Representation and Access of Chinese Compound Words

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A Thesis Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

in

Education

The Chinese University of Hong Kong

August 2011

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ABSTRACT

This dissertation reports on three studies of the cognitive representations and processes in visual recognition of Chinese two-character compound words. Because Chinese two-character compound words are composed of two spatially separated characters which themselves are words, there has been a debate about whether these words are represented and processed in the mental lexicon as unitary wholes or as combinations of the component characters (Zhang & Peng, 1992; Taft & Zhu, 1995).

The first two studies are concerned with whether Chinese two-character compound words have decomposed or holistic *orthographic* representations in the mental lexicon. Study 1 made use of the high frequency orthographic neighbor inhibition effect (Grainger & Jacobs, 1996; Davis & Lupker, 2006) in the masked priming paradigm. It was found that a high frequency orthographic neighbor (e.g., 简直, means *virtually* in English) inhibited recognition of a low frequency target word (e.g., 简略, means *brief* in English). The high frequency orthographic neighbor inhibition effect was supposed to be caused by lexical competition between prime and target words (Grainger & Jacobs, 1996). Therefore, the observation of inhibition in Study 1 suggests that the prime words have word-level representations that compete with those of target words for lexical access. It is argued that the activated word-level lexical representation is likely to be orthographic representation, rather than phonological and semantic representations, because the influence of phonology was found to be limited in a follow-up experiment, and the semantic relatedness between the prime and target words was low. Furthermore, because the inhibition effects were stronger for semantically opaque than transparent compound words, it seems that opaque words are more likely than transparent words to be represented as unitary units.

Study 2 adapted the transposed-letter similarity effect in English (Forster, Davis, Schoknecht, & Carter, 1987; Acah & Perea, 2008) into transposed-character similarity effect in Chinese to further examine the orthographic representation of Chinese compound words. Study 2 examined the processing of both transposable and untransposable compound words to distinguish the decomposed account (which assumes morpheme-to-word activation) and the holistic account (which assumes activation of word-level orthographic representation) of the mental representation of Chinese compound words. It was found that transposable word-word pairs (e.g., 领带, means *tie* in English-带领, means *lead* in English) did not produce significant priming effects. This result is inconsistent with the decomposed account, but is

explicable in terms of the holistic account. Two follow-up experiments show that the transposed-character similarity effects differ for transparent (e.g., 骄傲, means *proud* in English) and opaque words (e.g., 马虎, means *careless* in English). Transposed nonwords show significant facilitation effect to the original words when the original words were opaque (e.g., 虎马-马虎) but not when they were transparent words (e.g., 傲骄-骄傲). It suggests that opaque words are more likely than transparent words to be represented as orthographic wholes. The findings of word-level orthographic representation and the influence of semantic transparency provide convergent evidence for the conclusions reached by Study 1.

The third study investigated whether or not the meaning of a component morpheme would be activated in the process of recognizing a Chinese two-character compound word. Current accounts of morphological processing disagree on whether morphological processing is form then meaning, or form with meaning (Feldman, O'Connor, & Del Prado Martin, 2009; Davis & Rastle, 2010). The focus of the debate is actually whether morpheme meaning activation occurs at early stage of compound word processing. This study attempted to contribute to that debate by trying to dissociate morphological processing of form and meaning. The method was to investigate masked priming effects produced by prime-target pairs that contained a pair of semantically related morphemes but without any overlap in orthography, phonology or whole-word meaning (e.g., 吃惊 /*surprised* in English/-食言/*break one's promise* in English/). Since there was no overlap between the prime and the target in form, any priming effects produced could be attributed unequivocally to activation of morpheme meaning (e.g., 吃-食, both means *eat* in English). The results of Study 3 show that morpheme meaning activation without form overlap occurred as early as the first 60ms of word processing. This finding is more consistent with the form-with-meaning than the form-then-meaning account.

In sum, the three studies suggest that, on one hand, Chinese compound words, particularly the opaque ones, seem to be represented as holistic orthographic units in the mental lexicon. On the other hand, the meanings of the component morphemes are activated in visual recognition of Chinese compound words, suggesting a decomposed access. The implications of these results for a model of Chinese compound word representation and access, as well as the dispute between morpho-orthographic and morpho-semantic decomposition accounts of morphological processing in other languages, were discussed.

摘 要

中文复合双字词由两个可单独成词的汉字构成。在汉语字词研究领域对于复合双字词的表征和通达历来存在整体表征和分解表征两种观点 (Zhang & Peng, 1992; Taft & Zhu, 1995)。为了解决这一争论，本文试图通过三个研究进一步探讨中文复合双字词的表征和通达。

研究一和研究二均关注中文复合双字词在心理词典中的词形表征问题。研究一使用掩蔽启动范式下的*高频家族临近词抑制效应* (Grainger & Jacobs, 1996; Davis & Lupker, 2006) 来探讨此问题。研究结果显示，高频家族临近词（如，*简直*）干扰被试对低频家族临近词（如，*简略*）的识别。Grainger 和 Jacobs (1996) 认为*高频家族临近词抑制效应*是启动词和目标词之间的词汇竞争引起的。研究一的结果表明启动词和目标词整词水平的表征得到了激活并在词汇通达过程中相互竞争。再进一步而言，在上述加工过程中最有可能被激活的整词表征是词形表征，而不是语音或语义表征。这是因为后续研究表明语音方面的影响非常有限，而启动词和目标词之间的语义相关度也不高。另外，实验结果显示高频不透明启动词（如，*成就*）比高频透明启动词（如，*举办*）对其低频家族临近词（*成见 & 举例*）产生更大的*高频家族临近词抑制效应*。据此推断，不透明词比透明词更有可能拥有整词水平的词形表征。

为了进一步探讨中文复合双字词的心理表征，研究二把英文研究中所发现的*字母换位相似性效应*发展成*汉字换位相似性效应*并加以使用 (Forster, Davis, Schoknecht, & Carter, 1987; Acah & Perea, 2008)。为了鉴别分解表征假说（认为存在词素到整词的激活）和整词表征假说（认为存在整词水平词形表征的激活），研究二同时考察了可换位复合词 （如，*领带-带领*）和不可换位复合词（如，*傲骄-骄傲*）的加工过程。研究结果显示，可换位词对（如，*领带-带领*）并不会促进彼此的加工。整词表征假说可以对结果做出解释。后续实验发现透明词（如，*骄傲*）和不透明词（如，*马虎*）的*汉字换位相似性效应*不同。具体而言，汉字换位后得到的非词有助于不透明词的加工（如，*虎马-马虎*），但对透明词的加工（如，*傲骄-骄傲*）并无影响。该结果表明，透明词比不透明词更有可能以整体表征的方式存储在心理词典中。研究二证实了整词词形表征的存在及语义透明度的影响。这些结果与研究一的结果一致。

本文关注的第二个焦点是“中文复合双字词的心理表征是如何通达的？”。目前在词素加工方面的研究对于词素语义和形式激活的相对速度仍存在争论：词素语义激活滞后于词素形式激活还是二者是同时激活的 (Feldman, O'Connor, & Del Prado Martin, 2009; Davis & Rastle, 2010)？争论的焦点实质上是词素语义能否在复合词加工的早期阶段得到激活。研究三试图分离词素语义激活和词

素形式激活，以期对解决上述争论有所帮助。该研究中词素语义相关的启动词和目标词（如，*吃惊-食言*）在字形、语音、和整词语义方面均无相关。因而，所观测到的启动效应只能归因于启动词和目标词中语义相关词素的激活（如，*吃-食*）。研究三发现词素语义在复合词加工的最初60毫秒就得到了激活。该结果支持词素语义和词素形式同时激活的假说。

简而言之，上述三个研究的结果表明中文复合双字词（特别是不透明词）可能在心理词典中有整词水平的词形表征；同时，在中文复合双字词的通达过程中，词素语义得到了激活，从而支持分解通达的理论假说。这些结果深化了对我们中文复合双字词认知表征和通达的理解，也为解决词素形式论和词素语义论提供了实验证据。

ACKNOWLEDGEMENTS

My great gratitude should be first expressed to my supervisor, Professor Shiu Ling-po, for his professional advice and constant support during the process of formulating a research plan, undertaking experiments and conducting data analyses for my PhD thesis. I really appreciate his support and encouragement since my first arrival at the Chinese University of Hong Kong.

I am deeply indebted to my committee members, Professor Cheng Pui-wan and Professor Ni Yŭjing, who provided me with constructive suggestions and timely feedback over my work. I appreciate valuable comments from Professor Marcus Taft that help to improve my work. The remaining errors are, of course, mine. I would also like to thank Professor Mo Lei, Professor Chang Lei, Professor Tse Chi-shing and Professor Wang Ruiming for their support and encouragement.

Last but not least, my thanks are due to my family and my fellow students of Faculty of Education at the Chinese University of Hong Kong, for whom, I was not lonely during my academic journey at Hong Kong.

Thank you all.

Lingyan Zhang

19 June 2011, G08, Li Wai Chun Building

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Chapter 1 Introduction

1.1 Context of the study

One of the hotly debated issues concerning visual recognition of Chinese words is the representation and processing of compound words. Despite the fact that Chinese compound words are formally composed of two components (characters), previous studies have shown that they may be processed as wholes and that word-level representations and processing may affect character-level processing.

Take Word Superiority Effect (WSE) in Chinese as an example. It was found that characters included in real compound words are more likely to be correctly reported than those included in two-character nonwords (Mok, 2009) (e.g., 态 /*appearance* in English/ in 态度 /*manner* in English/ vs. in 态备). Similar findings were also observed in an eye movement study by Yan, Tian, Bai and Rayner (2006). They found that word frequency affects reading time on compound words and moderates the effect of character frequency. Specifically, the frequency of characters included in low frequency compound words affected reading time on compound words, while the frequency of characters embedded in high frequency compound words did not. The moderation effect of compound words on component characters was also observed by Li, Rayner and Cave (2009), who found that character identification accuracy was much higher when the characters comprised one four-character word (e.g., 不知所措, /*be at a loss* in English/) than two two-character words (e.g., 急速 切实, /*rapidly* in English/; /*practical* in English/).

If Chinese compound words are represented as wholes, it is not surprising that compound words rather than characters are found to be the basic processing units in normal Chinese reading. Bai, Yan, Zang, Liversedge and Rayner (2008) found that inserting a space between every two two-character words in a text did not interfere with normal reading, while inserting a space between every two characters that form a word did. It suggests that two-character words are likely to be processed as unitary units. However, their results should be taken with cautions because abnormal spacing between characters destroys word boundaries and may increase cognitive processing load.

Although these studies show that Chinese compound words may be represented and processed as unitary wholes, one aspect that they did not make clear is which kind of whole-word representation exists for Chinese compound words. A word's representation in the mental lexicon consists of three interlocking parts - an orthographic, a phonological and a semantic representation (Perfetti, Liu, & Tan, 2005). Researchers have found that Chinese compound words are likely to have word-level phonological representations (Law, Wong, & Chiu, 2005) and word-level semantic representations (Zhou, Marslen-Wilson, & Shu, 1999). However, the status of orthographic representation remains a question. In visual word recognition, the most important component of lexical representation is orthographic representation because it opens the door of the mental lexicon. Thus, the present study aims to investigate word-level orthographic representations of Chinese compound words.

How are lexical representations of Chinese compound words accessed? This question concerns morphological processing of compound words. Morphemes are linguistic units that conjoin both word form (orthography and phonology) and meaning information. Thus, morphemes may function as orthographic indicators for access of compound word entries in the mental lexicon. At the same time, morphemes may also act as meaning atoms for access of compound word meaning.

Compound words are one kind of complex words that are composed of two free morphemes. On the one hand, the majority of Chinese words are compound words, and therefore, studies of morphological effects in Chinese mainly deal with compound words. On the other hand, the main types of complex words in the English language are inflected and derived words. Thus, the review of previous studies of morphological effects will be mainly about such complex words when it comes to the English language.

The effects of component morphemes on complex word processing have been extensively studied in the past three decades since Taft and Forster's (1975; 1976) pioneering studies. Researchers have proposed several models to account for numerous empirical findings about complex word processing. In accordance with their fundamental theoretical assumptions, such models can be divided into two sides: localist and distributed accounts.

The localist accounts can be further divided into early and late variants, depending on the assumed time course of morphological decomposition. Early decomposition accounts include the Prelexical Model (Taft & Froster, 1975; 1976), the Interactive Activation Model (Taft, 1994; Taft & Zhu, 1995) and the Dual route Model (AAM model, Caramazza, Laudana, & Romani, 1988; MR model, Baayen, Dijkstra, & Schreuder, 1997). Both the Prelexical Model and the Interactive Activation Model assume that form-based morphological decomposition is prelexical and obligatory. However, the Dual Route Model assumes that there are both a morphological decomposition route and a whole word access route and the two routes are relatively independent of each other.

Late decomposition accounts include the Supra-lexical Model (Giraudo & Grainger, 2000; 2001) and the Hybrid Model (Diependaele, Sandra, & Grainger, 2005; 2009). The Supra-lexical Model asserts that morphological activation lags behind whole word activation. But the Hybrid Model includes both a sublexical morpho-orthographic decomposition and a supra-lexical morpho-semantic activation.

The Distributed Model, also called the Connectionist Model (Plaut & Gonnerman, 2000), denies the existence of discrete morphological units. It is proposed that a distributed network of nodes representing form and meaning can capture morphological relationships by changes in the weights of the connections between the nodes.

Morphological processing has also been examined in Chinese, mainly with compound words. The first documented study of Chinese compound word processing is Zhang and Peng (1992), who found that character frequency affected lexical decisions to compound word targets, suggesting that component characters/morphemes are activated in Chinese compound word processing. In the following decade, a great amount of research on Chinese compound words was conducted and theoretical frameworks were developed. Influential models include the Multi-level Interactive Activation Model (Taft & Zhu, 1995; 1997; Taft, Liu, & Zhu, 1999), the Intra/Inter Connection Model (Peng, Liu, & Wang, 1999) and the Non-Hierarchical Semantically Based model (Zhou, Marslen-Wilson, & Shu, 1999). All models of Chinese compound word processing acknowledge the coexistence of morpheme and word-level representations. The Multi-level Interactive Activation Model assumes that morpheme-level representation is set at a lower level than whole word level representation. The other two models contend that the two types of representations are set at the same level. However, a review of the literatures shows that few developments have been made since these early works.

In short, current models of morphological processing in compound word recognition differ with respect to two major issues: (1) the locus of morphological processing - prelexical or supralexical; and (2) the nature of morphological processing - morpho-orthographic or morpho-semantic (Davis & Rastle, 2010; Feldman, O'Connor, &

Del Prado Martin, 2009).

1.2 Research questions

The present research has two foci. The first is about the mental representation of Chinese compound words; the second is about morphological processing in the access of Chinese compound words. These two research questions were tackled in three studies.

1.2.1 Research question 1

Previous studies have revealed that Chinese compound words may be represented as wholes but they did not make a distinction among different types of representations. Thus the first research question, addressed in Studies 1 and 2, concerns whether Chinese compound words have word-level orthographic representations in the mental lexicon. The influence of semantic transparency on compound word representation will also be addressed.

1.2.2 Research question 2

The second research question is related to the access of Chinese compound words. Study 3 investigated morpho-semantic activation and its time course in the processing of Chinese compound words.

1.3 Significance

The research will contribute to the field of compound word processing from the following three perspectives:

Firstly, the present study will show whether Chinese two-character compound words are represented as two individual orthographic representations or one holistic orthographic representation. The influence of semantic transparency on compound word representation will also be revealed. The results of the present study, together with the findings of word-level phonological representations (Law et al., 2005) and word-level semantic representations (Zhou et. al., 1999), will reveal a full picture of lexical representations of Chinese compound words. Meanwhile, the findings will also bear on whether human's cognitive system emphasizes more on storage economy or computation/processing efficiency.

Secondly, the findings of Study 3 will be used for distinguishing among different models of morphological processing. The results may reveal the occurrence and the time-course of morpheme meaning activation in Chinese compound words processing

Chapter 2 Literature Review

2.1 Chinese compound word

According to the State Language Work Committee (2008), approximately 72.05% of the most commonly used Chinese words (40351 out of 56008) are two-character words. The major word-forming device for Chinese two-character words is compounding, which refers to a language mechanism of creating new words by combining or putting together two mono-morphemic words (or characters in Chinese). Compounding is the easiest way to create or transfer new meanings in both Chinese and alphabetic languages (Libben & Jarema, 2006, p2). Thus, investigation of the storage and processing of Chinese compound words will not only help to clarify certain issues about Chinese words, but also contributes to our knowledge on the most important morphological mechanism in human languages.

