effects are relatively stable across repetitions. Given that the mean error rates were rather low in the experiment, we only describe the results of error rates analyses if their patterns were in conflict with those of the RTs. Separate analyses of variance (ANOVAs) were carried out by subject (F_1, t_1) and by item (F_2, t_2). Our analyses included three variables: concreteness (concrete vs. abstract), relationship type (semantically similar vs. associative), and relatedness (related vs. unrelated). All variables were within-subject variables in the subject analyses. In the item analyses, concreteness and relationship type were between-item variables, and relatedness was a within-item variable.

Table 2 presents the complete ANOVA results. The main effects for all variables were significant both by subject and by item. The concrete words were translated significantly faster than abstract words. Words in the related blocks were translated slower than those in the unrelated blocks. Items in the semantically similar blocks were translated slower than those in the associative blocks.

Of particular interest here are the planned paired comparisons for each related condition against its corresponding unrelated condition. Significant interference effects were observed for the abstract associative condition: AA: t_1 (23) = 2.35, $p < .05$; t_2 (31) = 4.41, $p < .001$, the abstract semantically similar condition: AS: t_1 (23) = 3.10, $p < .01$; t_2 (35) = 5.23, $p < .001$, and the concrete semantically similar condition: CS: t_1 (23) = 3.42, $p < .01$; t_2 (31) = 3.48, $p < .01$. The concrete associative condition, however, did not yield any effect: CA: t_1 (23) = 0.40, $p = .70$; t_2 (31) = 0.94, $p = .36$.

To summarize, in comparison to corresponding controls, the translation latencies of concrete words were prolonged in the semantically similar (categorical) condition and not in the associative condition. For abstract words, however, both semantically similar blocking and associative blocking produced an interference effect.

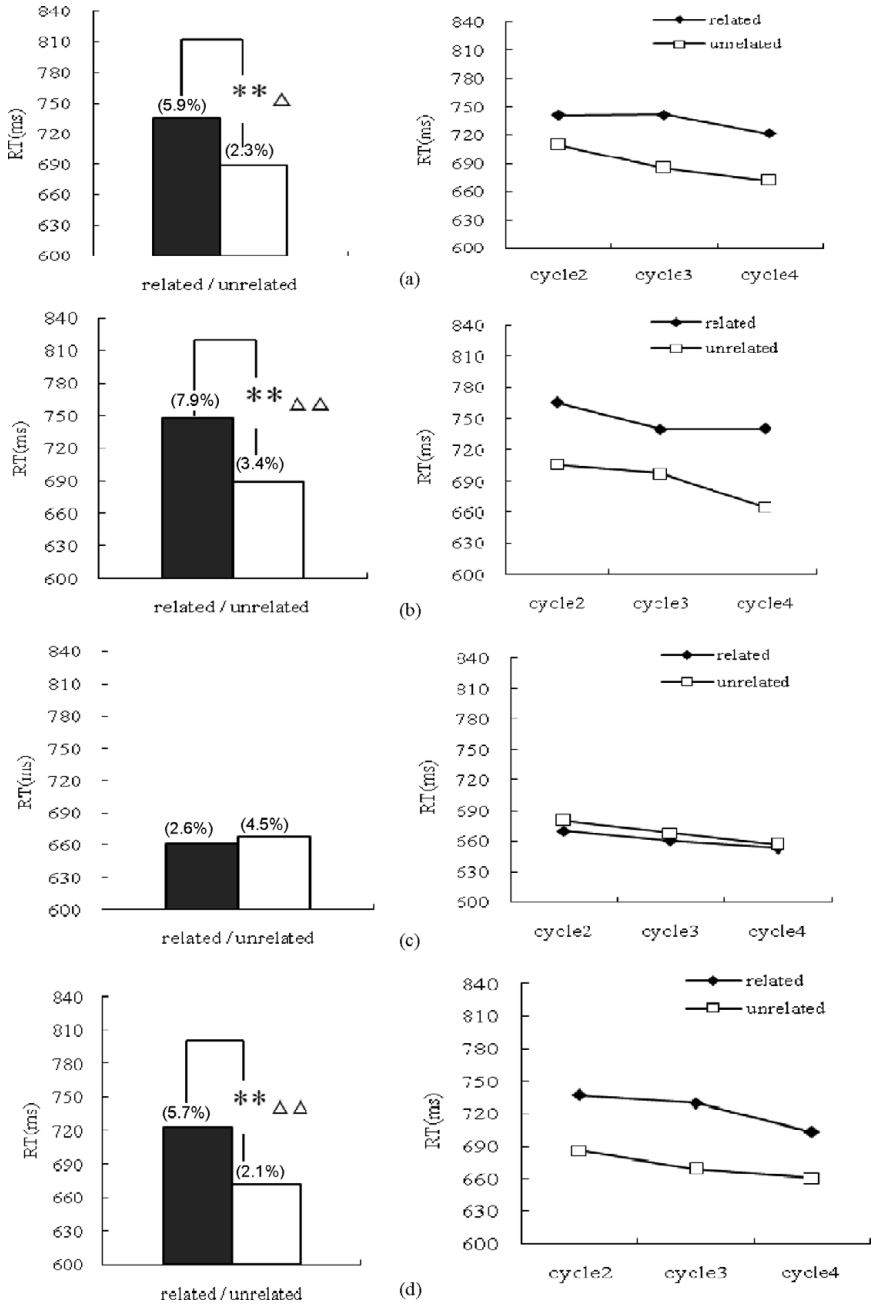

Figure 1. Translation latencies and error rates in Experiment 1 for the (a) abstract–associative condition, (b) abstract–semantically similar condition, (c) concrete–associative condition, and (d) concrete–semantically similar condition. Mean reaction times (RTs; ms) for various types of blocking condition and their corresponding controls are presented both collapsing (left) across the last three repetitions and (right) by each cycle. Statistical significance levels are shown in the bar graphs: triangular labels for subject analyses ($^{\Delta}p < .05$, $^{\Delta\Delta}p < .01$) and asterisks for item analyses ($^{**}p < .01$). The mean error rates of the last three cycles for each condition are in parentheses.

Table 2. *Analysis of variance results of the naming latencies in Experiments 1–3*

	Experiment 1		Experiment 2		Experiment 3	
	Subject ($df = 1, 23$)	Item ($df = 1, 128$)	Subject ($df = 1, 23$)	Item ($df = 1, 188$)	Subject ($df = 1, 23$)	Item ($df = 1, 140$)
Main Effects						
Con						
F	37.94	20.51	15.96	19.09	1.2	0.32
MSE	1487	3735	2552	4158	1278	6336
p	<.0001	<.0001	.001	<.0001	.28	.57
ReT						
F	15	7.07	93.75	32.66	74.74	16.09
MSE	1253	3735	765	4158	905	6336
p	.001	.008	<.0001	<.0001	<.0001	<.0001
Re						
F	25.15	43.53	13.89	115.7	100.77	40.22
MSE	2606	2111	5798	1331	918	3547
p	<.0001	<.0001	0.001	<.0001	<.0001	<.0001
Three-Way Interactions						
Con × ReT × Re						
F	2.05	4.03	0.12	0.22	0.07	0.32
MSE	2645	2111	1287	1331	10288	3547
p	.17	.047	.74	.64	.8	.57
Two-Way Interactions						
Con × ReT						
F	1.23	2.95	2.01	0.81	3.38	1.57
MSE	5888	3735	805	4158	1770	6336
p	.28	.088	.17	.37	.08	.21
Con × Re						
F	1.37	7.28	1.48	19.88	0.94	2.28
MSE	8188	2111	8889	1331	7386	3547
p	.25	.008	.24	<.0001	.34	.13
ReT × Re						
F	7.9	9.87	8.8	15.47	3.812	2.21
MSE	2008	2111	1284	1331	1438	3547
p	.01	.002	.007	<.0001	.06	.14

Note: Subject, subject analysis; Item, item analysis; Con, concreteness (concrete vs. abstract); ReT, relationship type (associative vs. similar); Re, relatedness (related vs. unrelated).