Chinese compound words represent meaningful wholes but are formally composed of two free morphemes. Each component morpheme corresponds to one character on print and one syllable in sound. Chinese Characters are highly productive in that each can combine with as many as hundreds of other characters to form different two-character words. Take the character 风 (*wind* in English) as an example, it can combine with other characters to form 357 different words (State Language Work Committee, 2008). Given that Chinese compound words are formally composed of two highly productive characters, it is tempting to ask whether Chinese compound words are represented as holistic units or as two decomposed units in the mental lexicon.

The representation and access of Chinese compound words may be affected by factors such as semantic transparency and word frequency. Semantic transparency refers to the degree of semantic relatedness between component morphemes and the whole word. Such relationship is much closer in transparent than opaque compound words. Compared to transparent words, it is much harder to get the meaning of opaque words by the sum of the component morpheme meanings. Thus, opaque words are more likely than transparent words to be represented and accessed as wholes.

Another factor that may affect compound words' whole-word representation is word surface/token frequency. Word surface/token frequency refers to the total number of times a word appears in a corpus (Diependaele, Grainger, & Sandra, in press). Whole-word frequency has been found to facilitate the processing of complex words in studies of both alphabetic languages (e.g., Niswander, Pollatsek, & Rayner, 2000) and Chinese (e.g., Yan, Tian, Bai, & Rayner, 2006). For example, Yan and colleagues (Yan, et al., 2006) found that word frequency affect eye fixations in reading Chinese texts and moderate the effect of character frequency. Although the frequency of the characters embedded in low frequency words shows significant influence on participants' reading speed, the frequency of the characters embedded in high frequency words does not. Such findings may suggest that high but not low frequency words may have whole word representation and their component characters do not play a role in word processing.

The following section is divided into two parts: the first part concerns the representation/storage of Chinese compound words; the second part concerns the role of morphological processing in the access of Chinese compound words. Previous studies of these two aspects will be reviewed and the research gap the present research aims to fill will then be brought forward at the end of each part.

2.2 Representation of Chinese compound words

2.2.1 Decomposed representation of Chinese compound words

As mentioned in the last section, compound words are highly productive because characters can combine with one another to form a large number of new words. Thus, it is reasonable to suspect that Chinese compound words are represented in terms of characters. If this is the case, characters in different words should share one node in the representational network. Each character will not be represented more than once. Otherwise, the same character would be represented repeatedly in different compound words. Obviously, representing Chinese compound words in terms of characters may save some cognitive capacity. Thus, pioneer researchers of Chinese compound word studies have suggested that Chinese compound words are represented in a decomposed way in the mental lexicon (Zhang & Peng, 1992).

However, there are reasons to doubt that Chinese characters may not be the optimal unit in which Chinese words are represented. First of all, because of its high productivity, a character may have very different meanings when it appears as a component in different words. Such characters are quite similar to homographs in English. For example, the meanings of the character 打 in the words 打听 (means *inquire about* in English) and 打架 (means *fight* in English) are entirely different. Thus, it is hard to determine the exact meaning of the character based on character representation alone. A word context is often necessary for determining the meaning of component characters.

Secondly, the pronunciation of some characters is undetermined with the visual form of a single character. For example, 会 can be pronounced as /hui4/ in 会议 (means *conference* in English) and /kuai4/ in 会计 (means *accountant* in English). For such characters, it is quite necessary to rely on word context to decide their sounds and meanings.

Considering the above two aspects, if component characters are the basic representational units, the processing of Chinese compound words would not be efficient. Alternatively, if Chinese compound words are represented as unitary wholes, the match between visual input and internal mental representation would be as fast as a dictionary look-up process. The processing of component character/morpheme within the word context would also be facilitated after the compound word has accessed its corresponding representation in the mental lexicon. Hence, there are processing efficiency advantages for representing Chinese compound words as orthographic wholes in the mental lexicon.

2.2.2 Holistic representation of Chinese compound words

Previous models of Chinese compound words representation and processing hold different views on the status of word-level orthographic representations. Specifically, the Semantic Overlap Model (Zhou, Marslen-Wilson, Taft, & Shu, 1999) denies the existence of word-level orthographic representations of Chinese compound words. Instead, it assumes that word-level orthographic representations are simply a combination of component characters' orthographic representations. Conversely, the Multilevel Interactive-activation Framework (Taft et al., 1999) acknowledges the existence of word-level orthographic representations of compound words in the mental lexicon. It also assumes that morpheme-level representations are located at a lower level than word-level representations and are connected upwardly with word-level representations. In addition to the above two accounts, the balso acknowledges the existence of word-level representation but did not make a distinction among semantic, phonological and orthographic representations.

Some empirical studies provided evidence for word-level representations of Chinese compound words. For example, the influence of word-level information on component character processing has been revealed by the word superiority effect (WSE) in Chinese. It has been found that a single character is perceived better when it is part of a two-character word than when it is embedded in a two-character nonword (Mok, 2009). These results can be explained if two-character words activate word-level representations in the mental lexicon that facilitate character-level processing.

Positive feedback from word-level processing to character-level processing was also observed in other studies. For example, in Li, Rayner and Cave (2009), four characters were briefly presented on the screen and the participants were asked to report them verbally. The four characters can be combined into a single four-character word or two 2-character words. It was found that the reporting accuracy was much higher in the single word condition than the two words condition. It implies that the presented characters were processed in terms of words. The advantage of single word condition over two words condition may reflect the ease of processing one word than two words.

Two-character words are likely to be the basic processing units in normal Chinese reading, too. Bai and colleagues (Bai, Yan, Zang, Liversedge, & Rayner, 2008) found that inserting a space between two two-character words did not interfere with normal reading, while inserting a space between two characters that do not form a word did. However, although these results suggest that two-character words are processed as wholes, they should be taken with cautions because abnormal spacing between characters destroys word boundaries and may increase cognitive processing load.

The existence of word-level representations is further supported by the finding that compound words can be automatically activated in normal reading. Inhoff and Wu (2005) inserted four characters constituting two words in a sentence and asked participants to read them. In the ambiguous condition, the central two characters of the four target characters can also form a word (e.g., 专科学生, means *students of vocational school* in English; 科学 is also a word that means *science* in English). But in the control condition, the central two characters did not form a word (e.g., 自然科学, means *natural science* in English)..The results show that the gaze duration and total time on the four target characters were much longer in the ambiguous condition than the control condition. It suggests that any two characters falling in the perceptual span can be activated even though this word does not fit the parsing.

However, one aspect that these studies did not make clear is which kind of word-level representation is activated. Different kinds of word-level representations should be distinguished. For semantic representation, it is quite likely for opaque compound words to have word-level representations; but it is uncertain whether word-level semantic representation is necessary for transparent words because whole word meaning is almost equivalent to the combination of component morpheme meanings. For phonological representation, word level representation is especially important for characters that have more than one pronunciation (e.g., 会议/hui4 yi4/ vs. 会计/kuai4 ji4/). But such characters are not the majority of Chinese characters. Importantly, the situation of whole-word orthographic representation is entirely unknown because characters are written in the same way no matter it is used alone or as components of compound words. Word-level orthographic representation may not be necessary because it is exactly the same as a combination of component characters.

2.3 Access of Chinese compound words

After discussion of the representation of Chinese compound words, another question is how such words are accessed. Whether compound words are accessed as wholes or as two units in compound word processing has been hotly debated. Recently, however, the involvement of component morphemes has been accepted by most researchers. The focus of the debate now is in what ways component morphemes are involved. In other words, the concern is whether component morphemes act as orthographic cues for compound word access or as semantic components for compound word meaning computation. The two accounts are called morpho-orthographic account and morpho-semantic account in the following part.

2.3.1 Morpho-semantic account

Morpho-semantic activation has been routinely examined with the morpho-semantic transparency effect in previous studies (Morris, Frank, Grainger, & Holcomb, 2007; Rueckl & Aicher, 2008). Specifically, if transparent and opaque complex prime words produce significantly different magnitude of priming effects on their stems, morpho-semantic activation is inferred. Conversely, if transparent and opaque words produce similar priming effects, it is inferred that morpho-semantic information is not involved in early morphological processing. Behavioral, eye movement and neural studies have been used to test morpho-semantic activation.

One of the pioneer studies of semantic transparency effect on complex words processing is Marslen-Wilson, Tyler, Waksler, and Older (1994) in English. In a cross modal (auditory-visual) priming experiment, they found morphological priming for transparent complex words and their stems (e.g., *government-govern*) only, but not for opaque complex words and their stems (e.g., *apartment-apart*). The results suggest that transparent complex words were processed in a decomposed way, while opaque words were treated as wholes. Thus, it is inferred that semantic factors affect morphological processing because the only difference between transparent prime-target pairs and opaque prime-target pairs was the degree of semantic relationship. Similar results were also obtained with the long term priming paradigm (Rueckl & Aicher, 2008).

The semantic transparency effect was also observed with Chinese compound word by Wang and Peng (2000). Using unmasked visual priming paradigm (prime duration 100ms), initial morpheme-compound word priming (e.g., 美、*beautiful* in English－美丽, *beautiful* in English), final morpheme-compound word priming (e.g., 丽 *beautiful* in English －美丽 *beautiful* in English) and morphologically related compound word priming (e.g., 美好, *fine* in English －美丽 *beautiful* in English) all revealed larger priming effect produced by transparent pairs than opaque pairs. This finding suggests that morpheme meaning activation occurs in Chinese compound word processing.

Morpho-semantic activation was also observed in neuropsychological studies. For example, Bolte, Schulz and Dobel, (2010) measured the neural activation (indicated by MEG) of lexical decisions to derived German adjectives, pseudo-derived words that replace the suffix of a real word by a synonymous suffix, and anomalous pseudo-derived words that replace the suffix of a real word by a suffix out of role. The results show that compared to real words and synonymous suffix pseudowords, lexical decisions to anomalous suffix pseudowords increase brain activity of the left temporal lobe in the time window of N400. The results suggest that morpho-semantic analysis took place in complex words processing.

The influence of morpho-semantic processing on neural activation was also observed by Morris, Frank, Grainger, and Holcomb (2007) with a backward masked priming paradigm (prime duration 50ms, backward mask 20ms) in a lexical decision task. They observed graded effects for semantically transparent pairs (e.g., *hunter-HUNT*), semantically opaque pairs (e.g., *corner-CORN*), and orthographically related pairs (e.g., *scandal-SCAN*) for both N250 and N400 component. The results show that semantic transparency affects morphological decomposition and thus provide more evidence to morpho-semantic processing. Feldman et al. (2009) found similar results.

The above studies used indirect methods to infer the activation of morpho-semantic information. Direct evidence of morpheme meaning activation was also observed in normal reading by White, Bertram and Hyönä (2008), who found that a parafoveal preview word semantically related to the second constituent morpheme of a target compound word brought facilitation effect on later eye movement indictors (i.e., gaze duration, total reading time) on the target.

2.3.2 Morpho-orthographic account

Although the studies reviewed in the last section show that morpho-semantic activation occurs in complex word processing, other researchers observed semantically blind morphological decomposition. The latter groups of studies used both complex word-root pairs and root-complex word pairs as prime-target pairs, both bimorphemic and multi-morphemic words, and both low frequency words and high frequency words.

Morpho-orthographic decomposition is different from pure orthographic processing. For example, Rastle, Davis, and New (2004) found that transparent (e.g., *cleaner-CLEAN*) and opaque (e.g., *corner-CORN*) complex words produced similar amount of facilitation to lexical decisions of their roots, in a masked priming paradigm (SOA[1] 42ms). However, pure orthographic primes (e.g., *brothel-BROTH*) did not bring significant effect to target word recognition. This finding was confirmed by Longtin and Meunier (2005) by the masked priming paradigm (SOA 47ms) with pseudowords consisting of roots and suffixes and by Marslen-Wilson, Bozic, and Randall (2008) with different SOA conditions (i.e., SOA 36, 48, & 72ms). All these studies show that

[1] Stimulus-Onset Asynchrony (SOA) refers to the length of time between the beginning of prime and the beginning of target.

morpheme processing is form-based and insensitive to semantics, but it differs from orthographic processing.

Morpho-orthographic decomposition was also evidenced for multi-morphemic Russian words with the masked priming paradigm (prime duration 59ms) (Kazanina, Dukova-Zheleva, Geber, Kharlamov, & Tonciulescu, 2008). Multi-morphemic words containing two suffixes were used as primes and their roots containing one suffix were used as targets. The results show that both transparent prime-target pairs (e.g., *gor-k-a* → *GOR-A*) and pseudo-derived prime-target pairs (e.g., *lunk-a* →*LUN-A*) produced similar facilitation, but orthographically related pairs (e.g., *part-a* →*PAR-A*) did not.

The conclusion of automatic morpho-orthographic decomposition in most of the studies reviewed above was drawn on low frequency complex words processing. The influence of word frequency on morphological processing was examined by McCormick, Brysbaert, and Rastle (2009). They found that complex primes produced similar facilitation to their stems, regardless of word frequency, with a forward masked priming experiment. The results show that morphological decomposition took place in both low and high frequency complex words.

The morpho-orthographic decomposition account also received support from eye movement studies (Pollatsek & Hyönä, 2005; Frisson, Niswander-Klement, & Pollatsek, 2008). For example, Pollatsek et al. (2005) recorded eye movements of participants when they were reading sentences containing a Finnish compound target word. Semantic transparency of the target words was manipulated. The results show that the semantic transparency of the target words did not have significant effect on the gaze duration on the target words. It suggests that semantic information may not affect the processing of Finnish compound words.

Besides eye movement studies, morpho-orthographic decomposition was also observed in neuropsychological studies. For example, Lavric, Clapp, and Rastle (2007) used the masked priming paradigm (prime duration 42ms) to test the influence of semantics on morphological decomposition in an ERP study. The N400 component activated by opaque morphological pairs (e.g., *corner-CORN*) and transparent morphological pairs (e.g., *hunter-HUNT*) was quite similar. Both morphological pairs elicit greater priming effect than orthographic pairs (e.g., *brothel-BROTH*).

Similar pattern of brain activation was observed for transparent and opaque Hebrew complex word pairs with priming paradigm (Bick, Goelman, & Frost, 2008). In this study, half of the prime-target pairs were semantically related and the other half were semantically unrelated despite sharing a root. The FMRI results show that the activation of semantically related and unrelated morphologically related pairs did not differ significantly. The results suggest that morphological processing in Hebrew was also independent of semantics.

It was also found that the brain region of morphological processing overlapped more with that of orthographic processing than semantic processing in an FMRI study (Gold & Rastle, 2007). In this study, lexical decisions to pseudo-morphological complex word pairs (e.g., *corner-CORN*), orthographically related pairs (e.g., *brothel-BROTH*) and semantically related word pairs (e.g., *forest-TREE*) were recorded in a masked priming paradigm (SOA 30ms). The results show three brain regions for morphological decomposition, with two of them (the posterior portion of the fusiform gyrus and the extrastriate region in a posterior portion of the middle occipitall gyrus) overlapped with orthographic activation. The specific region for morphological decomposition was the anterior portion of the middle occipital gyrus. These results provided a neural basis for morpho-orthographic account of morphological processing.

2.3.3 Form-then-meaning account

The reason that there is evidence supporting either morpho-semantic processing or morpho-orthographic decomposition may lie in the differences in the experimental paradigms. Specifically, significant differences between transparent and opaque words were found in cross-modal priming, unmasked visual-visual priming and masked priming with long prime duration. However, under masked priming, where the prime words are not consciously perceived, null effect of semantic transparency was often observed. If this is the case, these findings are consistent with a form-then-meaning account of morphological processing of complex words.

The form-then-meaning account has gained some empirical supports in the past decade. For example, Rastle, Davis, Marslen-Wilson, and Tyler (2000) found that transparent complex words produced consistent facilitation to their roots (e.g., *departure-DEPART*) in both short and long SOA conditions, while opaque complex words produced facilitation in the two shorter SOAs (43 and 72ms) but not in the long SOA condition (230ms). It suggests that morpho-orthographic decomposition that can be observed with both transparent and opaque words took place at the very early stage of compound word processing, while morpho-semantic activation that can only be observed with transparent words occurred at a later stage of complex word processing.

The form-then-meaning processing was also observed by Longtin, Segui, and Hallé (2003), who examined morphological processing with French complex words by both masked visual priming (SOA46ms) and unmasked auditory-visual priming. The results of masked visual priming experiments show that prior presentation of a transparent complex word, an opaque complex word, and a pseudo-derived word produced similar facilitation to target root words. However, the results of auditory-visual priming experiment show that only transparent complex words produced facilitation to target root words. The contrasting findings with masked visual priming and unmasked cross-modal priming experiments suggest that semantically blind morphological decomposition may takes place at the early stage of complex word processing, while the semantic factors took effect at a later stage. Similar findings were also found by Feldman, Soltano, Pastizzo, and Francis (2004).

The form-then-meaning hypothesis also received support from neural studies. For example, Morris, Grainger and Holcomb (2008) found that the brain activities of the participants might differ when they were processing transparent and opaque related prime-target pairs, depending on the stage of processing. They found that transparent and opaque words elicited similar pattern in the early stage of the N250 component that should be regarded as an early stage activation component. However, the neural activation pattern for transparent and opaque words differed from each other on the late stage of N250 component that may reflect top-down semantic activation.

2.3.4 Debate between form-then-meaning and form-with-meaning accounts

Although the form-then-meaning account was supported by some empirical studies, the debate between morpheme-orthographic account and morpho-semantic account is far from settled. The critical issue is whether morpho-semantic activation occurs at the very early stage of complex word processing. Some found that morpheme meaning activation occurs at a later stage of compound word processing and thus supported the form-then-meaning account (Rastle, Davis, Marslen-Wilson, & Tyler, 2000); while others observed morpheme meaning activation at the very early stage of compound word processing and thus supported the form-with-meaning account (Feldman, O'Connor, & Del Prado Martin, 2009). In fact, it is difficult to differentiate the two accounts. The critical difference between them seems to lie in the sequence of morpheme form and meaning activation. If morpheme meaning activation is observed as soon as morpho-orthographic decomposition, it is supposed to support the form-with-meaning account. Otherwise, if morpheme meaning activation lags behind morpho-orthographic decomposition, it is supposed to support the form-then-meaning account.

On the one hand, Rastle and Davis (2008) concluded that the facilitation produced by transparent and opaque complex words to their root were quite similar in size (30 vs. 23ms) after a review of nineteen recent studies on semantic transparency effect in morphological processing under masked priming. Considering that the durations of the primes in the reviewed studies ranged from 33ms to 59ms, their analysis show that at the very early stage of complex word processing, morpho-orthographic decomposition may be blind to semantic factors.

On the other hand, an opposite conclusion was reached by Feldman, O'Connor, and Del Prado Martin (2009) after reanalyzing the same set of masked priming experiments reviewed by Rastle et al. (2008). Feldman and colleagues noted that there was a small but statistically insignificant effect of semantic transparency found in the reviewed studies. When the results from the individual studies were pooled in a combined analysis, a significantly larger priming effect by transparent words than opaque words on their respective stem was found. Similar result was also found in their new experiment (Feldman et al., 2009) and other studies with masked priming (e.g., Diependaele, Sandra, & Grainger, 2009). Such findings suggest that morpho-semantic processing was indeed observable at the very early stage of complex word processing and thus were against the form-then-meaning account.

In the face of the counterview from Feldman et al. (2009), Davis and Rastle (2010) pointed out that some unmatched orthographic factors for transparent and opaque complex words may contribute to the results of Feldman et al., (2009). Specifically, some opaque complex words containing quite irregular suffix changes (e.g., *bliss-blistery*) were not treated as morphologically related pairs by other researchers (e.g., McCormick et al., 2009). Including such words as opaque words may contribute to the significant difference observed between transparent and opaque words by Feldman et al., (2009). In addition, Davis and Rastle (2010) used a more sophisticate method (funnel plots) to summarize former studies and confirmed their original conclusions (Rastle & Davis, 2008).

2.4 Summary

Chinese compound words are meaningful units but composed of two morphemes/characters. How such words are represented in the mental lexicon is an intriguing question. Previous studies have not reached a consensus (e.g., Zhang & Peng, 1992; Taft et al., 1999). They did not distinguish among orthographic, phonological and semantic representations (e.g., Bai et al., 2008). Whether Chinese two-character compound words are represented as orthographic wholes or not in the mental lexicon is still an open question. The present study aims to fill this research gap.

The second focus of the present study concerns the access of Chinese compound words. The current debate on morphological processing centers on two aspects: the time course of morphological processing (prelexical or supralexical) and the nature of morphological processing (morpho-orthographic or morpho-semantic). These two points can be combined into one question: Can morpheme meaning be activated at early stage of compound words processing? The second aim of the present study is to test morpheme meaning activation during Chinese compound words processing.

In order to answer the above two research questions, a series of masked priming experiments was conducted. These experiments used the masked priming paradigm instead of the unmasked priming paradigm, because of two reasons: (1) It has been reported that in the masked priming paradigm with short prime duration, participants are likely to perceive the prime unconsciously. But in the unmasked priming paradigm, participants are likely to perceive and process the primes consciously. As a result, the observed effects might be affected by the response strategies of the participants. (2) The masked priming paradigm is supposed to detect early, automatic processing. According to Perfetti, Tan and Liu (2005), activation of orthography in Chinese character processing is quite fast and precedes phonological and semantic processing. Since the aim of the first two studies was to examine orthographic processing of Chinese compound words, the masked priming paradigm is more appropriate than the unmasked priming paradigm. Similarly, because study 3 aims to test whether or not morpheme meaning activation occurs at early stage of Chinese compound words processing, the masked priming paradigm is appropriate.

Chapter 3

Study 1: High frequency orthographic neighbor inhibition effect in Chinese

3.1 Introduction

The orthographic representation of Chinese compound words was investigated with high frequency orthographic neighbor inhibition effect in Study 1. Orthographic neighbors in English initially referred to words that differ only in one letter, with the other letters remaining at their positions (e.g., *take-lake*) (Coltheart, Daelaar, Jonasson, & Besner, 1977). Later, researchers (e.g., Davis, Perea, & Acha, 2009) held that orthographic neighbors should include addition (e.g., *width-with*), deletion (e.g., *fright-freight*) and transposed neighbors (e.g., *trial-trail*). Some researchers (Nakayama, Sears, & Lupker, 2008; Janack, Pastizzo, & Feldman, 2004) went even further to suggest that two words with 50% orthographic similarity should be regarded as neighbors.

High frequency neighbor inhibition effect refers to the finding that lexical decision responses to words with a high frequency orthographic neighbor are slower than to those without a high frequency neighbor (Grainger & Jacobs, 1996). In masked priming, a high frequency neighbor prime (e.g., *able*) inhibits a lexical decision response to a low frequency neighbor target (e.g., *AXLE*), compared to control (e.g., *door*). However, a low frequency neighbor does not inhibit but facilitate the lexical decision response to a high frequency target (Forster & Davis, 1984; Segui & Grainger, 1990; De

Moor, Verguts, & Brysbaert, 2005; Davis & Lupker, 2006).

In accordance with Grainger and Jacobs (1996), the high frequency neighbor inhibition effect is caused by selective lateral inhibition among word candidates, as proposed in the Interactive Activation Model (McClelland & Rumelhart, 1981). Word candidates refer to words that get activation to some degree in the lexical access of target word because they are related to the target word in certain aspects, such as orthography, phonology and semantics. Selective lateral inhibition refers to the inhibition produced by a word candidate to all the other activated word candidates. In visual word recognition, words sharing orthographic similarity are strong competitors of each other for lexical access. A word's ability to inhibit another word's activation is assumed to be a function of its word frequency. In other words, a high frequency word that has a high baseline activation level can be activated to a much stronger level than a low frequency word. Thus, the activated lexical representation of a high frequency word can interfere with the lexical access of its low frequency neighbors.

This explanation predicts that nonword primes sharing orthographic similarity with target words would not produce inhibition because nonwords are not assumed to occupy lexical representation at all. Many studies (Forster, Mohan, & Hector, 2003; Perea & Lupker, 2004) have confirmed that compared to an unrelated nonword (e.g., *doir*), a nonword orthographic neighbor (e.g., *axue*) brought facilitation to target word (e.g., *AXLE*) processing due to orthographic similarity. The results show that the orthographic neighbor effect is modulated by prime lexicality.

If the high frequency neighbor inhibition effect is caused by two lexical representations competing for lexical access, this effect can be used to investigate whether or not Chinese compound words are represented as wholes in the mental lexicon. Specifically, if Chinese two-character compound words are represented as holistic units (i.e., occupy lexical entries in the mental lexicon), the representation of a high frequency neighbor would inhibit lexical access of a low frequency neighbor. Otherwise, if there are no word-level representations, facilitation will be found between two orthographic neighbors due to orthographic similarity. In short, inhibition effect is supposed to occur on the lexical level and facilitation effect is supposed to occur on the prelexical level. Thus, inhibition or facilitation between a high frequency orthographic neighbor and a low frequency orthographic neighbor in Chinese can shed light on the underlying representation status of Chinese compound words.

Orthographic neighbors in Chinese cannot be defined in the same way as in alphabetic languages, considering the great differences between the two writing systems. In Chinese, characters sharing the same phonetic radicals (e.g., 簧, 璜, 㨪, 磺, 横) were defined as orthographic neighbors by Li, Bi, and Zhang (2010). Two compound words sharing one component character (e.g., 美丽, means *beautiful* in English and 美食, means *choice food* in English) were defined as orthographic neighbors by Huang, Lee, Tsai, Tzeng, and Huang (2006). Because compound words are the objects investigated in the present study, orthographic neighbors used here follow Huang et al. (2006).

Overview of Study 1

Study 1 was designed to explore word-level orthographic representations of Chinese compound words. Four experiments were conducted to test high frequency orthographic neighbor inhibition effect in Chinese and to detect the influence of semantic transparency on such effect. The first two experiments each included two sub-experiments in which either the initial or final character overlapped in the prime-target word pairs. Experiment 1 attempted to reproduce the high frequency orthographic inhibition effect with Chinese compound words by following the procedure that previous studies had used to obtain such effects with alphabetic languages. Experiment 2 improved on Experiment 1 by matching the phonological lexicality of word and nonword neighbors.

To detect the effect of semantic transparency on compound word representation, semantic transparency of both prime and target compound words were added to the design of Experiment 2 to develop Experiments 3 and 4. Experiment 3 used neighbors sharing the initial character and Experiment 4 used neighbors sharing the final character. Experiments 3 and 4 both included four parts: (1) Transparent prime-transparent target (TT); (2) Opaque prime-transparent target (OT); (3) Transparent prime-opaque target (TO); (4) Opaque prime-opaque target (OO).

3.2 Experiment 1

The predictions of Experiment 1 are as following: (1) High frequency word neighbors should produce inhibition to low frequency targets due to lexical competition, if compound words have lexical entries in the mental lexicon. (2) Nonword neighbors should produce facilitation to target words due to orthographic similarity.

3.2.1 Experiment 1a

Method

Participants

Forty college students from the South China Normal University participated in the present study. All of them were native Chinese speakers, right handed, and had normal or correct-to-normal vision. They voluntarily took part in the study and were paid for their participation. Experiments 1 and 2 used the same participants.

Design

This was a 2×2 within subject design. The first factor was orthographic neighborhood of the prime and target words (neighbor or not). The second factor was lexicality of the prime words (orthographic word or nonword).

Materials

Twenty-eight low frequency compound words (e.g., 简略, means *brief* in English) were selected as target words. The mean frequency of target words was 54 per million (Institute of Language Teaching and Research, 1986). Each target word was paired with four types of primes: a high frequency orthographic neighbor (e.g., 简直, means *virtually* in English), a high frequency unrelated word (e.g., 实际, means *practical* in English), an orthographic nonword neighbor (e.g., 简贤) and an unrelated nonword (e.g., 实犹). The mean frequency of orthographic neighbors and unrelated word was 1377 and 1477 per million, respectively. The same number of nonword targets (e.g., 保蜡) was designed in the same way as word targets. Another 20 pairs of word pairs were used for practice.

The critical materials were arranged in a Latin-Square Design. All materials were divided into four blocks. Each block included 28 word targets and 28 nonword targets in four different conditions. Each target word only appeared once in one block, preceded by one type of primes. The participants were divided into four equal subgroups and each subgroup did only one block. In each block, the materials were presented in randomized order. Other linguistic characteristics of the prime words (i.e., frequency rank[2], neighborhood size and stroke number of component characters) are shown in Table 3-1.

[2] The character frequency rank was according to State Language Work Committee, 2008, that cut the commonly used 56,008 words into 2969 frequency ranks.

Table 3-1 Linguistic characteristics of the stimuli used in Experiment 1-2

Linguistics characteristics	Exp1a	Exp1b	Exp2a	Exp2b
Frequency rank of initial character	1842.51	2892.54	1808.96	2903.34
	(1952.00)	(4533.58)	(1887.46)	(4835.01)
Frequency rank of final character	2853.06	2277.10	3969.87	2250.70
	(3603.83)	(2840.68)	(3811.53)	(3004.86)
Neighborhood size of initial character	102.94	68.12	98.62	75.70
	(62.54)	(76.71)	(65.04)	(75.67)
Neighborhood size of final character	92.34	112.89	83.77	105.17
	(124.53)	(113.68)	(107.38)	(114.81)
Stroke number of initial character	7.98	8.28	8.10	8.43
	(2.44)	(2.64)	(2.36)	(2.81)
Stroke number of final character	7.95	8.37	8.00	7.90
	(2.95)	(2.89)	(2.84)	(2.61)

Note. Standard deviations in parentheses

Procedure

The stimuli were presented by a computer on a 15-inch liquid crystal display. All the characters were set in 18 font of *Song Font*. The words presented at the center of the screen were approximately 2.7cm×1.3cm in size. Participants sat about 60cm from the screen. The program was compiled by the E-Prime 2.0 software.

Forward masked priming paradigm was employed. In the beginning of the experiment, a red fixation signal in 46 Font (the same size as a word stimulus) was first shown at the center of the screen for 500ms. Then a series of symbols (####) appeared as mask and lasted for 500ms. After its disappearance, a prime word would be presented at the same position for 57ms. Then the target word turned up and stayed on the screen until the participant made a response on the keyboard. The task was a lexicon decision task in which the participants were to decide whether the target was a real word or not. As soon as the participants made a decision, the target word disappeared and the participants were asked to press a key to start the next trial. The participants could choose to rest every 20 trials.

At the beginning of the experiment, the participants were instructed about the procedure. Then there was a practice phase to make sure they understood the task. The practice phase consisted of 10 word-word and 10 word-nonword pairs.

Results

Table 3-2 RT (ms) and accuracy in Experiment 1a

	word prime		nonword prime	
	RT	Accuracy	RT	Accuracy
neighbor	855(192)	.94(.24)	794(209)	.97(.16)
unrelated	809(187)	.98(.15)	836(219)	.96(.20)

Note. Standard deviations in parentheses

The data of one participant was deleted due to high error rate. The data of another five participants were not used due to their long reaction time (M>2000ms). Only correct response was included for analysis. Reaction time that exceeded three standard deviations and those shorter than 300ms or longer than 1500ms was deleted (about 6%). One item was deleted because one of the four prime conditions was totally removed by the above criteria.

The data were analyzed with Linear Mixed Effect Model by R program, using subject and item as random intercepts. The p-values were estimated by the Monte Carlo Markov chain (MCMC) sampling (Baayen, 2008). The orthographic neighborhood between prime and target words, prime lexicality and interaction of these two factors were used as predictors for log RT. In addition, the model also included the linguistic characteristics of the prime words including the frequency rank, neighborhood size and stroke number of both the initial and final characters as covariates. An example of the equation is as follows: logRT = lexicality * neighborhood + (1|Subject) + (1|targetword) + freq1 + freq2 + N1 + N2 + stroke1 + stroke2.

In total, 822 data points were used in RT analysis. The results show that the main effect of prime lexicality was not significant (t =-.62, p>.05). The main effect of orthographic neighborhood was significant (t =-2.80, p<.01). The interaction between prime lexicality and orthographic neighborhood was significant (t =3.83, p<.01). Further analysis shows that this interaction was caused by inhibition produced by word orthographic neighbors (F=5.90, p<.05) and facilitation produced by nonword orthographic neighbors (F=4.06, p<.05) to target word. In addition, none of the effect of covariate reached statistical significance (ps>.05). The pattern of the results is shown in Figure 3-1.