EXPERIMENT 2

In this experiment we explored the semantic representation of abstract and concrete words within the noun word class, using the same paradigm as the one in Experiment 1. We included a further contrast between close versus distant relationships for the semantically similar (categorical) condition for concrete items to add a semantic similarity manipulation more comparable between concrete and abstract items. The manipulation was done this way because it is impossible to have clear categorical relationships for abstract items and clear similar but not categorical relationship for concrete items.

Method

Participants. Twenty-four new participants from the same subject pool as in Experiment 1 took part in the current experiment.

Materials. Abstract nouns and concrete nouns were used in this experiment. Because of the prevalence of homonym in the language, we chose words that are more frequently used as nouns than as other grammatical class in Chinese (Chinese word frequency counts; Yu et al., 1998; see Table 1) and also collected the English surface word frequency (Kucera & Francis, 1967). The words were arranged in similar ways as in Experiment 1, except that we had two categorically related conditions for concrete words (the CS condition in Experiment 1): categorically related but semantically distant (CS-distant), categorically related and semantically close (CS-close). Each condition was consisted of 12 arrays of 4 words, so 48 words needed to be translated into English within a condition (see Appendix B). The construction of unrelated conditions and the arrangements of blocks across participants were identical to those of Experiment 1 and we balanced the degree of initial phoneme overlap for the L2 (English) responses in the related conditions and control conditions. The semantic similarity and association ratings from eight naïve participants are shown in Table 1. Note that to establish the reliability of the rating results, we have asked eight additional native participants to rate only the related word sets (either associative or similar) and the results paralleled those obtained with the full stimuli set (similarity values: AA = 2.0, AS = 6.2, CA = 1.6, CS = 5.9, CC = 2.5; association values: AA = 6.4, AS = 3.6, CA = 6.6, CS = 3.0, CC = 3.0). The rating results with the full stimuli set were presented and used in the analyses.

Procedure and apparatus. The same procedures and apparatus as the ones in Experiment 1 were used here, with the only exception that the intertrial intervals were 500 ms and there were 10 blocks in total. With the shortened trial interval the whole experiment lasted about 120 min and took three sessions to complete.

Results

The same data trimming and error coding method as Experiment 1 were used. In total 3.6% of data points, including 1.8% errors and 1.8% outliers were discarded

from analyses. The mean RTs of last three repetitions and RTs of the last three cycles are shown in Figure 2.

We first carried out statistical analyses based on AA, AS, CA, and CS-close, because the semantic similarity rating for CS-close was more comparable to that of CS in Experiment 1 than CS-distant. As seen in Table 2, the main effects of all variables were significant both by subject and by item. The concrete words were translated significantly faster than the abstract words. Words in the related blocks were translated slower than those in the unrelated blocks. Items in the semantically similar blocks were translated slower than those in the associative blocks.

More informative are the planned pairwise comparisons for each related conditions against their corresponding unrelated conditions. Significant interference effects were observed for the abstract associative condition: AA: t_1 (23) = 2.29, $p = .03$; t_2 (47) = 5.66, $p < .00$, the abstract semantically similar condition: AS: t_1 (23) = 3.29, $p = .003$; t_2 (47) = 8.20, $p < .001$, and the concrete semantically categorical condition with high semantic similarity: CS-close: t_1 (23) = 2.12, $p = .04$; t_2 (47) = 5.30, $p < .00$. The concrete associative condition, however, did not yield any effect: CA: t_1 (23) = 0.49, $p = .63$; t_2 (47) = 1.22, $p = .23$. The concrete semantic category with distant semantic similarity was significant by item but not by subject: CS-distant: t_1 (23) = 1.23, $p = .23$; t_2 (47) = 2.11, $p = .03$.

To elucidate the effects of semantic category and degree of similarity, we further conducted two-way ANOVA on CS-distant and CS-close and their corresponding unrelated conditions. The main effect of semantic category was significant, with items in categorically related blocks being translated slower than those in unrelated ones: F_1 (1, 23) = 6.05, $MSE = 3115$, $p = .02$; F_2 (1, 94) = 28.98, $MSE = 1193$, $p < .001$. The two-way interaction between relatedness (related vs. unrelated) and similarity distance (close vs. distant) was significant in the item analysis, but not in the subject analysis, suggesting a trend of greater interference effect in the semantically close blocks: F_1 (1, 23) = 1.40, $MSE = 3112$, $p = .25$; F_2 (1, 94) = 6.82, $MSE = 1193$, $p = .01$.

To summarize, we replicated all findings in Experiment 1 using noun stimuli. We observed that abstract noun translation performance was inhibited by both semantically similar blocking and associative blocking. For concrete nouns, again the semantically similar (category-close) condition produced a significant effect and the associative condition did not. It was further observed that there was indeed a trend of semantic distance effect that was not fully accounted for by categorical membership, as the effect of CS-close was greater than that of CS-distant (for consistent results, see Viglioccoet al., 2002).

EXPERIMENT 3

In Experiment 3, we explored the semantic representation of abstract and concrete words within the verb word class using a similar design to that of Experiment 1. The CS-close versus CS-distant contrast in Experiment 2 was not included in the current experiment because the categorical membership for verbs is not clear-cut, and the near-synonym was used as a semantically similar condition for both abstract and concrete verbs.