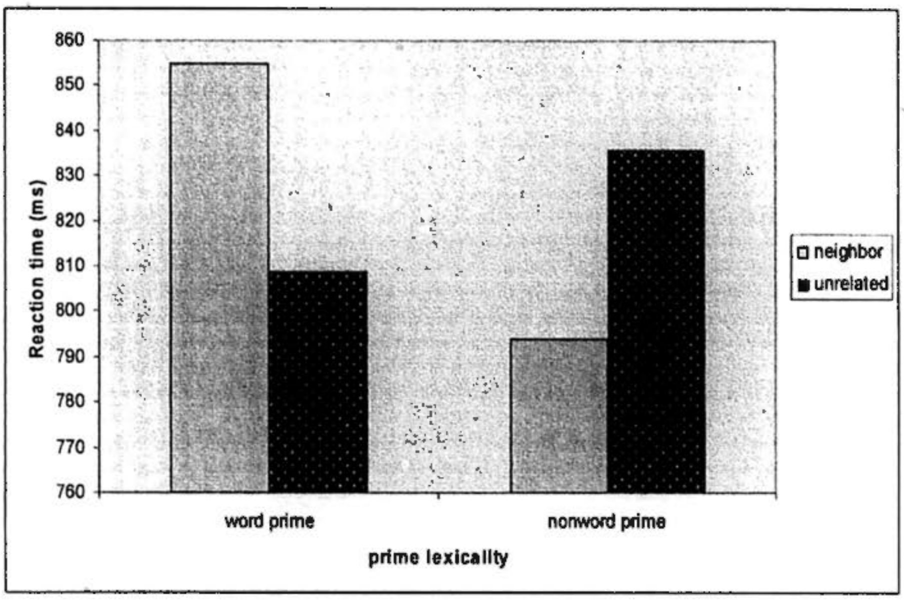

Figure 3-1 RT results in Exp 1a

For accuracy analysis, 1053 data points were used. A logit mixed effect model using the same predictors and covariates as in RT analysis were constructed. The results show that the main effect of the stroke number of the initial character in prime words reached significance, *odds ratio*=1.21, p<.05. It revealed that increase in the stroke number of the initial character enhanced the possibility for the participants to make a correct response. More importantly, the interaction between prime lexicality and orthographic neighborhood was also significant, *odds ratio*= 0.23, p<.05. Further analysis show that compared to unrelated words, high frequency orthographic word neighbors reduced accurate rate of the lexical decisions to target words (F=5.53, p<.05). However, the difference between nonword neighbors and unrelated nonwords was not significant

(F=0.92, p>.05). No other effect reached significance (ps>.05). The pattern of the results is shown in Figure 3-2.

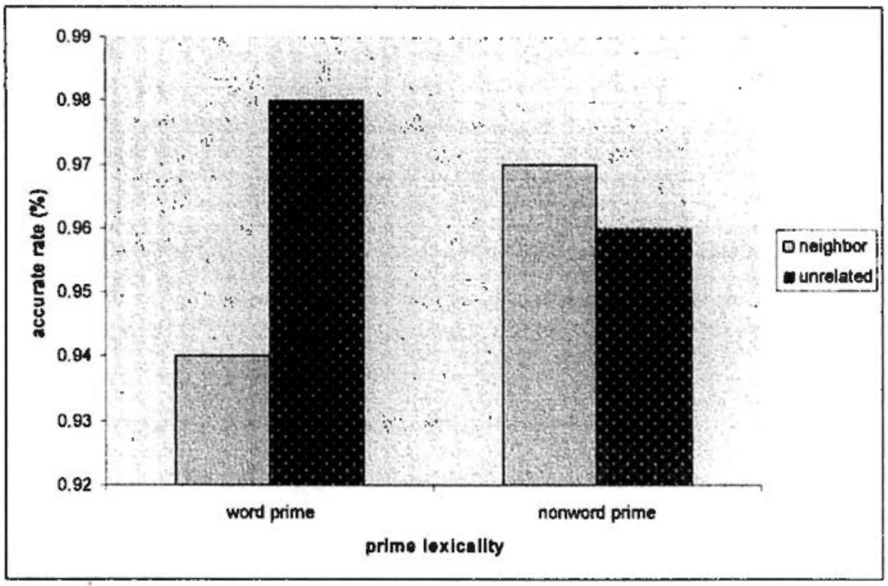

Figure 3-2 Accuracy results in Exp 1a

3.2.2 Experiment 1b

Experiment 1a used prime-target word pairs that share the initial morpheme. In order to explore the role played by character position in the processing of Chinese two-character, prime-target word pairs sharing the final character was tested in Experiment 1b.

Method

Participants, Design, and Procedure

The participants, design and procedure were the same as Experiment 1a.

Materials

Twenty-eight low frequency two-character Chinese words (e.g., 路途, means *on the way* in English) were selected as target words. The mean frequency of target words was 54 per million. Each target word was paired with four types of primes: an orthographic neighbor (e.g., 前途, means *future* in English), an unrelated prime word (e.g., 阴谋, means *conspiracy* in English), an orthographic nonword neighbor (e.g., 紘途) and an unrelated nonword (e.g., 驰谋). The mean frequency of related and unrelated prime word was 667 and 672 per million, respectively. The linguistic characteristics of the prime words including the mean frequency rank, the orthographic neighborhood size and the stroke number of the initial and final characters are shown in table 1-1. The same number of nonword targets was included.

Results

Table 3-3 RT (ms) and accuracy in Experiment 1b

	word prime		nonword prime	
	RT	Accuracy	RT	Accuracy
neighbor	733(168)	.97(.18)	689(167)	.99(.12)
unrelated	721(175)	.97(.16)	708(151)	.99(.12)

Note. Standard deviations in parentheses

The data of one participant was deleted due to high error rate. Only correct response was included for analysis. Reaction time that exceeded three standard deviations and those shorter than 300ms or longer than 1500ms was deleted (about 3.2%).

In total, 1035 data points were used in RT analysis. The results show that the main effect of prime lexicality was not significant (t=.69, p>.05). The main effect of orthographic neighborhood was significant (t=-2.61, p<.01). The interaction between prime lexicality and orthographic neighborhood was significant (t=3.10, p<.01). But simple effect analysis did not reveal significant difference between high frequency neighbor and unrelated word primes (F=0.67, p>.05) or between nonword neighbor and unrelated nonword primes (F=2.33, p>.05). The effect of the neighborhood size of the second character in prime words reached significance (t=-2.09, p<.05). It shows that neighborhood size of the second character facilitate target word processing. No other effect of covariate reached statistical significance (ps>.05). The pattern of the results is shown in Figure 3-3.

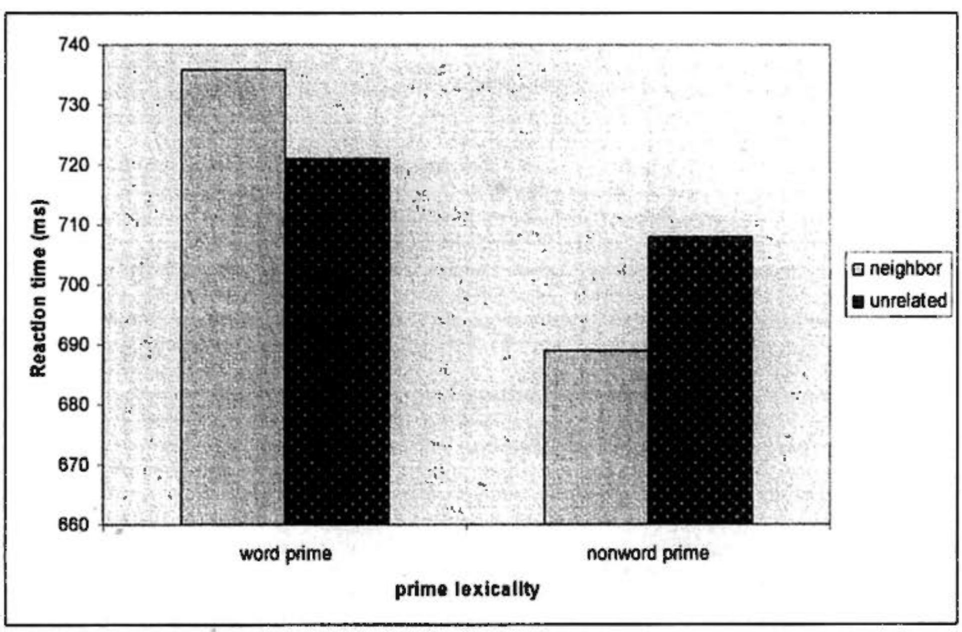

Figure 3-3 RT results in Exp 1b

For accuracy analysis, 1092 data points were used. A logit mixed effect model using the same predictors and covariates as in RT analysis were constructed. The results did not reveal any significant effect (*ps*>.05).

3.2.3 Discussion of Experiment 1

The results of Experiment 1a show that lexical decision responses to a low frequency word target preceded by a high frequency orthographic neighbor were slower than by an unrelated word. However, nonword neighbor primes produced facilitation to lexical decision responses to target words, compared to unrelated nonwords. On the one hand, the observed inhibition effect is likely to be caused by lexical competition between prime and target words. Otherwise, the visual similarity between prime and target words would produce facilitation instead. Additionally, the inhibition is most likely to be caused by competition between word-level orthographic representation of prime and target words. That is because phonological and semantic similarities between prime and target words are likely to produce facilitation in visual word recognition task. On the other hand, the observed facilitation for nonword targets shows that nonwords did not have lexical entries and thus did not produce lexical competition to target words.

Despite the results of Experiment 1b showing that the effect produced by word neighbors and nonword neighbors, compared to their respective controls, were significantly different, the inhibition effect produced by prime-target pairs with the same final characters was not quite reliable as revealed by simple effect analysis ($p>.05$). Such results suggest inferiority of the final character in Chinese compound word processing.

3.3 Experiment 2

One aspect that was not matched for word and nonword neighbors in Experiment 1 was phonological lexicality. Specifically, the orthographic word neighbors in Experiment 1 can be pronounced as real Chinese words, but the nonword neighbors cannot. Thus, the difference produced by them may be confounded by phonological factors. To test this possibility, both orthographic word and nonword neighbors were made as phonological words in Experiment 2 (e.g., 划算, means *cost-effective* in English and 华算, the first characters, 划 and 华, were homophones, thus 华算 was a phonological word). In this way, any difference between the priming effects produced by orthographic word and nonword neighbors should be free from phonological influence.

3.3.1 Experiment 2a

Method

Participants

The same participants of experiment 1 took part in Experiment 2.

Design

This was a 2×2 within subject design. The first factor was orthographic neighborhood of the prime and target words (neighbor or not). The second factor was orthographic lexicality of the prime words (orthographic word or nonword). It should be noted that all prime words were phonological words.

Materials

The word targets were twenty-eight low frequency two-character Chinese words (e.g., 路途, means *journey* in English). Their mean frequency was 44 per million. Each target word was paired with four types of primes: an orthographic word neighbor (e.g., 路线, means *route* in English), an unrelated word (e.g., 实现, means *accomplish* in English), an orthographic nonword neighbor (but phonological word) (e.g., 路限, homophone of 路线) and an unrelated nonword (but phonological word) (e.g., 实献, homophone of 实现). The mean frequencies of the related and unrelated words were 1313 and 1380 per million, respectively. In sum, there were 112 pairs of word target. The same number of nonword targets was also used.

In addition to the 224 critical target words, another 20 pairs of materials (half word targets and half nonword targets) were created for practice. The target words used in this experiment were arranged in a Latin-Square design as in Experiment 1. The mean frequency rank, the orthographic neighborhood size and the stroke number of the initial and final characters of prime words are shown in table 3-1.

Procedure

The procedure was the same as that of Experiment 1.

Results

Table 3-4 RT (ms) and accuracy in Experiment 2a

	word prime		nonword prime	
	RT	Accuracy	RT	Accuracy
neighbor	757(182)	.92(.27)	742(174)	.96(.19)
unrelated	712(178)	.97(.16)	713(174)	.95(.23)

Note. Standard deviations in parentheses

The data of one participant was deleted due to high error rate. Only correct responses were included in the analyses. Reaction times that exceed three standard deviations and those shorter than 300ms or longer than 1500ms were deleted (about 4.0%).

In total, 996 data points were used in RT analysis. The results (Figure 3-4) show that the main effect of prime lexicality was not significant (t=-.39, p>.05).. The main effect of orthographic neighborhood was significant (t=2.05, p<.05). The interaction between prime lexicality and orthographic neighborhood was not significant (t=1.20, p>.05). In addition, none of the effects of the covariates reached statistical significance (ps>.05).

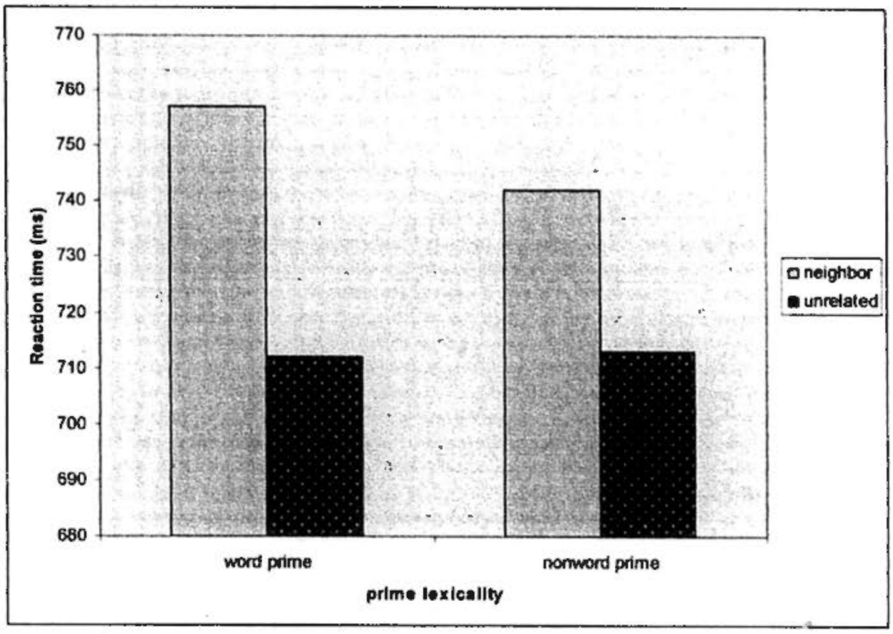

Figure 3-4 RT results in Exp 2a

For accuracy analysis, 1092 data points were used. A logit mixed effect model using the same predictors and covariates as in RT analysis were constructed. The results show that increase in the neighborhood size of the initial character reduced the possibility to produce a correct response (*odds ratio*=0.99, $p<.05$), but that of the final character enhanced the possibility to produce a correct response (*odds ratio*=1.01, $p<.05$). More importantly, the interaction between prime lexicality and orthographic neighborhood was also significant, *odds ratio*= 0.15, $p<.01$. Further analysis shows that the accuracy to target word recognition preceded by a high frequency orthographic neighbor was lower than by an unrelated word control (F=8.29, $p<.01$). However, the accuracy to target words recognition preceded by a nonword neighbor was not significantly different from that preceded by an unrelated nonword control (F=1.05, $p>.05$). No other effect reached statistical significance ($ps>.05$). The pattern of the results is shown in Figure 3-5.