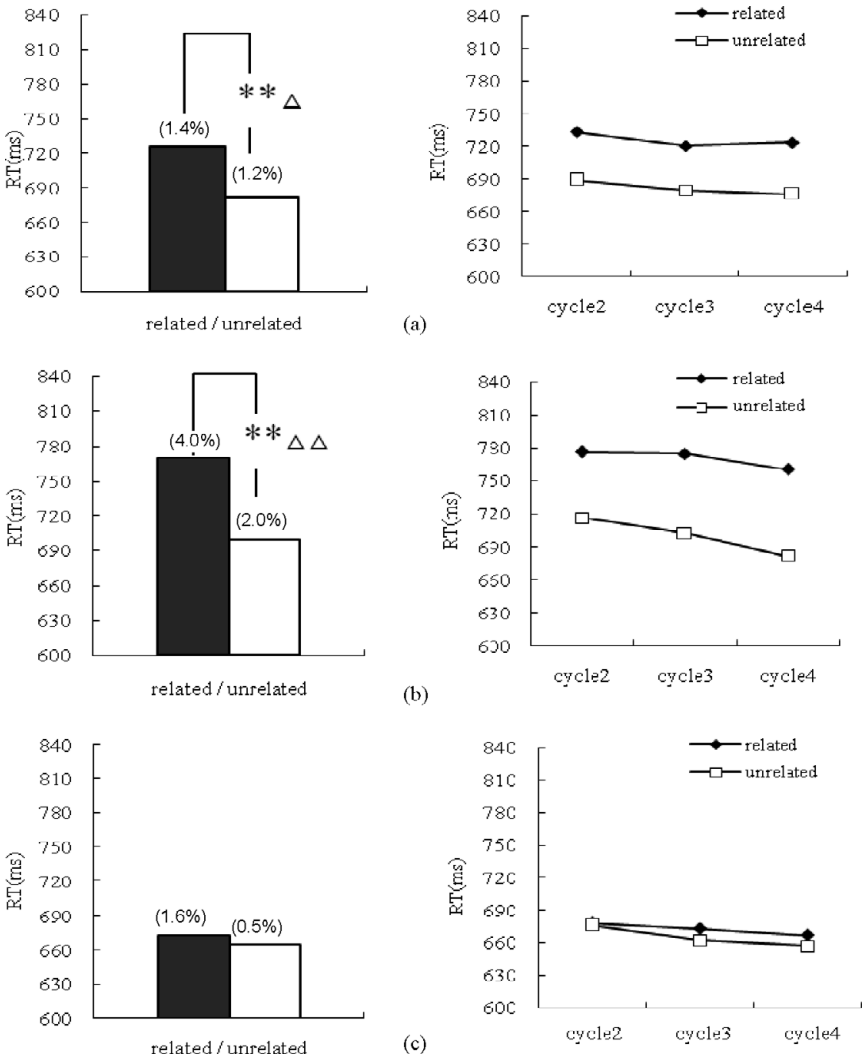

Figure 2. Translation latencies and error rates in Experiment 21 for the (a) abstract–associative condition, (b) abstract–semantically similar condition, (c) concrete–associative condition, (d) concrete–semantically similar condition, and (e) concrete–semantically distant condition. Mean reaction times (RTs; ms) for various types of blocking condition and their corresponding controls are presented both collapsing (left) across the last three repetitions and (right) by each cycle. Statistical significance levels are shown in the bar graphs: triangular labels for subject analyses ($^{\Delta}p < .05$, $^{\Delta\Delta}p < .01$) and asterisks for item analyses ($^{*}p < .05$, $^{**}p < .01$). The mean error rates of the last three cycles for each condition are in parentheses.

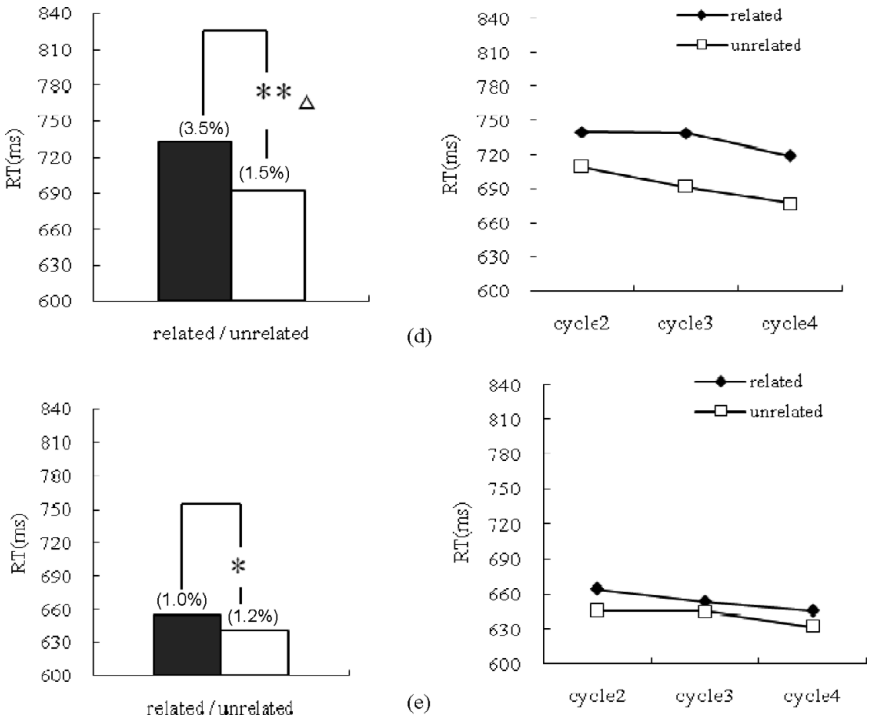

Figure 2 (*cont.*)

Method

Participants. Twenty-four new participants from the same subject pool as in Experiments 1 and 2 took part in the present experiment.

Materials. Abstract verbs and concrete verbs here were used. We chose words that are more frequently used as verbs than as other grammatical class in Chinese corpus (Chinese word frequency counts; Yu et al., 1998; see Table 1) and also collected the English surface word frequency (Kucera & Francis, 1967). The words were arranged in similar ways as in Experiment 1, except that each condition comprised of 12 arrays of 3 words, that is, 36 words needed to be translated within a condition (see Appendix C). The construction of unrelated conditions and the arrangements of blocks across participants were identical to those of Experiment 1. The semantic similarity and association ratings for the word arrays were collected using the method identical to that of Experiments 1 and 2 (see Table 1 for results). We also balanced the degree of initial phoneme overlap for the L2 (English) responses in the related conditions and control conditions.

Procedure and apparatus. The same procedures and apparatus as in Experiment 2 were used here. This whole experiment lasted for about 70 min and took two session to complete.

Results

The same data trimming and error coding method as Experiments 1 and 2 were employed. In total 5.3% of data points, including 3.9% errors and 1.4% outliers were discarded from analyses. The mean RTs of last three repetitions and RTs of the last three cycles are shown in Figure 3. The ANOVA results are shown in Table 2.

The main effects for the relatedness (related vs. unrelated) and relatedness types (similar vs. associative) were significant both by subject and by item. Words in the related blocks were translated slower than those in the unrelated blocks, and those in the semantically similar blocks slower than those in the associative blocks. The main effect of concreteness was not significant.

Pairwise comparisons between each related condition and its corresponding control showed significant interference effects for the abstract associative condition: AA: t_1 (23) = 2.23, p = .004; t_2 (35) = 3.42, p = .002; the abstract semantically similar condition: AS: t_1 (23) = 3.02, p = .006; t_2 (35) = 4.17, $p < .001$; and the concrete semantically similar condition: CS: t_1 (23) = 2.37, p = .03; t_2 (35) = 3.35, p = .002. The concrete associative condition did not yield any significant effect: CA: t_1 (23) = 0.90, p = .38; t_2 (35) = 1.54, p = .13.

The results in Experiment 1 were fully replicated here using words that are primarily used as verbs. For concrete verbs, there was a significant semantically similar blocking interference effect but no associative effect; for abstract verbs, both semantically similar and associative blocking produced significant interference effects. Note that the main effect of concreteness did not reach significance here. It might be because the difference in terms of concreteness in the abstract versus concrete verb stimuli was not as large as that in the noun stimuli (see Table 1).

ANALYSIS ACROSS ALL THREE EXPERIMENTS

To better understand the effects of associative and similarity variables on participants' behavior, we carried out multiple regression analyses across all items combining the three experiments, treating the mean RT of the last three repetitions for each word as the dependent variable. The predictors included the concreteness rating, the similarity rating, and the associative rating of each word (estimated with the rating for the particular set it appeared in), as well as the interactions between the concreteness rating and the similarity rating, and between the concreteness rating and the associative rating (after mean-centering both variables). The five predictors were simultaneously entered into the regression model. The variables concreteness, similarity, and the Concreteness × Association interaction showed significant effects in predicting the RT: (R^2 = .18, $p < .001$; concreteness: $\beta = -0.23$, $t = -8.28$, $p < .001$; similarity: $\beta = 0.31$, $t = 10.27$, $p < .001$; Concreteness × Association: $\beta = -0.095$, $t = -3.12$, $p = .002$; all other variables,

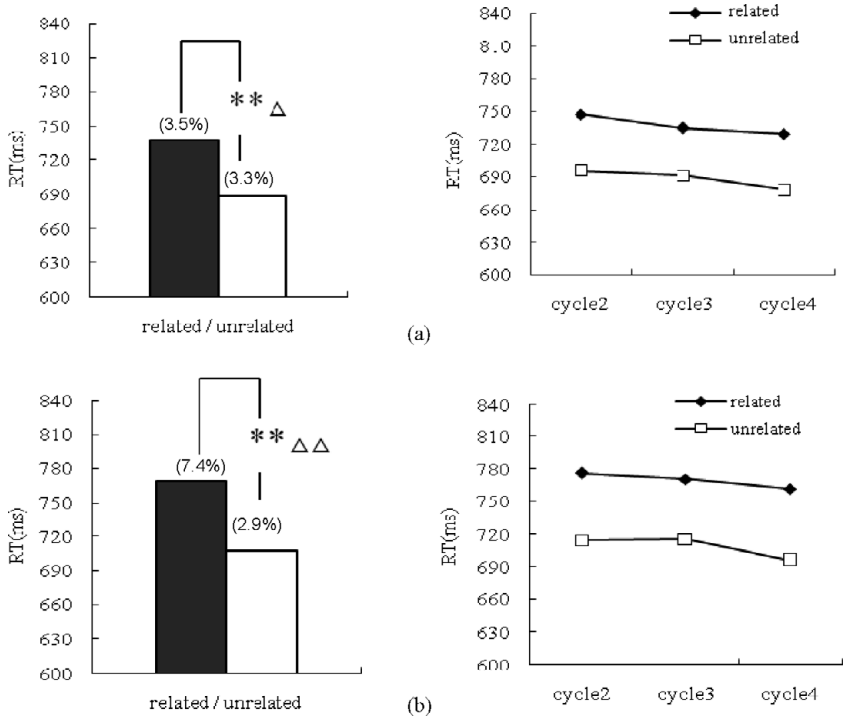

Figure 3. Translation latencies and error rates in Experiment 3 for the (a) abstract–associative condition, (b) abstract–semantically similar condition, (c) concrete–associative condition, and (d) concrete–semantically similar condition. Mean reaction times (RTs; ms) for various types of blocking condition and their corresponding controls are presented both collapsing (left) across the last three repetitions and (right) by each cycle. Statistical significance levels are shown in the bar graphs: triangular labels for subject analyses ($^{\Delta}p < .05$, $^{\Delta\Delta}p < .01$) and asterisks for item analyses ($^{**}p < .01$). The mean error rates of the last three cycles for each condition are in parentheses.

*t*s < 1.5). We then used the "stepwise" method for the five variables, and again the concreteness, similarity, and the interaction of Concreteness × Association were the significant predictors (first step: similarity; second step: concreteness; third step: Concreteness × Association; final model: $R^2 = .18$, $p < .001$). Finally, we used a method to test any unique contribution of the interaction variables by entering the main variables (concreteness, similarity, association) as a first block and then the interaction variables as a second block (Concreteness × Similarity or Concreteness × Association). Again, there was a greater improvement induced by entering the interaction variables (Concreteness × Association: R^2 change = .011, $p < .001$; Concreteness × Similarity: R^2 change = .003, $p = .041$). The robust effect of similarity in predicting the RT across all items here converges with the results of similarity effect in both abstract and concrete blocks obtained using other statistical method (paired *t* test).

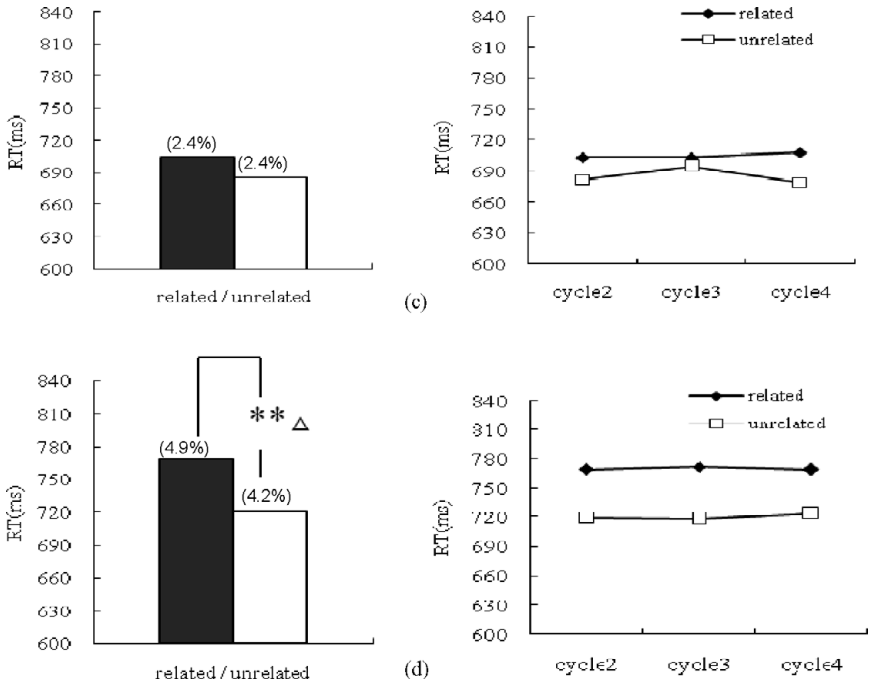

Figure 3 (*cont.*)

GENERAL DISCUSSION

In three experiments using the blocked translation paradigm with healthy Chinese–English bilinguals, we consistently observed the following patterns: for concrete words, the translation performance was interfered by semantically similar (categorical) blocking and not by associative blocking; for abstract words, both semantically similar and associative blocking prolonged subjects' translation performance. This pattern held when a mixture of words from various grammatical classes were used (Experiment 1), when words that are mostly used as nouns were used (Experiment 2), and when verbs were used (Experiment 3). The multiple regression analyses also confirmed the effects of similarity on all words, and that the effects of association being modulated by words' concreteness. Furthermore, for concrete nouns, a trend of semantic similarity distance effect was observed on top of the categorical effect (Experiment 2). We not only have extended the assessment of the organizational hypothesis about concrete and abstract concept representation to healthy subjects, but also have disentangled the potential confound of grammatical class and concreteness.

Before discussing the implications of our results, there are a few methodological caveats that need to be considered. First, word sets may not be equally related in both languages. In the current study, because the translation is driven by the

semantic system (and lexical system) of L1 (Chinese), we specifically manipulated the semantic relationships using Chinese words. For the stimuli in Experiment 1, both the words in L1 (current paper) and their corresponding L2 words (English) had been considered (Crutch & Warrington, 2005) and the patterns of semantic relationship manipulations paralleled in these two languages, suggesting that such manipulations can be generalized across these two languages to a great extent, at least for the stimuli set used here. Another issue is translation equivalency—there is usually more translation equivalency among concrete than among abstract words, and Tokowicz and Kroll (2007) showed that abstract words are influenced by the ambiguity in the translation but that concrete words are not. However, given that we used a within-item design in our study, with identical words to be translated in related and unrelated conditions (only the set construction they appear in were different), the effects of translation equivalency differences among concrete and abstract words could be minimized. Finally, we notice that the CA-related conditions were the fastest across three experiments; thus, the lack of any interference effect in the CA condition might be due to a ceiling situation. We think that this is not likely because our results here regarding CA were in line with earlier studies looking at associative relationships for concrete items (e.g., Duñabeitia et al., 2009).