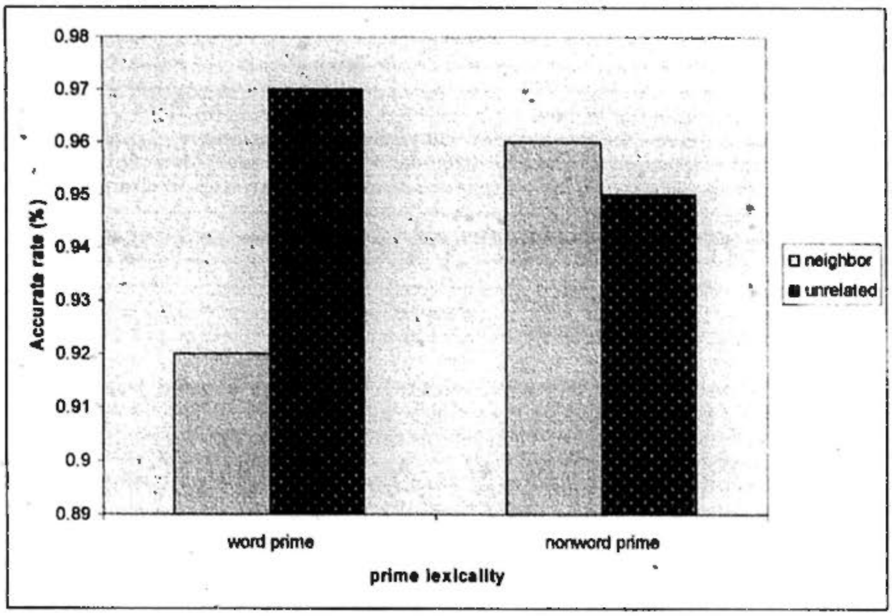

Figure 3-5 Accuracy results in Exp 2a

3.3.2 Experiment 2b

The difference between Experiment 2b and 2a was materials. The prime-target pairs examined in Experiment 2b shared final characters.

Method

Participants, Design, and Procedure

The participants, design and procedure were the same as Experiment 2a.

Materials

Twenty-eight low frequency two-character Chinese words (e.g., 路途, means *journey* in English) were selected as target words. The mean frequency of the target words was 52 per million. Each target word was paired with four types of primes: an orthographic word neighbor (e.g., 前途, means *future* in English), an unrelated word (e.g., 阴谋, means *conspiracy* in English), an orthographic nonword neighbor (but phonological word) (e.g., 钱途, homophone of 前途) and an orthographic unrelated nonword (but phonological word) (e.g., 音谋, homophone of 阴谋). The mean frequencies of related and unrelated word (i.e., 前途 and 阴谋) were 728 and 728 per million, respectively. The same number of nonword targets was also included. The mean frequency rank, the orthographic neighborhood size and the stroke number of the initial and final characters of prime words are in Table 3-1.

Results

Table 3-5 RT (ms) and accuracy in Experiment 2b

	word prime		nonword prime	
	RT	Accuracy	RT	Accuracy
neighbor	687(161)	.96(.19)	673(160)	.97(.17)
unrelated	697(169)	.97(.17)	686(145)	.97(.18)

Note. Standard deviations in parentheses

The data of one participant were deleted due to high error rate. Only correct data was included for RT analysis. Reaction times that exceed three standard deviations and those shorter than 300ms or longer than 1500ms were deleted (about 3.1%).

In total, 1024 data points were used in RT analysis. The results revealed no significant effect (ps>.05).

For accuracy rate analysis, 1092 data points were used. A logit mixed effect model using the same predictors and covariates as in RT analysis was constructed. The results show that the neighborhood size of the final character enhanced the possibility to produce a correct response (*odds ratio*=1.02, $p<.05$). It also shows that the stroke number of the final character enhanced the possibility to produce a correct response (*odds ratio*=1.25, $p<.05$). No other effect reach significance ($ps>.05$).

3.3.3 Discussion of Experiment 2

Experiment 2a but not 2b reveal significant inhibition effect produced by high frequency orthographic neighbors to low frequency target words. In other words, the initial characters seem to be more important than the final characters in determining lexical competition. The implication of this finding for the representation of Chinese compound words will be discussed in the General Discussion of this chapter.

An unexpected finding of Experiment 2a was that nonword neighbors (which were phonological words) also produced inhibition to lexical decision responses to target words. This inhibition effect may be caused by the nonword neighbors activating the orthographic representations of their base words. This is possible, considering that the nonwords in this experiment share an initial character with their base words and can be pronounced identically. Still, the word neighbors seem to produce a more reliable inhibition effect than the nonword neighbors, because the accuracy analyses show a significant interaction effect between neighborhood and prime lexicality

3.4 Experiment 3

The results of Experiment 2 show that high frequency Chinese compound words are likely to produce lexical competition to the recognition of target words. Experiments 3 and 4 went further to test the influence of the semantic transparency of prime and target words on the observed high frequency orthographic neighbor inhibition effect. It is predicted that high frequency opaque compound words are more likely to inhibit the processing of their low frequency orthographic neighbors than transparent compound words.

3.4.1 Method

Participants

Eighty new subjects from the same subject pool participated.

Design

This was a 2(orthographic neighborhood) × 2(prime lexicality) × 2(target transparency) × 2(prime transparency) mixed design. Orthographic neighborhood, prime lexicality and prime transparency were within-subject factors. Target transparency was a between-subject factor[3].

Materials

[3] It is worth noting that inclusion of pseduohomophone nonword neighbors in the present study aims to make a balance between word and nonword neighbors on phonological aspects.

The transparent and opaque words were initially selected by the author and then were further examined by the participants after they had finished the main experiment. Eighty participants in Experiment 3 and 4 were divided into eight groups to evaluate the semantic transparency of 818 words. Each group evaluated the semantic transparency of about 100 Chinese compound words. Participants were invited to evaluate the semantic relatedness between component characters and whole words on a seven-point scale with '1' representing 'highly unrelated' and '7' 'highly related'. T-test show significant difference between transparent (M=5.10, SD=0.76) and opaque (M=3.82, SD=0.91) words (t=-21.82, p<.01).

Materials for transparent prime-transparent target (TT) part

Thirty-six low frequency Chinese compound words (e.g., 货船, means *cargo ship* in English; 货 means *goods* and 船 means *ship*) were used as word targets. The mean frequency of target words was 37 per million. Each target word was preceded by each of the following primes once -- an orthographic neighbor (e.g., 货币, means *currency* in English; 货 means *goods* and 币 means *money*), an unrelated word (e.g., 稳定, means *stable* in English; 稳 means *steady* and 定 means *fixed*), an orthographic nonword neighbor (e.g., 货毕, 毕 is a homophone of 币) and an unrelated nonword (e.g., 稳订, 订 is a homophone of 定). The mean frequency of orthographic word neighbor and control words was 956 and 966 per million, respectively.

The prime-target pairs were arranged in a Latin-Square design. The total materials were divided into four blocks. Each block included 36 word targets and 36 nonword targets in four different conditions (word neighbor, unrelated word, nonword neighbor, unrelated nonword). Each target word only appeared once in one block, preceded by one type of primes. The participants were divided into four equal subgroups and each subgroup did only one block. In each block, the materials were randomized anew.

Materials for opaque prime-transparent target (OT) part

Thirty-six low frequency two-character Chinese words (e.g., 抽查, means *random inspection* in English; 抽 means *draw out* and 查 means *check*) were used as word targets. The mean frequency of target words was 32 per million. Each target word was paired with an orthographic neighbor (e.g., 抽象, means *abstract* in English; 抽 means *draw out* and 象 means *resemble* in English), an unrelated word (e.g., 正经, means *serious* in English; 正 means *correct* and 经 means *pass through* in English), an orthographic nonword neighbor (e.g., 抽向, 向 is a homophone of 象) and an unrelated nonword (e.g., 正京, 京 is a homophone of 经). The mean frequency of orthographic word neighbor and control words was 719 and 714 per million, respectively.

Materials for transparent prime-opaque target (TO) part

Thirty-six low frequency two-character Chinese words (e.g., 表白, means *confess* in English; 表 means *watch* and 白 means *white* in English) were used as word target. The mean frequency of the target words was 39 per million. Each target word was paired with an orthographic neighbor (e.g., 表演, means *performance* in English; 表 means *watch* and 演 means *play* in English), an unrelated word (e.g., 防护, means *protect* in English; 防 means *defend* and 护 means *protect* in English), an orthographic nonword neighbor (e.g., 表眼; 眼 is a homophone of 演) and an unrelated nonword (e.g., 防互, 互 is a homophone of 护). The mean frequency of orthographic word neighbor and control words was 941 and 931 per million, respectively.

Materials for opaque prime-opaque target (OO) part

Thirty-six low frequency two-character Chinese words (e.g., 机智, means *tactful* in English; 机 means *machine* and 智 means *wisdom* in English) were used as word targets. The mean frequency of target words was 38 per million. Each target word was paired with an orthographic neighbor (e.g., 机会, means *opportunity* in English; 机 means *machine* and 会 means *conference* in English), an unrelated word (e.g., 消息, means *message* in English; 消 means *eliminate* and 息 means *rest* in English), an orthographic nonword neighbor (e.g., 机汇, 汇 is a homophone of 会) and an unrelated nonword (e.g., 消希, 希 is a homophone of 息). The mean frequency of orthographic word neighbor and control words was 809 and 804 per million, respectively. The same number of nonword targets was included in each part. The arrangement of the materials was similar as Experiment 1. Other linguistic characteristics of the prime words (i.e., frequency, neighborhood size and stroke number of component characters) are shown in table 3-6.

Table 3-6 Linguistic characteristics of the stimuli used Experiment 3

Linguistics characteristics	T-T part	O-T part	T-O part	O-O part
Frequency rank of initial character	2018.26	1391.36	1671.60	1140.22
	(3836.50)	(1527.42)	(3799.73)	(1099.99)
Frequency rank of final character	2893.92	2485.11	2589.43	2986.19
	(3855.46)	(3085.65)	(2751.11)	(4493.11)
Neighborhood size of initial character	118.72	171.36	116.45	163.14
	(85.07)	(102.87)	(85.82)	(101.02)
Neighborhood size of final character	79.51	90.54	89.27	90.72
	(75.10)	(107.38)	(103.84)	(104.89)
Stroke number of initial character	8.11	7.24	8.16	7.22
	(3.04)	(2.74)	(2.69)	(2.68)
Stroke number of final character	8.44	8.25	7.99	7.97
	(2.69)	(2.96)	(2.98)	(3.08)

Note. Standard deviations in parentheses

Procedure

Forward masked priming paradigm was used in the present study. The procedure was the same as that of Experiment 1.

3.4.2 Results

Table 3-7 RT (ms) and accuracy in Experiment 3

		Transparent target				Opaque target			
		Transparent prime		Opaque prime		Transparent prime		Opaque prime	
		word	nonword	word	nonword	word	nonword	word	nonword
neighbor	RT	817(145)	789(134)	768(137)	739(133)	854(137)	822(132)	804(150)	759(119)
	Accuracy	.88(.33)	.93(.26)	.91(.29)	.94(.24)	.84(.36)	.86(.35)	.81(.39)	.85(.36)
control	RT	810(135)	785(126)	761(130)	760(126)	845(140)	832(145)	776(119)	773(128)
	Accuracy	.92(.27)	.90(.30)	.93(.26)	.92(.27)	.86(.34)	.88(.32)	.87(.33)	.86(.34)

Note. Standard deviations in parentheses

The data of one participant were deleted due to high error rate. Only correct data were included for analysis. Reaction time that exceeded three standard deviations and those shorter than 300ms or longer than 1500ms was deleted (about 5.9%).

In total, 4744 data points were used in RT analysis. The results show that the main effect of prime lexicality was not significant (t=-.16, p>.05). The effect of orthographic neighborhood was not significant (t=-.92, p>.05). The effect of prime transparency was significant (t=3.16, p<.05). Compared to opaque primes, transparent primes produced longer response to target words. The effect of the stroke number of initial character was significant (t=2.44, p<.05). The more number of strokes the initial character of the prime words contained, the longer the responses to the target words were. The interaction between prime lexicality and orthographic neighborhood was marginally significant (t=1.89, p=.06). However, simple effect analysis does not show significant differences between high frequency neighbor and unrelated word control ($F=1.74$, $p>.05$), and between nonword neighbor and unrelated nonword control ($F=0.77$, $p>.05$). No other effect reached significance ($ps>.05$).

For accuracy analysis, 5688 data points were used. A logit mixed effect model using the same predictors and covariates as in RT analysis were constructed. The results show that compared to opaque target words, transparent words enhanced the possibility for the participants to make correct responses (*odds ratio*=2.41, $p<.05$). No other effect reached significance ($ps>.05$).

Because different response latencies were produced by different types of prime and target, we also did analyses for each kind of word pairs. In each part, prime lexicality and orthographic neighborhood between prime and target were used as within-subject and within-item factors. The mean frequency rank, orthographic neighborhood size and stroke number of the initial and final characters were used as covariates.

Results of transparent prime - transparent target (TT) part

For RT analysis, 1217 data points were used. The results (Figure 3-6) show that the main effect of prime lexicality was significant ($t=2.19$, $p<.05$). Compared to nonword primes, word primes produced longer response to target words. No other effect reached significance ($ps>.05$).

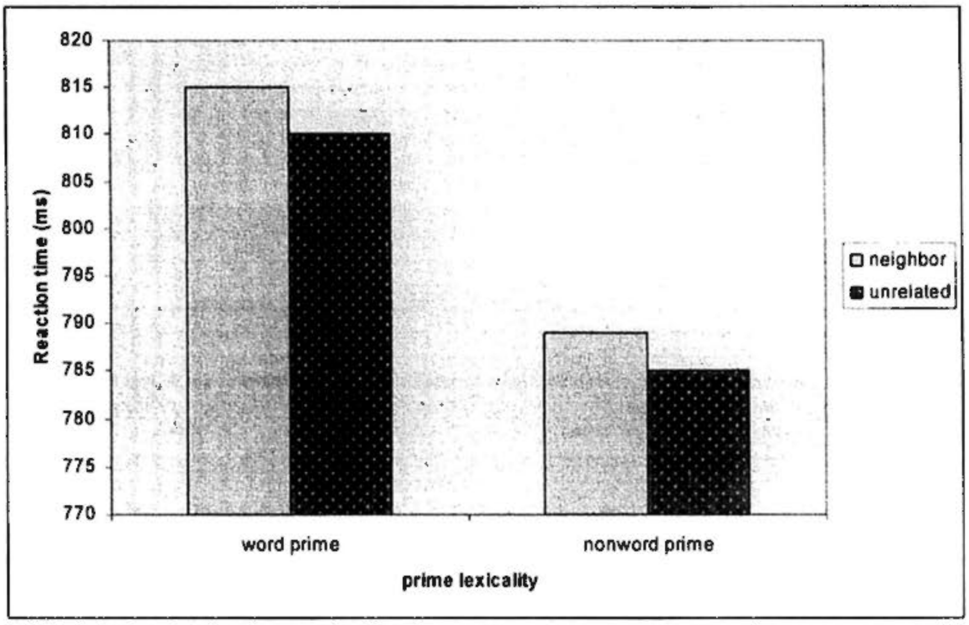

Figure 3-6 RT result in Exp 3 (TT part)

For accuracy rate analysis, 1440 data points were used. A logit mixed effect model using the same predictors and covariates as in RT analysis were constructed. The results (Figure 3-7) show that the interaction between prime lexicality and orthographic neighborhood between primes and targets was significant (*odds ratio*=0.39, $p<.05$). Simple effect analysis show that this interaction was caused by significant inhibition produced by high frequency neighbor compared to unrelated word control (F=8.29, $p<.01$), and a null effect produced by nonword neighbor compared to unrelated nonword control (F=0.18, $p>.05$). No other effect reached significance ($ps>.05$). The pattern of results is shown in Figure 3-7.

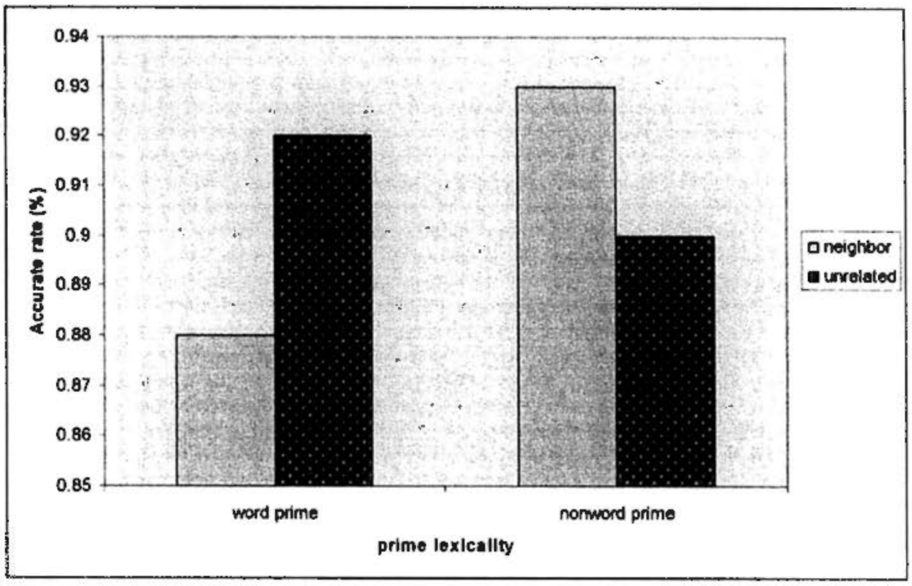

Figure 3-7 Accuracy results in Exp 3 (TT part)

Results of opaque prime - transparent target (OT) part

For RT analysis, 1285 data points were used. The results (Figure 3-8) show that the main effect of neighborhood between prime and target was significant (t=-2.16, p<.05). More importantly, the interaction between prime lexicality and neighborhood was significant (t=1.99, p<.05). Simple effect analysis shows that the difference between high frequency neighbor and unrelated word control was not significant (F=0.06, p>.05), and facilitation produced by nonword neighbor compared to unrelated nonword control was marginally significantly (F=3.07, p=.07). No other effect reached significance (ps>.05).