Comparing current results to the findings in the literature

Relating our results to similar studies in the literature is complicated because the most closely related ones yielded different results. As discussed in the introductory section, Crutch and colleagues (Crutch, 2006; Crutch et al., 2006; Crutch & Warrington, 2005, 2007) observed a significant interference effect only by semantically similar blocking for concrete words and associative blocking for abstract words. Hamilton and Coslett (2008), studying a patient with similar disorders, observed effects of both semantic similarity and association for both types of words. Given the difficulty in interpreting null results, we will primarily consider the data points that yielded significant results, that is, those in Hamilton and Coslett (2008). Our results with the abstract words were consistent with this study, and the results with the concrete words were not. Hamilton and Coslett (2008) observed significant effects of both semantic similarity and association in concrete word processing, and we found only the effects of semantic similarity. Such discrepancies might be attributed to the types of subjects being studied, with the effects being more easily observed in a compromised system (see below).

Our current results are in accord with the majority of similar studies in the literature with healthy participants that assessed the effect of association in concrete versus abstract words comprehension, or the effects of semantic category versus association in concrete word processing. Duñabeitia et al.'s (2009) results, that concrete words that are associated with abstract targets had greater and earlier effects than for concrete targets using eye movement measures, are in line with our finding that the effect of association is more visible for abstract targets. For concrete words, the effect of semantically categorical interference was consistently observed in various semantic-mediated tasks such as object picture naming or translating words (Belke et al., 2005; Bloem & La Heij, 2003; Damian & Bowers,

2003; Damian et al., 2001; Howard, Nickels, Coltheart, & Cole-Virtue, 2006; Kroll & Stewart, 1994; Lupker, 1979; Rosinski, 1977; Schnur et al., 2006; Schriefers et al., 1990). The association effect, in contrast, was rather unreliable (Alario, Segui, & Ferrand, 2000; La Heij et al., 1990; Lupker, 1979), with only one study observing the effects of associative relationship under special circumstances, that is, when the experimental contexts were fully established after the subjects had named the test items several times (Abdel Rahman & Melinger, 2007).

Several convergent points emerged from the above analyses. Semantic similarity was found to affect both abstract and concrete word processing, except for studies presenting a floor situation (Crutch et al., 2006; Crutch & Warrington, 2005) or a study where semantic relationship yielded facilitation effect (Crutch et al., 2009). The effect of association is stronger in abstract words than in concrete words (current study; Crutch, 2006; Crutch et al., 2006, 2009; Crutch & Warrington, 2005, 2007; Duñabeitia et al., 2009). The only study that reported an equal strength of associative effect for concrete and abstract words was with a patient (Hamilton & Coslett, 2008).

Theoretical implications of our findings

What are the implications of these results? First, CW's findings (Crutch, 2006; Crutch et al., 2006; Crutch & Warrington, 2005, 2007) could not be generalized to other subjects and paradigms; hence, their corresponding theory about the fundamental organizational principle difference between concrete and abstract concepts is challenged. In addition, theories that suggested richer representations for concrete words (e.g., Paivio, 1986; Plaut & Shallice, 1991; Schwanenflugel & Shoben, 1983) do not readily explain the results either. If anything, the representation for abstract concepts might be richer, respecting both association and semantic similarity organizations.

These results can be accommodated by the theories about the content of semantic representations that (a) assume multiple dimensions of conceptual representation; and (b) attribute different weight distributions to the common set of concept organizational principles, with more weights to the association connections for abstract concepts than for concrete concepts (e.g., Breedin et al., 1994; see also Gentner, 1981; Hamilton & Coslett, 2008; Markman & Stilwell, 2001; Vigliocco et al., 2009). According to these theories, the organization of the semantic space is a product that emerges from differences in content. For instance, Breedin et al. (1994) proposed that concrete concepts are acquired through sensory experiences and once acquired contain rich sensory features; abstract concepts are acquired through linguistic and referent contexts and after acquisition also have a more ambiguous content (i.e., more senses) that are realized through the contexts they appear in. A related theory (Vigliocco et al., 2009) makes similar proposals about the semantic representation in the adult system: the dichotomy between concrete and abstract word meanings arises because of the distribution differences of various types of information underlying those meanings, with a statistically greater amount of sensory-motor information for concrete word meaning representation and a greater amount of affective and linguistic information for abstract word meaning representation.

This line of theories can therefore accommodate our findings that a semantic similarity effect is significant for both abstract and concrete words, as both sensory-motor feature overlap and linguistic information in the representations correlate with semantic similarity strength. Consistent with the proposal that the association strength is largely linguistic in nature and is more important in the abstract word representation, the effect of association is more easily seen with abstract items. In concrete items the association effect might be weak in normal circumstances and can only become visible when the system breaks down (e.g., Hamilton & Coslett, 2008). They could account for the other lines of empirical findings relating to the target issue, such as the double dissociation between abstract and concrete conceptual processing (see introductory section).

These theories might be criticized for being too vague, as empirical predictions depend on the actual weights being given to various types of semantic features/connections for a particular concept. It does make the following more specific prediction, however: there should be effects of semantic similarity across all items, and the effect of association should be modulated by the abstractness/concreteness of concepts. This was exactly confirmed by the post hoc multiple regression analyses we carried out: similarity strength significantly predicted the RT across all items, and by contrast the effect of association only significant when in modulation by the words' concreteness. The results of this post hoc analysis suggest that the organization principle does not treat concrete and abstract words categorically, but rather is influenced by the abstractness of words in a continuous fashion.

Considering semantic category versus similarity and nouns versus verbs

Note that so far in the discussion, we have followed the seminal studies and considered the semantically categorical relationship in concrete concepts to be semantic similarity that is in parallel with synonymy in abstract concepts. However, this is oversimplifying the issue. Although synonyms or near synonyms share most critical semantic features and could substitute for each other in many contexts, words belonging to the same semantic categories are mostly distinguished by critical semantic features and can rarely substitute for each other (consider "cat" and "mouse"). The associate relationships among concrete words and those among abstract words may also differ systematically. We here intended to reduce such potential problems by using identical procedures/instructions in the rating collections across concrete and abstract words. Furthermore, in Experiment 2 of the current study, we have empirically shown that the degree of semantic similarity yielded an effect (significant in item analyses) in concrete word translation on top of the categorical effects. That is, although it is still open as to whether the semantically categorical effect in concrete noun processing can be fully accounted for by a semantic similarity effect, there is indeed a comparable semantic similarity dimension that is respected by both abstract and concrete concepts (see also Mahon et al., 2007). Thus, in this sense, featural overlap matters for both types of concepts and provides more straightfoward explanation than accounts in terms of categorical organization of concrete words.

Furthermore, we observed parallel results for nouns and verbs in Experiment 2 and 3, indicating that the organization principles for noun and verb concepts are

similar, at least with regard to the concreteness dimension (abstract vs. concrete) and organizational principles (similarity vs. association). Such results are compatible with theories that propose the same structure for noun and verb concepts, such as the "FUSS" theory proposed by Vigliocco and colleagues (Vigliocco et al., 2004; Vinson & Vigliocco, 2002), which assumes the same feature space for all types of concepts. Note that our results do not exclude the possibilities that the nature of semantic similarity and categorical relationships differ across nouns and verbs and/or that noun and verb concepts are separately stored (e.g., Bi, Han, Shu & Caramazza, 2007; Bird, Howard, & Franklin, 2001; Caramazza & Hillis, 1991; McCarthy & Warrington, 1985).

CONCLUSIONS

In healthy subjects we obtained results that challenge the organizational hypothesis of CW (Crutch, 2006; Crutch et al., 2006, 2009; Crutch & Warrington, 2005, 2007), which assumes that abstract and concrete concepts are constrained by distinct semantic organizations. Although the associative relationship was indeed found to be more important for abstract items, both concrete and abstract concepts were observed to be sensitive to semantic similarity contexts. Our conceptual system might be represented by a set of common dimensions, with the weights of specific dimensions varying according to the characteristics of concepts such as concreteness.

APPENDIX A

Stimuli used in Experiment 1 (Chinese words and English target words)

Set								
				Abstract–Associative Related Condition				
1	锻炼	exercise	健康	healthy	健美	fitness	慢跑	jogging
2	打架	fight	拳击	punch	暴力	violent	挣扎	struggle
3	赌博	gamble	赌场	casino	纸牌	poker	运气	chance
4	将来	future	过去	past	总是	always	现在	present
5	巫婆	witch	符咒	spell	魔法	magic	咒语	curse
6	画廊	gallery	雕塑	sculpture	艺术家	artist	展览	exhibition
7	喜剧	comedy	玩笑	joke	大笑	laugh	有趣	funny
8	旅行	journey	游览	travel	出国	abroad	假期	Holiday
				Abstract–Similar Related Condition				
1	煮沸	boil	加热	heat	烹调	cook	油炸	fry
2	注视	look	偷看	peek	浏览	glance	看见	see
3	阵风	gale	旋风	wind	暴风	storm	微风	breeze
4	干净	clean	整洁	neat	纯净	pure	新鲜	fresh
5	吃	eat	咀嚼	chew	咬	bite	品尝	taste
6	打	beat	敲	knock	重击	thump	碰撞	strike
7	伪装	mask	掩护	cloak	躲藏	hide	屏蔽	screen
8	欺骗	cheat	诡计	trick	偷窃	steal	谎言	deceit
9	柔软	soft	粘稠	mush	果肉	pulp	平滑	smooth

APPENDIX A (*cont.*)

Concrete–Associative Related Condition								
1	农场	farm	黄牛	cow	拖拉机	tractor	谷仓	barn
2	烤炉	oven	围裙	apron	厨房	kitchen	汤	soup
3	水手	sailor	小船	boat	锚	anchor	大海	sea
4	书架	shelf	墙壁	wall	书	book	木头	wood
5	猴子	monkey	铁笼	cage	香蕉	banana	动物园	zoo
6	机场	airport	飞机	plane	手提箱	suitcase	机票	ticket
7	图画	picture	画笔	brush	颜料	paint	帆布	canvas
8	帐篷	tent	野营	camp	森林	woods	篝火	Fire
Concrete–Similar Related Condition								
1	鹅	goose	乌鸦	crow	麻雀	sparrow	鸽子	pigeon
2	羊毛衫	cardigan	夹克	jacket	衬衫	blouse	套头衫	pullover
3	比萨	pizza	蛋糕	cake	面包	bread	饼干	biscuit
4	柠檬	lemon	葡萄	grape	桃子	peach	香蕉	banana
5	水壶	kettle	烤面包器	toaster	烤箱	oven	冰箱	fridge
6	兔子	rabbit	刺猬	hedgehog	松鼠	squirrel	猪獾	badger
7	韭菜	leek	胡萝卜	carrot	洋葱	onion	土豆	potato
8	康乃馨	carnation	郁金香	tulip	玫瑰	rose	紫罗兰	Violet
Abstract–Associative Unrelated Condition								
1	赌博	gamble	将来	future	锻炼	exercise	拳击	punch
2	赌场	casino	过去	past	健康	healthy	打架	fight
3	纸牌	poker	总是	always	健美	fitness	暴力	violent
4	运气	chance	现在	present	慢跑	jogging	挣扎	struggle
5	巫婆	witch	展览	exhibition	有趣	funny	游览	travel
6	画廊	gallery	魔法	magic	出国	abroad	大笑	laugh
7	玩笑	joke	雕塑	sculpture	咒语	curse	旅行	journey
8	假期	holiday	艺术家	artist	喜剧	comedy	符咒	Spell
Abstract–Similar Unrelated Condition								
1	煮沸	boil	注视	look	阵风	gale	干净	clean
2	加热	heat	偷看	peek	旋风	wind	吃	eat
3	整洁	neat	咀嚼	chew	油炸	fry	浏览	glance
4	烹调	cook	暴风	storm	纯净	pure	咬	bite
5	看见	see	品尝	taste	新鲜	fresh	微风	breeze
6	打	beat	掩护	cloak	欺骗	cheat	柔软	soft
7	平滑	smooth	伪装	mask	诡计	trick	敲	knock
8	重击	thump	躲藏	hide	偷窃	steal	果肉	pulp
9	屏蔽	screen	碰撞	strike	谎言	deceit	粘稠	Mush
Concrete–Associative Unrelated Condition								
1	水手	sailor	书架	shelf	农场	farm	烤炉	oven
2	小船	boat	墙壁	wall	黄牛	cow	围裙	apron
3	锚	anchor	书	book	拖拉机	tractor	厨房	kitchen
4	大海	sea	木头	wood	谷仓	barn	汤	soup
5	帐篷	tent	猴子	monkey	手提箱	suitcase	画笔	brush

APPENDIX A (*cont.*)

				Concrete–Associative Unrelated Condition				
6	动物园	zoo	飞机	plane	帆布	canvas	篝火	fire
7	颜料	paint	机场	airport	森林	woods	香蕉	banana
8	图画	picture	野营	camp	机票	ticket	铁笼	cage
				Concrete–Similar Unrelated Condition				
1	鹅	goose	柠檬	melon	套头衫	pullover	饼干	biscuit
2	香蕉	banana	羊毛衫	cardigan	比萨	pizza	麻雀	sparrow
3	鸽子	pigeon	面包	bread	夹克	jacket	葡萄	grape
4	蛋糕	cake	衬衫	blouse	乌鸦	crow	桃子	peach
5	阵风	gale	洋葱	onion	烤面包器	toaster	紫罗兰	violet
6	猪獾	badger	玫瑰	rose	土豆	potato	冰箱	fridge
7	兔子	rabbit	水壶	kettle	康乃馨	carnation	韭菜	leek
8	郁金香	tulip	烤炉	oven	胡萝卜	carrot	刺猬	hedgehog

APPENDIX B

Stimuli used in Experiment 2 (Chinese words and English target words)

Set								
				Abstract–Associative Related Condition				
1	宗教	religion	上帝	god	虔诚	piety	教条	dogma
2	数学	math	考试	examination	答案	result	公式	formula
3	质量	quality	商品	merchandise	贸易	trade	市场	market
4	外科	surgery	疾病	disease	手术	operation	疼痛	ache
5	爱情	love	婚姻	marriage	家庭	family	幸福	happiness
6	海关	custom	关税	tariff	利润	profit	出口	export
7	网络	network	黑客	hacker	软件	software	病毒	virus
8	速度	velocity	引力	gravitation	物理	physics	实验	experiment
9	保险	insurance	健康	health	生命	life	平安	safety
10	气候	climate	地域	zone	温度	temperature	环境	environment
11	干旱	drought	饥荒	famine	难民	refugee	贫困	poverty
12	货币	money	银行	bank	税收	revenue	储蓄	Savings
				Abstract–Similar Related Condition				
1	焦虑	anxiety	紧张	nerves	害怕	fear	恐惧	scare
2	资本	capital	股份	stock	基金	fund	财产	wealth
3	心愿	wish	希望	hope	理想	ideal	梦幻	dream
4	地理	geography	方向	direction	空间	space	位置	location
5	能力	ability	技巧	skill	才干	talent	智力	intellect
6	风格	style	类型	type	品种	variety	款式	pattern
7	过失	mistake	缺点	shortcoming	错误	error	不足	deficiency
8	信号	signal	暗示	hint	线索	clue	标记	sign
9	思想	thought	道德	moral	精神	spirit	品质	character
10	程序	procedure	步骤	process	规则	regulation	序列	sequence
11	榜样	example	典型	representative	模范	model	偶像	idol
12	想法	idea	意见	notion	态度	attitude	观点	viewpoint