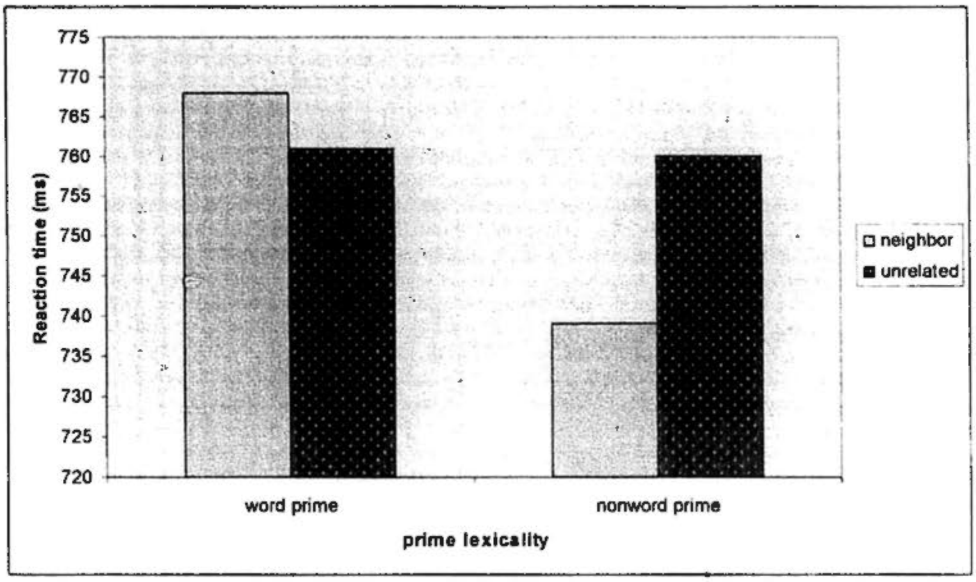

Figure 3-8 RT result in Exp 3 (OT part)

For accuracy rate analysis, 1404 data points were used. A logit mixed effect model using the same predictors and covariates as in RT analysis were constructed. No other effect reached significance (*p*s>.05)

Results of transparent prime-opaque target (T-O) part

For RT analysis, 1115 data points were used. The results show that no effect reached significance (*p*s>.05).

For accuracy rate analysis, 1404 data points were used. A logit mixed effect model using the same predictors and covariates as in RT analysis were constructed. The results show that the frequency of both the initial and final characters enhance the probability to produce a correct response (*odds ratio*=1.01, *p*<.05; *odds ratio*=1.01, *p*<.05). It also shows that the neighborhood size of the final character enhanced the probability to produce a correct response (*odds ratio*=1.01, *p*<.05). No other effect reached significance

($ps>.05$).

Results of opaque prime-opaque target (OO) part

For RT analysis, 1117 data points were used. The results (Figure 3-9) show that the interaction between prime lexicality and neighborhood between prime and target was significant (t=2.00, $p<.05$). Simple effect analysis show the inhibition (20ms) produced by high frequency neighbor compared to unrelated word control was not significant (F=1.19, $p>.05$) and facilitation produced by nonword neighbor compared to unrelated nonword control was also not significant (F=0.08, $p>.05$). But the significant interaction effect did reveal different pattern produced by word neighbor and nonword neighbor compared to their respective control. No other effect reached significance ($ps>.05$). .

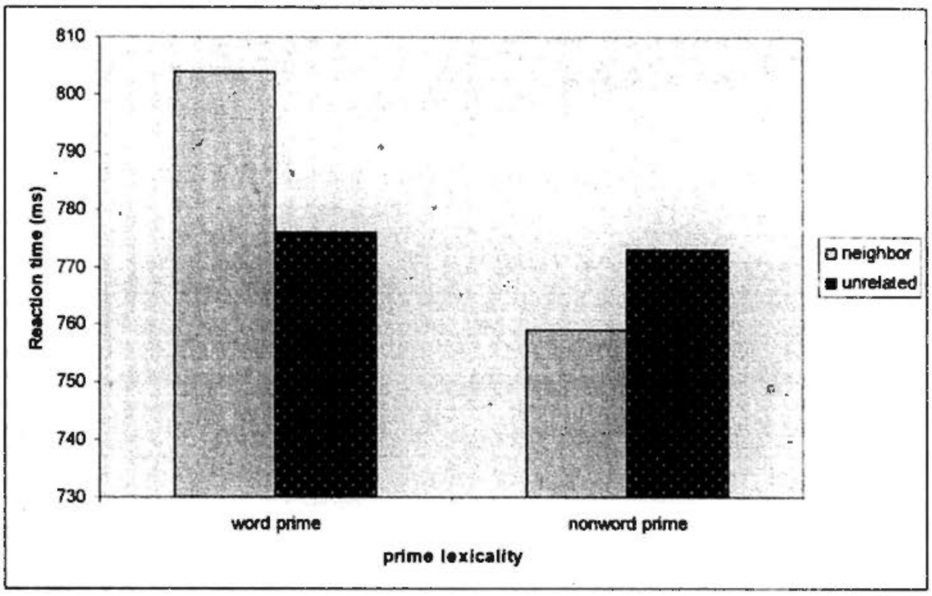

Figure 3-9 RT result in Exp 3 (OO part)

For accuracy rate analysis, 1404 data points were used. A logit mixed effect model using the same predictors and covariates as in RT analysis were constructed. The results do not show any significant effect (*p*s>.05).

3.4.3 Discussion of Experiment 3

The results of the combined analysis in Experiment 3 revealed a marginally significant interaction between neighborhood and prime lexicality. Separated analyses of RT for each type of prime-target pair show significant interaction for opaque prime-transparent target and opaque prime-opaque target pairs. The common characteristic of these two types of prime-target pairs was that they both had opaque words as primes. Thus, the observed interaction indicates that high frequency opaque neighbors were more likely than transparent neighbors to bring inhibition to lexical decision responses to low frequency target words (transparent or opaque). In other words, opaque compound words are more likely to occupy lexical representations that compete with target words for lexical access.

This conclusion should be taken with cautions, because the accuracy analysis for transparent prime-transparent target also revealed a significant interaction between prime lexicality and neighborhood. Further analysis show that high frequency neighbors were less likely to induce a correct response than control. It may suggest that high frequency transparent words are likely to occupy word level representations that may compete with other transparent words for lexical access. However, the results of RT analysis do not show significant inhibition effect produced by a high frequency transparent neighbor a low frequency opaque target word.

3.5 Experiment 4

3.5.1 Method

In this experiment, the orthographic neighbors shared the final character. The linguistic characteristics of prime words were shown in table 3-8. All the other aspects were the same as Experiment 3.

Table 3-8 Linguistic characteristics of the stimuli used Experiment 4

Linguistics characteristics	T-T part	O-T part	T-O part	O-O part
Frequency rank of initial character	2864.75	2608.96	2794.78	2652.40
	(3077.35)	(3799.07)	(3534.03)	(3668.32)
Frequency rank of final character	2338.79	2061.49	1732.78	2154.88
	(4790.68)	(4823.60)	(2172.25)	(3624.84)
Neighborhood size of initial character	88.74	109.24	93.61	107.26
	(110.13)	(102.62)	(113.88)	(97.32)
Neighborhood size of final character	126.42	90.54	145.24	147.47
	(87.96)	(107.38)	(109.53)	(104.80)
Stroke number of initial character	8.87	9.84	9.03	8.43
	(3.65)	(2.74)	(5.95)	(3.07)
Stroke number of final character	7.86	7.78	7.99	8.22
	(2.74)	(2.74)	(2.78)	(2.72)

Note. Standard deviations in parentheses

3.5.2 Results

Table 3-9 RT (ms) and accuracy in Experiment 4

		Transparent target				Opaque target			
		Transparent prime		Opaque prime		Transparent prime		Opaque prime	
		word	nonword	word	nonword	word	nonword	word	nonword
neighbor	RT	677(84)	696 (75)	708(103)	722(121)	727(111)	731(111)	734(115)	721(96)
	Accuracy	.92(.27)	.90(.30)	.86(.35)	.88(.32)	.83(.37)	.87(.34)	.85(.36)	.88(.33)
control	RT	682(87)	704(83)	699(103)	714(102)	715(99)	719(103)	727(86)	719(82)
	Accuracy	.94(.24)	.91(.29)	.89(.32)	.88(.33)	.85(.36)	.89(.32)	.87(.34)	.85(.36)

Note. Standard deviations in parentheses

The data of one participant was deleted due to high error rate. Only correct data were included for analysis. Reaction time that exceeded three standard deviations and those shorter than 300ms or longer than 1500ms was deleted (about 3.3%).

In total, 4840 data points were used in RT analysis. The results show that the effect of prime transparency was marginally significant (t 1.75, p=.07). Compared to opaque primes, transparent primes produced longer response to target words. No other effect reached significance (ps>.05).

For accuracy rate analysis, 5688 data points were used. A logit mixed effect model using the same predictors and covariates as in RT analysis were constructed. The results show that the effect of the neighborhood size of the final character was significant (*odds ratio*=1.01, p<.05). It suggests that neighborhood size of the final character enhanced the probability for participants to make a correct response.

Results of transparent prime-transparent target (TT) part

1284 data points were used in RT analysis. The results show that the effect of prime lexicality was significant (t=-2.10, p<.05). It shows that lexical responses to target words were much faster preceded by word primes than nonword primes. No other effect reached significance (ps>.05).

For accuracy rate analysis, 1440 data points were used. A logit mixed effect model using the same predictors and covariates as in RT analysis were constructed. The results show that the effect of the stroke number of the final character was marginally significant (*odds ratio*=0.89, p=.07). Stroke number of the final character reduced the probability for participants to make a correct response.

Results of opaque prime-transparent target (OT) part

1223 data points were used in RT analysis. The results does not show any significant effect (ps>.05). For accuracy rate analysis, 1440 data points were used. A logit mixed effect model using the same predictors and covariates as in RT analysis were constructed. The results show that the effect of the stroke number of the final character was significant (*odds ratio*=0.92, p<.05). It suggests that increase in the stroke number of the final character reduced the probability for participants to make a correct response.

Results of transparent prime-opaque target (TO) part

1168 data points were used in RT analysis. The results does not show any significant effect (*ps*>.05). For accuracy rate analysis, 1404 data points were used. A logit mixed effect model using the same predictors and covariates as in RT analysis were constructed. The results show that the effect of the neighborhood size of the final character was significant (*odds ratio*=1.01, *p*<.05). It suggests that the neighborhood size of the final character enhanced the possibility for participants to make a correct response.

Results of opaque prime-opaque target (OO) part

1165 data points were used in RT analysis. The results does not show significant effect (*ps*>.05). For accuracy rate analysis, 1404 data points were used. A logit mixed effect model using the same predictors and covariates as in RT analysis were constructed. The results also does not show any significant effect (*ps*>.05).

3.5.3 Discussion of experiment 4

The results of Experiment 4 show that high frequency orthographic neighbors sharing the final character did not produce inhibition effect to lexical decision response to low frequency target words. The null findings of Experiment 4 show the inferior status of the final character in Chinese compound words.

3.6 General Discussion of Study 1

The results of Experiment 1 show that high frequency orthographic neighbors produce inhibition to low frequency target words. Supposing that the inhibition is caused by lexical competition (Grainger & Jacobs, 1996), it can be argued that Chinese compound words have unitary lexical representations. The lexical representations are likely to be orthographic because the contribution of phonological influence to the high frequency neighbor inhibition effect was found minimal in Experiment 2. The contribution of semantic representations is also unlikely because the orthographic neighbors used in the present study were mostly semantically unrelated. There is no reason that their semantic representations would compete with each other for activation. Another reason that semantic representations cannot explain the inhibition effect is that semantic effects should be facilitative rather than inhibitory. Thus, the occurrence of inhibition between orthographic neighbors is mainly caused by competition between word-level orthographic representations of prime and target words.

Additional results of Study 1 (Experiments 3 and 4) suggest that word-level orthographic representations of Chinese compound words are affected by semantic transparency[4]. Opaque compound words are more likely to be represented as wholes than transparent words. Furthermore, the results of Study 1 also show that the initial character plays a more important role than the final character in compound words processing.

Orthographic representations of Chinese compound words

Besides the high frequency neighbor inhibition effect observed in the present

[4] It should be noted that the semantic transparency effect was revealed in separated analysis for each type of prime-target pairs. The combined analysis of Experiment 3 did not reveal a significant interaction between relatedness and semantic transparency of the primes.

study, the existence of word-level orthographic representations for Chinese compound words is further supported by the prime lexicality effect observed in Experiment 1. It was found that although inhibition occurred for word prime (HF)-word target (LF) pairs, prior presentations of nonword orthographic neighbors facilitated target words recognition. This indicates that lexical competition cannot occur if the primes do not occupy unitary lexical entries. Instead, facilitation due to prelexical similarity (i.e., form overlap) between primes and targets was observed. The findings are consistent with studies of alphabetic languages (e.g., Forster, Mohan, & Hector, 2003).

The present finding is consistent the Multilevel Interactive-activation Framework (Taft et al., 1999), which acknowledges the existence of word-level orthographic representations of compound words in the mental lexicon. Word-level orthographic representation may provide a theoretical explanation for the up-down interaction between word-level and character-level processing revealed by the WSE in Chinese (e.g., Mok, 2009), and is probably a reason for automatic activation of compound words in normal Chinese reading (Inhoff & Wu, 2005).

Besides the Multilevel Interactive-activation Framework, a more recent model of lexical processing system that incorporates a 'lemma' level representation but not whole word orthographic representation/form may also be able to explain the high frequency orthographic neighbor inhibition effect in Chinese (Taft, Liu, & Zhu, 1999; Taft & Nguyen-Hoan, 2010). Lemma refers to 'an abstract level of representation that is intermediate between the form and function levels' (Taft & Minh, 2010). Both complex words and component morphemes have lemma representations. Lemmas of words that have morphological relationship but are semantically unrelated (e.g., *corner-CORN*) compete with each other. However, such competition does not actually inhibit the activation of the 'loser', but affect which lemma reach activation threshold first. Even if inhibition occurs, the loser (lemma of the target) is protected from being fully inhibited with short prime duration. Thus, small but significant facilitation is often observed with pseudo-derived complex words and their stems (e.g., *corner-CORN*), which is much smaller than that produced by truly derived word paris (*hunter-HUNT*).

Such competition between lemmas may not be able to provide a complete explanation of the present results. Firstly, it seems to predict a null effect for orthographically related but semantically unrelated prime-target pairs because of counteraction between character/morpheme-to-word lemma facilitation and word lemma competition. Secondly, lemma competition cannot exclude the existence and the influence of whole-word orthographic representation (at lexical level) entirely, because lemma of whole words is not totally unrelated to whole-word orthographic representation. Instead, it is an abstract reflection of the connection of form and meaning. As a result, the competition attributed to lemma level can hardly be determined as being caused by form or by meaning. If there is lemma for whole words, both whole-word orthographic representations and semantic representations should also exist in the network.

It is worth noting that there were important differences in the word materials used in previous studies that support the notion of lemma competition and the present study. Studies in alphabetic languages usually used complex words as primes and their stems as targets (e.g., *corner-CORN*); while the present study used two morphologically related compound words as prime-target pairs (e.g., *货船-货币*).