APPENDIX B (*cont.*)

				Concrete–Associative Related Condition				
1	农民	farmer	黄牛	cattle	土地	soil	庄稼	crops
2	读者	reader	书架	bookshelf	报纸	newspaper	图书馆	library
3	猴子	monkey	铁笼	cage	动物园	zoo	小孩	child
4	足球	football	草坪	lawn	教练	coach	球门	gate
5	森林	forest	帐篷	tent	野营	camping	篝火	need fire
6	沙滩	beach	大海	sea	波浪	wave	贝壳	shell
7	鲜花	flower	园丁	yardman	花园	garden	蝴蝶	butterfly
8	火炉	oven	围裙	apron	厨房	kitchen	母亲	mother
9	公园	park	凉亭	arbor	长椅	bench	游客	visitor
10	裁缝	tailor	衣服	clothing	量尺	ruler	模特	model
11	罪犯	criminal	警察	policeman	手铐	shackle	监狱	jail
12	护照	passport	飞机	plane	皮箱	luggage	旅客	passenger
				Concrete–Similar–Close Related Condition				
1	长椅	bench	凳子	stool	椅子	chair	沙发	sofa
2	快艇	yacht	轻舟	canoe	竹筏	raft	帆船	sailboat
3	马	horse	驴	donkey	骡子	mule	斑马	zebra
4	夹克	jacket	衬衫	shirt	毛衣	sweater	外套	coat
5	公寓	apartment	别墅	villa	木屋	cottage	城堡	castle
6	钱包	purse	手提包	handbag	背包	pack	公文包	briefcase
7	啤酒	beer	葡萄酒	wine	鸡尾酒	cocktail	白兰地	brandy
8	微风	breeze	飓风	hurricane	龙卷风	cyclone	暴风	storm
9	机关枪	machinegun	手枪	pistol	步枪	rifle	猎枪	shotgun
10	小溪	stream	河流	river	湖泊	lake	海洋	sea
11	小汽车	car	卡车	truck	出租车	taxi	公交车	bus
12	高脚杯	goblet	茶杯	cup	玻璃杯	glass	广口瓶	Jar
				Concrete–Similar–Distant Related Condition				
1	冰箱	frig	吸尘器	vacuum	洗衣机	washer	收音机	radio
2	老虎	tiger	蜻蜓	dragonfly	蛇	snake	青蛙	frog
3	西瓜	watermelon	桔子	orange	草莓	strawberry	香蕉	banana
4	台风	typhoon	地震	earthquake	冰雹	hail	酸雨	acid rain
5	啤酒	beer	咖啡	coffee	茶	tea	可乐	coke
6	眼睛	eye	大脑	brain	胳膊	arm	手指	finger
7	枪	gun	军舰	warship	直升机	helicopter	坦克	tank
8	熊	bear	兔子	rabbit	狗	dog	马	horse
9	芹菜	celery	土豆	potato	蘑菇	mushroom	玉米	corn
10	毛衣	sweater	帽子	hat	鞋	shoes	领带	tie
11	工人	worker	农民	farmer	医生	doctor	老师	teacher
12	飞机	plane	自行车	bike	小船	boat	火车	Train
				Abstract–Associative Unrelated Condition				
1	宗教	religion	考试	examination	贸易	trade	疼痛	ache
2	数学	math	商品	merchandise	手术	operation	幸福	happiness
3	质量	quality	疾病	disease	家庭	family	出口	export
4	外科	surgery	婚姻	marriage	利润	profit	病毒	virus
5	爱情	love	关税	tariff	软件	software	实验	experiment
6	海关	custom	黑客	hacker	物理	physics	平安	safety
7	网络	network	引力	gravitation	生命	life	环境	environment
8	速度	velocity	健康	health	温度	temperature	贫困	poverty
9	保险	insurance	地域	zone	难民	refugee	储蓄	savings
10	气候	climate	饥荒	famine	税收	revenue	教条	dogma

APPENDIX B (*cont.*)

Abstract–Associative Unrelated Condition								
11	干旱	drought	银行	bank	虔诚	piety	公式	formula
12	货币	money	上帝	god	答案	result	市场	Market
Abstract–Similar Unrelated Condition								
1	焦虑	anxiety	股份	stock	理想	ideal	位置	location
2	资本	capital	希望	hope	空间	space	智力	intellect
3	心愿	wish	方向	direction	才干	talent	款式	pattern
4	地理	geography	技巧	skill	品种	variety	不足	deficiency
5	能力	ability	类型	type	错误	error	标记	sign
6	风格	style	缺点	shortcoming	线索	clue	品质	character
7	过失	mistake	暗示	hint	精神	spirit	序列	sequence
8	信号	signal	道德	moral	规则	regulation	偶像	idol
9	思想	thought	步骤	process	模范	model	观点	viewpoint
10	程序	procedure	典型	representative	态度	attitude	恐惧	scare
11	榜样	example	意见	notion	害怕	fear	财产	wealth
12	想法	idea	紧张	nerves	基金	fund	梦幻	dream
Concrete–Associative Unrelated Condition								
1	农民	farmer	书架	bookshelf	动物园	zoo	球门	gate
2	读者	reader	铁笼	cage	教练	coach	篝火	needfire
3	猴子	monkey	草坪	lawn	野营	camping	贝壳	shell
4	足球	football	帐篷	tent	波浪	wave	蝴蝶	butterfly
5	森林	forest	大海	sea	花园	garden	母亲	mother
6	沙滩	beach	园丁	yardman	厨房	kitchen	游客	visitor
7	鲜花	flower	围裙	apron	长椅	bench	模特	model
8	火炉	oven	凉亭	arbor	量尺	ruler	监狱	jail
9	公园	park	衣服	clothing	手铐	shackle	旅客	passenger
10	裁缝	tailor	警察	policeman	皮箱	luggage	庄稼	crops
11	罪犯	criminal	飞机	plane	土地	soil	图书馆	library
12	护照	passport	黄牛	cattle	报纸	newspaper	小孩	child
Concrete–Similar–Close Unrelated Condition								
1	长椅	bench	轻舟	canoe	骡子	mule	外套	coat
2	快艇	yacht	驴	donkey	毛衣	sweater	城堡	castle
3	马	horse	衬衫	shirt	木屋	cottage	公文包	briefcase
4	夹克	jacket	别墅	villa	背包	pack	白兰地	brandy
5	公寓	apartment	手提包	handbag	鸡尾酒	cocktail	暴风	storm
6	钱包	purse	葡萄酒	wine	龙卷风	cyclone	猎枪	shotgun
7	啤酒	beer	飓风	hurricane	步枪	rifle	海洋	sea
8	微风	breeze	手枪	pistol	湖泊	lake	公交车	bus
9	机关枪	machinegun	河流	river	出租车	taxi	广口瓶	jar
10	小溪	stream	卡车	truck	玻璃杯	glass	沙发	sofa
11	小汽车	car	茶杯	cup	椅子	chair	帆船	sailboat
12	高脚杯	goblet	凳子	stool	竹筏	raft	斑马	zebra
Concrete–Similar–Distant Unrelated Condition								
1	冰箱	frig	蜻蜓	dragonfly	草莓	strawberry	酸雨	acid rain
2	老虎	tiger	桔子	orange	冰雹	hail	可乐	coke
3	西瓜	watermelon	地震	earthquake	茶	tea	手指	finger
4	台风	typhoon	咖啡	coffee	胳膊	arm	坦克	tank
5	啤酒	beer	大脑	brain	直升机	helicopter	马	horse