The influence of word-level orthographic representation on phonological neighbor processing

The results of RT analysis in Experiment 2a reveals that orthographic nonword neighbors that can be pronounced as real Chinese words also produced inhibition to lexical decision responses to target words. However, phonological/syllable neighbors in Spanish (e.g., words sharing the first syllable) were found to produce facilitation instead (Carreiras & Perea, 2002). In this study, responses to prime-target pairs (nonword-word) sharing not only the first two letters but also the first syllable was compared to that of prime-target pairs (nonword-word) sharing only the first two letters but not the first syllable. The results show that syllable-related primes brought larger facilitation to lexical decision to target words than letter-related primes.

One aspect that differs from Carreiras and Perea (2002) and the present study is that the phonological neighbors were nonwords in the former, but real phonological words in the latter. Thus, it is not surprising to observe different priming effect in the two studies. It is possible that the orthographic nonwords/phonological words (e.g., 作舒) in the present study can activate whole word orthographic representation of the base words (e.g., 划算, means *cost-effective* in English) considering their orthographic overlap. The activated orthographic representations of the base words compete with that of the low frequency target words (e.g., 计算, means *calculate* in English) and thus produce inhibition effect.

The present finding is consistent with Zhou and Marslen-Wilson (2009) who found that lexical decisions to psdudohomophones (e.g., 严革) that shared a component character with the base words (e.g., 严格, means *rigid* in English) were more difficult to be refused as real words. However, pseudohomophones (e.g., 研革) without orthographic overlap with the base words were not slower than control words to make a decision. It was supposed to be caused by semantic activation of the base words by orthographic overlapped pseudohomophones that counteract with the visual input. However, the difference between the two kinds of pseudohomophone is the degree of orthographic overlap with the base word. Thus it is possible that psdudohomophones sharing a component character with the base words firstly activate word-level orthographic representations and then semantic representation of the base words.

Despite the important influence of orthography, it is possible that the influence of phonology contributes to the null effect of nonword neighbors observed in Experiments 3 and 4. That is to say, phonological representations of their base words may be activated by nonword neighbors and produce competition to target words. However, such competition may counteract with facilitation produced by perceptual similarity between primes and targets, producing a null effect. Such interference is reasonable if phonological influence produces inhibition effect in primed lexical decision task. However, phonological neighbors were found to produce facilitation (Carreiras & Perea, 2002). Hence, although phonological effect in the present study cannot be eliminated entirely, its influence should be limited.

Semantic transparency effect

Word-level orthographic representations of Chinese compound words are found to be affected by semantic transparency in Study 1. The results show that lexical competition occurs only with opaque prime words (regardless of the semantic transparency of target words). In contrast, high frequency transparent orthographic neighbors do not bring inhibition to the low frequency target words (transparent or opaque). These results may imply that opaque compound words are more likely to be represented and accessed in a holistic way, while transparent words are stored and processed in a decomposed way, at least in the early stage of lexical access considering masked priming used in Study 1.

The importance of character position

The influence of character position is also investigated in Study 1. The main findings of the present experiments do not reveal any significant effect brought by orthographic neighbor pairs sharing a final character. This finding has important implications on the mental representation of Chinese compound words. It indicates the initial and final characters may have different roles in the processing of the compound words. The initial character should have processing priority over the final character. With respect to the mental representation of compound words, it is possible that the connection between compound words sharing an initial character is much stronger than those sharing a final character. Taft, Liu and Zhu (1999) considered that order information of the two components in a compound word should be marked in the representational network. In such a way, transposed nonwords (e.g., 掌马) will not be recognized as real words (e.g., 马掌).

Limitations and directions for further research

It should be noted that the orthographic neighbors used in the present study are not exactly the same as that used in alphabetic language studies. Neighbors refer to pairs of compound words sharing a component character. However, most of the orthographic neighbors used in the alphabetic studies are mono-morphemic words. This divergence is inevitable because two-character compound words occupy the majority of modern Chinese words. As a result, cautions should be made to draw a cross-language conclusion on the effect of orthographic neighbors.

For further studies, the influence of orthographic neighborhood size on neighborhood frequency effect should be examined. Using English words as materials, Nakayama et al., (2008) found that the high frequency neighbor inhibition effect was only true for primes that have small family size. For primes that have large family size, both high and low frequency primes can produce inhibition to low and high targets. Whether the orthographic neighborhood size of component characters affect the mental representation of Chinese compound words or not needs further studies.

Conclusion

Study 1 provides evidence for the existence of word-level orthographic representations and that they are affected by semantic transparency. Opaque compound words are likely to be represented as wholes. Considering that the existence of word-level/lexical representation is a prerequisite of lexical competition, the findings are hard to be incorporated into a distribute model (Plaut & Gonnerman, 2000) that denies the existence of discrete linguistic units, but are more consistent with localist models (e.g., Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981).

Chapter 4

Study 2: Transposed-character Similarity Effect in Chinese

4.1 Introduction

This study is an attempt to use a new method, namely, the transposed-character similarity effect in Chinese, to investigate the orthographic representations of Chinese compound words. The transposed-character similarity effect in Chinese is adapted from the transposed-letter similarity effect first reported in studies of English words.

Transposed-letter (TL) similarity effect refers to the facilitation brought by a transposed nonword (e.g., *jugde*) to the processing of the original word (e.g., *JUDGE*) compared to a substituted nonword (e.g., *jupte*) (Acah & Perea, 2008; Chirstianson, Johnson, & Rayner, 2005; Lupker, Perea, & Davis, 2008). This effect implies that the component letters of a word are coded for their identity information regardless of position. The reason is that if they are coded with specific position information, transposed and substituted nonwords should produce similar effect to the original words, considering that both of them have two letters different from the original words. Larger effect produced by transposed primes suggests that transposed words may activate orthographic representations of the original words, regardless of letter transposition (similar to repetition priming). It suggests that the correspondence relationship between position and letter is not exactly one-to-one and that the activation of position information lags behind letter activation. TL similarity effect is inconsistent with the traditional slot-coding system in visual word recognition models such as the Interactive Activation Model (McClelland & Rumelhart, 1981).

The most important theoretical implication of the TL similarity effect is that its locus seems to be lexical. Firstly, in recent studies (e.g., Lupker, Perea, & Davis, 2008), primes are often shown in lower case letters and targets in upper case letters to exclude the possibility that the transposed-letter similarity effect is due to visual overlap between primes and targets. Secondly, the lexicality of target words is found to affect the direction of observed effects. On the one hand, when the targets were words (e.g., *JUDGE*), prior presentation of transposed nonwords (e.g., *jugde*) produced facilitation to original words processing. On the other hand, when the targets were nonwords (e.g., *MERSE*), prior presentation of transposed nonwords (e.g., *meres*) did not produce facilitation to the processing of the original nonwords (Pear & Lupker, 2003a; Perea & Lupker, 2004; Christianson, Johnson, & Rayner, 2005). Thirdly, transposed nonword primes were also found to produce semantic priming effect to target words semantically related to the original words (e.g., *jugde-COURT*) (Perea & Lupker, 2003b). If repetition priming effect cannot exclude the influence of perceptual similarity, semantic priming can certainly do. Thus, semantic priming effect produced by TL nonwords clearly indicates that TL nonwords activate the orthographic representations of their base words. Based on these findings, it is quite certain that the locus of TL similarity effect is lexical rather than prelexical (but sees Kinoshita & Norris, 2009).

The size of the TL similarity effect may be affected by the positions of transposed letters in a word. Johnson, Perea and Rayner (2007) found that eye fixations on target words were much shorter with parafoveal previews of transposed nonwords than substituted nonwords. Furthermore, transposition of internal letters produced similar effect on target words processing as identical previews; while transposition of final letters produced much longer eye fixations on target words.

Similarly, White, Johnson, Liversedge, and Rayner (2008) found that total reading time decreased gradually from sentences containing nonwords produced by transposition of initial letters, sentences containing nonwords produced by transposition of final letters, and sentences containing nonwords produced by transposition of internal letters. These findings suggest that nonwords produced by transposition of internal letters were more likely than those produced by transposition of external letters to activate orthographic representations of the original words.

The direction of TL similarity effect has been found to be affected by the lexicality of transposed primes. In other words, if the transposed word is a word itself, the priming effect it produces is different from that produced by a transposed nonword. Words are called transposable words in the present study if the transposed words are real words themselves (e.g., salt-SLAT in English; 马上-上马[5] in Chinese). Those are not real words after transposition are called untransposable words. Take Dunabeitia, Perea and Carreiras (2009) as an example. They examined the TL similarity effect in Spanish with masked priming paradigm. They found facilitation for untransposable prime-target pairs (e.g., *cdero-CEDRO, cedar* in English) but a null effect for transposable prime-target pairs (e.g., *cerdo, pig* in English-*CEDRO, cedar* in English). The null effect was attributed to lexical level lateral inhibition between prime and target words that may offset the facilitation produced by their orthographic similarity. Nonword primes did not produce such lateral inhibition because they were not lexical units.

Lexical inhibition produced by a high frequency transposed word neighbor to the base word was observed by Acha and Perea (2008) in an eye movement study. They found that later eye movement indicators (i.e., regression and total reading time) were much longer for target words (e.g., *silver*) with a high frequency transposed word neighbor (e.g., *sliver*) than those without a high frequency neighbor. The effect observed on later stage indicators of eye movement indicates that it occurred at lexical level rather than prelexical/perceptual level. Similar results were also obtained by Johnson (2009). These findings suggest that orthographic representation of a word's high frequency TL neighbor is automatically activated in the processing of visual word recognition.

Can this effect be adopted with Chinese two-character words?

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[5] 马上 means *immediately* in English and 上马 means *launched* in English

One underlying assumption of TL similarity effect is that words have holistic orthographic representations that can be activated by their corresponding transposed nonwords. Thus, if transposed two-character Chinese words produce similar effect to the processing of real compound words, it can be inferred that two-character compound words in Chinese have holistic orthographic representations in the mental lexicon. The assumption underlying such inference is that if Chinese two-character words are represented as an organic whole in our mental lexicon, the sequential arrangement within the whole may not affect the processing of whole words because perception and processing of holistic units may have superiority over that of part units (e.g., Word Superiority Effect, Reicher, 1969; Wheeler,1970; Mok, 2009). Navon (1977) revealed the precedence of global over local features in visual perception. Participants in his study were briefly shown letters composed of smaller letters (e.g., an H composed of small H or S) and were asked to make one of two types of response: local or global. In local response condition, participants were required to report the small letter regardless of the big letter. In global response condition, participants were required to report the big letter regardless of the small letter. The results showed that response to smaller letter was much longer under inconsistent condition (i.e., the big letter and small letter were different, such as a big H composed of some small S) than consistent condition (i.e., the big letter and small letter were identical). It suggests that perception of local features is affected by global features. However, the global response was not affected by local features. In other words, response latencies were similar under inconsistent and consistent condition. Such findings suggest that global features have advantage in human's perception and may not be influenced by local features with short presentation duration. Hence, it seems reasonable to assume that transposed nonwords can activate whole-word orthographic representations if original words have global representation in the mental lexicon, despite small changes in local features.

Transporting the TL similarity effect to Chinese words should proceed with great caution because Chinese compound words are composed of two characters only. Transposed words produced by transposition of the initial and final characters are quite different from transposed English words created by transposition of two internal letters. The difference between them may be related to word types (compound words vs. single words) of the target words.

In fact, the processing of transposed English compound words has been investigated. Taft (1985) found that transposed compound words such as *stooltoad* are more difficult to reject than controls such as *tallmop* for English speakers. There are two possible accounts. On the one hand, it may be that spreading activation of component morphemes to compound word leads to the observed effect. This is Taft's (1985) account. On the other hand, it is possible that the transposed nonwords activate orthographic representation of the original compound words in a position-insensitive way. Thus, the conflict between the activated orthographic representation and visual input of a nonword required longer time to deal with.

Processing of transposed Chinese compound words has also been investigated. Using unmasked semantic priming, Peng, Ding, Wang, Taft, and Zhu (1999) found that both the original word (e.g., *领带,* means *tie* in English) and a transposed compound word (e.g., *带领,* means *lead* in English) can produce facilitation to a semantically related word (e.g., *西装,* means *business suit* in English) with SOA 157ms. The result suggests that spread activation from component morphemes to compound word occurs and that activation of morpheme position information lags behind morpheme activation. Due to morpheme level activation of the prime word that is insensitive to position information, word-level representation of the original target word is supposed to get activated and produce priming effect to a semantically related word.

In addition to semantic priming effect, repetition priming effect was also observed between two transposable compound word pairs (e.g., *领带-带领*) with various SOA durations (SOA 57, 157 and 314ms) (Ding & Peng, 2006). An unexpected finding in this experiment was that for low frequency compound word targets, when the transposable word pairs were not highly semantically related, null effect rather than facilitation was observed. This effect was interpreted as word-level semantic competition canceling morpheme-level facilitation. However, it is possible that word-level orthographic representation is firstly activated before the activation of word-level semantic representation in visual word processing.

Studies on transposed compound words processing can be divided into two parts, based on whether the target compound words are transposable or not. For untransposable compound words, facilitation produced by transposed nonwords to original words processing can be explained by both morpheme-to-word activation and pre-activation of target words' word-level orthographic representation by the transposed primes. For transposable compound words, morpheme-to-word activation account can explain facilitation effect in semantic and repetition priming; while activation of word-level orthographic/semantic representation of prime words can explain the inhibition/null effect to target word processing. However, previous studies (Taft, 1985; Peng et al., 1999; Ding & Peng, 2006) did not make a distinction between the morpheme-to-word activation account and activation of word-level orthographic representation account.

To differentiate the above two possibilities – decomposed vs. holistic accounts, Study 2 investigated both transposable and untransposable Chinese compound words (Experiments 1 to 3). The predictions are as following: (1) If there are word-level orthographic representations, transposable prime-target pairs (e.g., 马上, means *immediately* in English-上马, means *launched* in English) would produce null effect or even inhibition because two activated orthographic representation would compete with each other for lexical access; while untransposable pairs (e.g., 虎马-马虎, means *careless* in English) would produce facilitation because such transposed primes would only activate the word-level orthographic representations of the target words. (2) On the other hand, if Chinese compound words do not have holistic orthographic representations in the mental lexicon, both transposable and untransposable prime-targe pairs should produce facilitation due to spreading activation of morpheme-level information in the prime words to target words processing.

To examine the influence of semantic transparency on word-level representation, transparent and opaque compound words were used in Experiments 2 and 3, respectively. Facilitation by transposed transparent words to the original words can be attributed to both morpheme-to-word activation and activation of word-level orthographic representation. However, facilitation by transposed opaque words to the original words can only be attributed to word-level orthographic representation activation because morpheme-level activation do not lead to whole word semantic activation for opaque words.

In addition to the above three experiments, binding words are examined in Experiment 4 to test the possibility that transposed words can activate word-level representation of the original words. Binding words contain two characters that can only combine with each other. Taft and Zhu (1995) found that the naming latencies for initial characters of binding words (e.g., 蚯 in 蚯蚓) were much shorter than that for final characters of binding words (e.g., 蚓 in 蚯蚓). This finding suggests that component characters of binding words do not have independent morpheme level representations. Binding words are much likely to occupy word level representations. Naming the final character needs longer time because participants have to skip the sound of the initial character in the activated word level pronunciations. This study suggests that binding words are represented as unitary wholes (or actually monomorphemic words) and thus can only be processing in a holistic way. If transposed binding words can facilitate original word processing, it is certain that the whole word representation is activated by transposed prime words.

4.2 Experiment 1: Transposable Words

The effect of prior presentation of a transposable word on later processing of the original word was tested in Experiment 1. As mentioned earlier, transposable words refer to those that are still real words after transposition of the initial and the final characters (e.g., 马上- 上马). If compound words occupy whole word orthographic representations, the transposed words (e.g., 上马) would compete for lexical access with the target words (i.e., their transposed form, e.g., 马上) in a priming paradigm. Otherwise, the transposed words would facilitate the processing of the original words due to spreading activation from component morphemes to compound word (Peng, et al., 1999).

4.2.1 Method

Participants

The participants were 40 undergraduate and postgraduate students of the Chinese University of Hong Kong. All of them had normal or correct-to-normal vision. They were native Chinese speakers. All the participants were right handed. They voluntarily took part in the study and were paid for their participation.