APPENDIX B (*cont.*)

				Concrete–Similar–Distant Unrelated Condition				
6	眼睛	eye	军舰	warship	狗	dog	玉米	corn
7	枪	gun	兔子	rabbit	蘑菇	mushroom	领带	tie
8	熊	bear	土豆	potato	鞋	shoes	老师	teacher
9	芹菜	celery	帽子	hat	医生	doctor	火车	train
10	毛衣	sweater	农民	farmer	小船	boat	收音机	radio
11	工人	worker	自行车	bike	洗衣机	washer	青蛙	frog
12	飞机	plane	吸尘器	vacuum	蛇	snake	香蕉	banana

APPENDIX C

Stimuli used in Experiment 3 (Chinese words and English target words)

Set						
			Abstract–Associative Related Condition			
1	犯罪	commit	诉讼	charge	辩护	defend
2	感染	infect	免疫	immunize	预防	prevent
3	雇佣	employ	培训	train	晋升	promote
4	禁止	ban	违反	disobey	惩罚	punish
5	起源	originate	进化	evolve	灭绝	die out
6	入侵	invade	反抗	resist	胜利	win
7	撒谎	lie	揭穿	expose	坦白	confess
8	生产	produce	销售	sell	经营	manage
9	完成	accomplish	满意	satisfy	表扬	Praise
10	牺牲	sacrifice	哀悼	mourn	纪念	commemorate
11	学习	learn	思考	think	掌握	master
12	造假	fake	否认	deny	投诉	Complain
			Abstract–Similar Related Condition			
1	安慰	comfort	平息	appease	缓和	relax
2	发明	invent	创造	create	建立	found
3	鼓励	encourage	容许	admit	同意	agree
4	呵斥	berate	批评	criticize	谴责	accuse
5	积累	accumulate	聚集	gather	增加	add
6	联系	contact	沟通	communicate	交流	exchange
7	强迫	compel	威胁	threaten	吓唬	scare
8	提高	increase	上升	rise	增长	grow
9	玩弄	dally	撒谎	lie	欺骗	cheat
10	羡慕	envy	钦佩	admire	欣赏	appreciate
11	修复	restore	改正	correct	补救	remedy
12	憎恨	hate	讨厌	dislike	反感	disgust
			Concrete–Associative Related Condition			
1	播种	sow	施肥	fertilize	收割	harvest
2	打仗	war	开枪	fire	受伤	wound

APPENDIX C (*cont.*)

Concrete–Associative Related Condition						
3	购物	shop	挑选	select	付款	pay
4	喝酒	drink	呕吐	throw up	脸红	blush
5	化妆	prink	拍摄	photograph	表演	act
6	流血	bleed	疼痛	ache	包扎	bundle
7	抢劫	rob	搏斗	fight	逮捕	arrest
8	睡觉	sleep	打鼾	snore	叫醒	wake
9	踢球	kickball	摔倒	tumble	射门	shoot
10	偷窃	steal	逃走	escape	追赶	chase
11	演出	perform	欢呼	cheer	鼓掌	applaud
12	装载	load	运输	transport	卸货	discharge
Concrete–Similar Related Condition						
1	步行	walk	闲逛	stroll	行进	march
2	刺伤	stab	捅破	poke	钻孔	drill
3	打碎	smash	破裂	break	分解	decompose
4	刮	scrape	擦	wipe	抹	smear
5	烘焙	bake	烧烤	grill	油煎	fry
6	离开	leave	溜走	glide	逃跑	escape
7	喷射	spray	飞溅	splash	冒出	emit
8	劈	cleave	剁	chop	切	cut
9	潜水	dive	游泳	swim	漂浮	float
10	说话	speak	演讲	lecture	汇报	report
11	旋转	revolve	滚动	roll	摇摆	swing
12	照耀	shine	发光	light	闪烁	glitter
Abstract–Associative Unrelated Condition						
1	辩护	defend	思考	think	感染	infect
2	预防	prevent	否认	deny	雇佣	employ
3	晋升	promote	诉讼	charge	禁止	ban
4	惩罚	punish	免疫	immunize	学习	learn
5	灭绝	die out	培训	train	入侵	invade
6	胜利	win	违反	disobey	撒谎	lie
7	坦白	confess	反抗	resist	起源	originate
8	经营	manage	哀悼	mourn	完成	accomplish
9	表扬	praise	揭穿	expose	牺牲	sacrifice
10	纪念	commemorate	销售	sell	犯罪	commit
11	掌握	master	进化	evolve	造假	fake
12	投诉	complain	满意	satisfy	生产	produce
Abstract–Similar Unrelated Condition						
1	容许	admit	谴责	accuse	安慰	comfort
2	批评	criticize	增加	add	发明	invent
3	聚集	gather	交流	exchange	鼓励	encourage
4	沟通	communicate	吓唬	scare	呵斥	berate

APPENDIX C (*cont.*)

			Abstract–Similar Unrelated Condition			
5	威胁	threaten	增长	grow	修复	restore
6	上升	rise	欣赏	appreciate	缓和	relax
7	建立	found	改正	correct	强迫	compel
8	钦佩	admire	补救	remedy	玩弄	dally
9	撒谎	lie	反感	disgust	提高	increase
10	讨厌	dislike	联系	contact	积累	accumulate
11	平息	appease	欺骗	agree	羡慕	envy
12	创造	create	同意	cheat	憎恨	Hate
			Concrete–Associative Unrelated Condition			
1	呕吐	throw up	播种	sow	受伤	wound
2	拍摄	photograph	打仗	war	收割	harvest
3	疼痛	ache	购物	shop	脸红	blush
4	搏斗	fight	喝酒	drink	表演	act
5	打鼾	snore	化妆	prink	付款	pay
6	摔倒	tumble	流血	bleed	逮捕	arrest
7	逃走	escape	抢劫	rob	叫醒	wake
8	挑选	select	睡觉	sleep	鼓掌	applaud
9	运输	transport	踢球	kickball	包扎	bundle
10	施肥	fertilize	偷窃	steal	射门	shoot
11	开枪	fire	演出	perform	卸货	discharge
12	欢呼	cheer	装载	load	追赶	chase
			Concrete–Similar Unrelated Condition			
1	擦	wipe	分解	decompose	步行	walk
2	演讲	lecture	抹	smear	刺伤	stab
3	飞溅	splash	油煎	fry	打碎	smash
4	烧烤	grill	逃跑	escape	刮	scrape
5	溜走	glide	冒出	emit	烘焙	bake
6	发光	light	切	cut	离开	leave
7	剁	chop	漂浮	float	喷射	spray
8	游泳	swim	汇报	report	劈	cleave
9	破裂	break	摇摆	swing	潜水	dive
10	滚动	roll	闪烁	glitter	说话	speak
11	捅破	poke	行进	march	旋转	revolve
12	闲逛	stroll	钻孔	drill	照耀	shine

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NOTES

1. We do not attempt to distinguish between concepts and semantics, and these two terms are used interchangeably.
2. Although these authors have recently embraced a more graded views (Crutch & Warrington, 2010), they still assumed the same kind of contrasting effects of associative/semantic relationships for abstract and concrete words. Here we focus on the stronger version of their hypothesis that was discussed in all their earlier papers.

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