Design

This was a 2 × 2 within subject design. The first factor was orthographic relatedness between prime and target words (related vs. unrelated). The second factor was the word order of the primes (normal vs. transposed).

Materials

Twenty Chinese compound words were selected as target words. Each target word (e.g., 马上, means *at once* in English) was paired with an identical word (e.g., 马上), a transposed word (e.g., 上马, means *start* in English), a control word (e.g., 性质, means *characteristics* in English) or a control nonword (e.g., 质性). The linguistic characteristics of the prime words such as the frequency rank, neighborhood size, stroke number of both the initial and final characters are shown in Table 4-1.

Table 4- 1 Linguistic characteristics of the stimuli used in Experiment 1-4

Linguistic characteristics	Exp1	Exp2	Exp3	Exp4
Frequency rank of normal words	9836.83 (9887.60)	7877.05 (6451.03)	9954.38 (6502.62)	15829.13 (7486.11)
Frequency rank of transposed words	11911.30 (12589.58)			
Frequency rank of initial character	1559.80 (2022.83)	2332.92 (2307.86)	3352.78 (7202.71)	
Frequency rank of final character	1866.88 (2269.50)	2662.00 (3158.26)	3081.13 (4512.09)	
Neighborhood size of initial character	203.40 (164.38)	123.98 (225.34)	149.38 (107.70)	
Neighborhood size of final character	229.75 (325.25)	67.88 (64.72)	132.98 (151.93)	
Stroke number of initial character	6.63 (3.29)	9.23 (3.29)	7.08 (2.89)	11.45 (3.73)
Stroke number of final character	9.13 (10.52)	9.61 (3.06)	8.18 (3.00)	11.08 (3.40)

Note. Standard deviations in parentheses

In addition to 80 pairs of critical materials, the same number of nonword targets was included as negative items of a lexical decision task. The design of nonword targets was made to be identical with word targets. Each nonword targets were (e.g., 阵止) paired with an identical nonword (e.g., 阵止), a transposed nonword (e.g., 止阵), a control word (e.g., 书写, means *writing* in English) or a transposed form of the control word (e.g., 写书, means *write a book* in English). Another 20 pairs of materials (half word targets and half nonword targets) were selected for practice.

The critical materials were arranged in a Latin-Square design. All materials were divided into four blocks. Each block included 20 word targets and 20 nonword targets in four different conditions. Each target word only appeared once in one block. In each block, the materials were randomized to present. Each participant only did one block.

Procedure

The stimuli were presented by a computer on a 17-inch liquid crystal display. All the characters were set in 18 font of *Song Font*. The words presented at the center of the screen were approximately 2.7cm×1.3cm in size. Participants sat about 60cm from the screen. The program was compiled by the E-Prime 2.0 software.

A forward masked priming paradigm was employed. At the beginning of the experiment, a red fixation signal in 46 Font (the same size as a word stimulus) was first shown at the center of the screen for 500ms. Then a series of symbols (####) appeared as mask and lasted for 500ms. After its disappearance, a prime word would be presented at the same position for 57ms. Then the target word turned up and stayed on the screen until the participant made a response on the keyboard. As soon as the participants made a decision, an interface would appear on the screen. The participants needed to press the "shift" button to begin the next trial. There was an interface for rest every 20 trials. Before the formal experiment, there was a practice phase to ensure that all the participants understood the task.

4.2.2 Results

Table 4-2 RT (ms) and accuracy in Experiment 1 6

Condition	Normal words		Transposed words	
	RT	Accuracy	RT	Accuracy
Related primed	676 (220)	.98(.14)	717(160)	.95(.22)
Control primed	739 (195)	.98(.16)	719 (190)	.97(.17)

Note. Standard deviations in parentheses

Only correct responses were used for RT analysis. Reaction time that exceeded three standard deviations of each subject was deleted. Those shorter than 300ms and longer than 1500ms were also deleted. The criteria delete about 3.6% of the total data points.

The RT data were analyzed with a Linear Mixed Effect Model, with subject and item as random intercepts. The p-values were estimated by the Monte Carlo Markov chain (MCMC) method (Baayen, 2008) using 10,000 samples. The relatedness between prime and target words, word order (normal vs. transposed) and interaction of these two factors were used as predictors for log RT. In addition, the model also included other factors that may affect the results as covariates. They are some linguistic characteristics of the prime words: the frequency rank* of the prime words, the frequency of the initial

[6] 'related normal words' refers to 'identical prime'; 'related transposed words' refer to 'transposed word prime'; 'control normal words' refer to 'word control prime'; 'control transposed words' refer to 'nonword control prime'.

*Refer to State Language Work Committee (2008).

and final characters, orthographic neighborhood size of the initial and final characters and stroke number of the initial and final characters.

In total, 748 data points were used in RT analysis. It was found that the main effect of word order was not significant (t=-.32, p>.05). The main effect of orthographic relatedness was not significant (t=.76, p>.05). The interaction between relatedness and word order was significant (t=-3.19, p<.01). Simple effect analysis shows that this interaction was caused by facilitation produced by normal related words (F=4.41, p<.05) and null effect produced by transposed related words (F=1.12, p>.05). In addition, none of the effect of covariates reached statistical significance (ps>.05). The pattern of the results is shown in Figure 4-1.

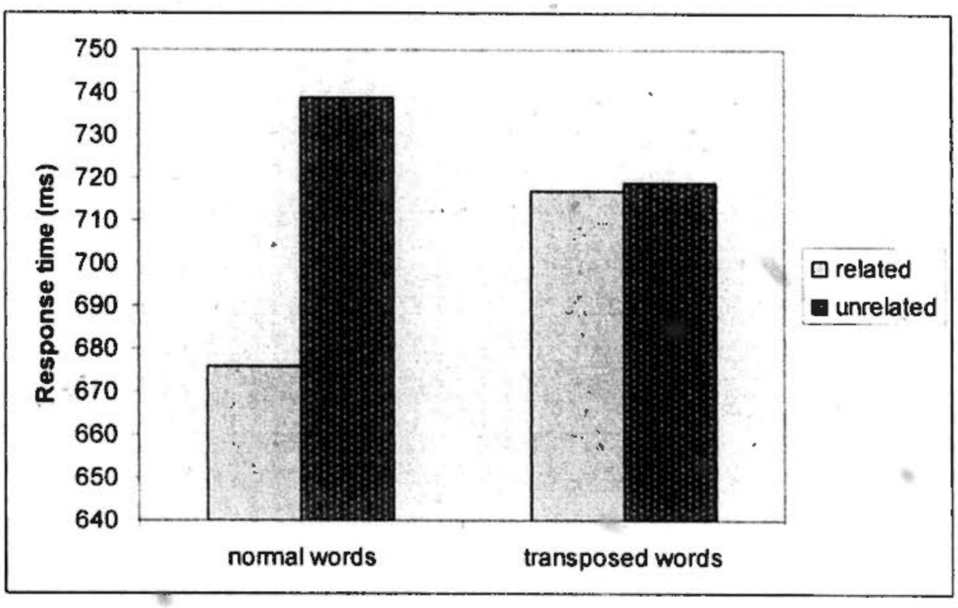

Figure 4-1 RT results of Exp 1 (Transposable words)

For accuracy rate analysis, 800 data points were used. A logit mixed effect model appropriate for nominal dependent variables was adopted. It used the same predictors and covariates as in RT analysis. However, the results did not reveal any significant effect (*ps*>.05).

4.2.3 Discussion

The observation of null effect by transposed words on the normal target words is inconsistent with the lexical competition hypothesis (which predicted inhibition effects) and the hypothesis that there is spreading activation from morphemes to words (which predicted facilitation effects). Yet it is explicable if it is supposed that the effect of the two cancels out each other.

Other researchers (Ding & Peng, 2006) have also found null effect with transposable prime-target pairs (e.g., 领带, means *tie* in English - 带领, means *lead* in English). On hindsight, the failure to observe inhibition effect with transposable prime-target pairs may be related to the word frequency of the prime and the target words. Presumably, strong competition occurs when high frequency words, which have a high baseline activation level, are paired with low frequency target words (Grainger & Jacobs, 1996). But, in this experiment and Ding and Peng (2006), the frequency of the prime and the target words was not manipulated to be high-low. Perhaps the orthographic representations of the prime words had not been activated sufficiently to inhibit lexical access of the target words. Of course, one should be extremely cautious to make an inference based on a null effect. What can be said is that the results of Experiment 1 neither reject nor support the notion that Chinese compound words have word-level orthographic representations in the mental lexicon. This unsolved question will be further explored in the following experiments.

4.3 Experiment 2: Transparent untransposable words

The processing of untransposable words may provide more credible evidence to the activation of word-level orthographic representations of Chinese compound words. The untransposable words are not real words after transposition (e.g., 骄傲, means *proud* in English, is a real word but turns into a nonword 傲骄 after transposition.) and thus do not occupy representations in the mental lexicon. If the transposed nonwords can activate word-level representation of the original words, they should facilitate the processing of the original words. The decomposed account of morpheme-to-word activation would also predict facilitation between prime and target words. However, it may have difficulty to explain the findings with opaque words. In other words, the decomposed account of morpheme-to-word activation would predict facilitation between transparent transposed nonwords and transparent target words, but not between opaque transposed nonwords and opaque target words. That is because semantic relatedness between component morphemes and opaque words is quite low.

As a result, investigation of the effect produced by transparent transposed nonwords to transparent target words and that produced by opaque transposed nonwords to opaque target words would not only examine the influence of semantic transparency on whole word representation of Chinese compound words, but also helps to make a distinction between the decomposed and holistic representation accounts. To achieve this goal, transparent and opaque compound words were used in Experiment 2 and Experiment 3, respectively.

4.3.1 Method

Participants

The same participants in Experiment 1 participated in this experiment.

Design

The design of this experiment was similar to that of Experiment 1.

Materials

Twenty transparent words were selected as target words. Each word target (e.g., 骄傲, means *proud* in English) was paired with an identical word (e.g., 骄傲), a transposed nonword (e.g., 傲骄), a control word (e.g., 利益, means *benefit* in English) or a control nonword (e.g., 益利). For nonword targets (e.g., 亲尝), each one was also paired with an identical nonword (e.g., 亲尝), a transposed nonword (e.g., 尝亲), a control word (e.g., 朗诵, means *read aloud with expression* in English) or a control nonword (e.g., 诵朗). The linguistic characteristics of the prime words such as the frequency rank, neighborhood size, stroke number of both the initial and final characters were in Table 4-1. The arrangement of materials was similar to that of Experiment 1.

Procedure

The procedure was the same as in Experiment 1.

4.3.2 Results

Table 4- 3 RT (ms) and accuracy in Experiment 2

Condition	Normal words		Transposed nonwords	
	RT	Accuracy	RT	Accuracy
Related primed	616 (168)	.98(.14)	715 (179)	.97(.16)
Control primed	676 (191)	.96(.21)	706(196)	.97(.17)

Note. Standard deviations in parentheses

Only correct responses were used for RT analysis. Reaction time that exceeded three standard deviations of each subjects was deleted. Those shorter than 300ms and longer than 1500ms were also deleted. The criteria delete about 4.9% of the total data points.

In total, 736 data points were used in RT analysis. The results (Figure 4-2) show that the main effect of word order was not significant (t=-.83, p>.05). The main effect of relatedness was significant (t=-3.33, p<.01). More importantly, the interaction between word order and relatedness was significant (t=-3.84, p<.01). Simple effect analyses show that this interaction was caused by facilitation produced by normal related words (F=29.84, p<.01) and null effect produced by transposed related nonwords (F=2.16, p>.05). In addition, none of the effect of covariate reached statistical significance

($ps > .05$).

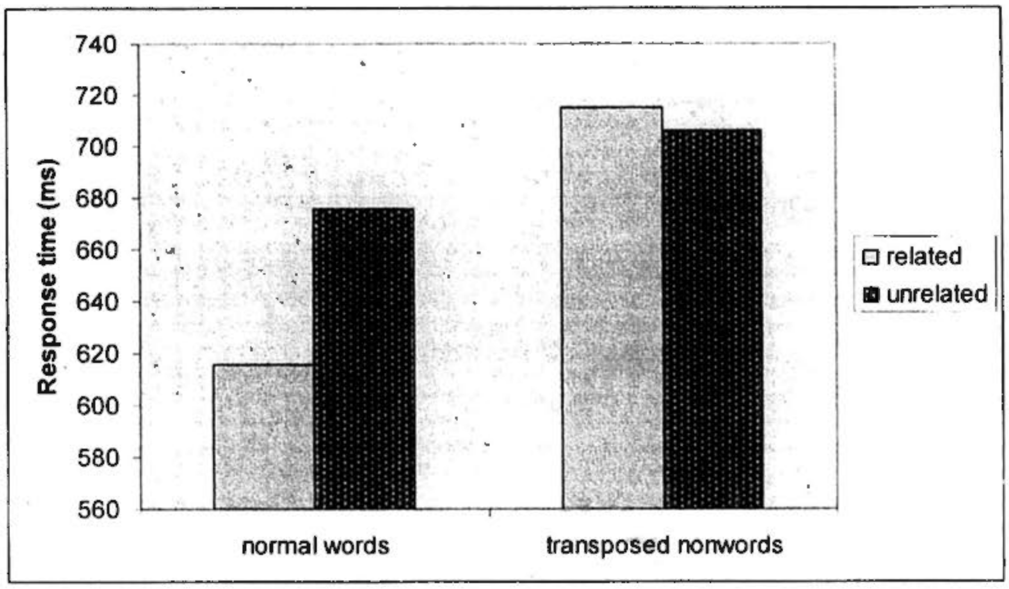

Figure 4-2 RT results of Exp 2 (transparent untransposable words)

For accuracy rate analysis, 800 data points were used. A logit mixed effect model appropriate for nominal dependent variables was adopted. It used the same predictors and covariates as in RT analysis. The results (Figure 4-3) show that the main effect of relatedness was significant, *odds ratio* =5.03, $p<.05$. It suggests that compared to unrelated primes, related primes enhanced the possibility for the participants to make a correct response. In addition, the main effect of stroke number of the second character in prime words was significant, *odds ratio*=0.81, $p<.05$. It suggests that increase of the stroke numbers of the final character decreased the possibility for the participants to make a correct response.

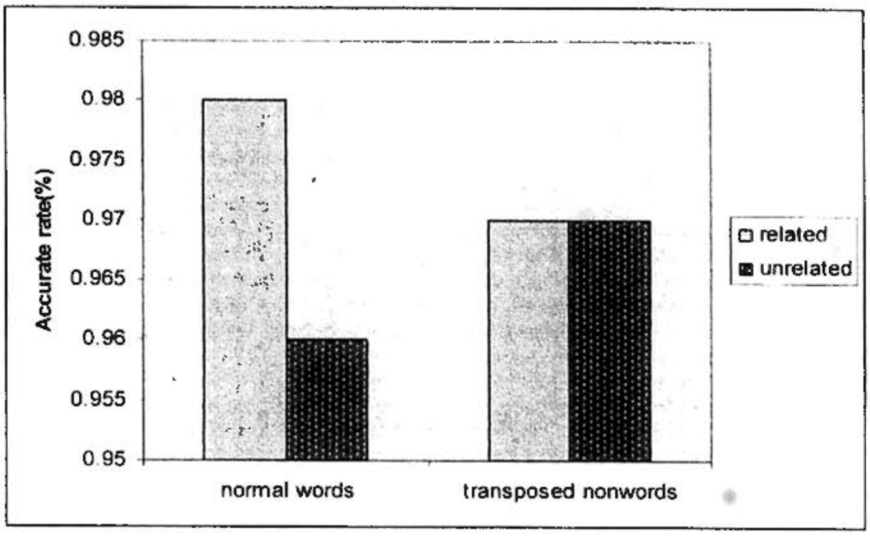

Figure 4-3 Accuracy results of Exp 2 (transparent untransposable words)

4.3.3 Discussion

The results of Experiment 2 reveal significant repetition masked priming effect with identical prime and target words. However, the transposed nonword primes did not produce significant effect to the processing of the original words. Such findings shed light on the following two aspects: First of all, it suggests that transposed nonwords in this experiment did not activate the orthographic representation of original words. Otherwise, facilitation would be observed. Secondly, it shows that the processing of transparent words is sensitive to position information. As a result, the same character/morpheme in different position (initial vs. final) was not coded as the same and thus did not facilitate each other's processing. To sum up, the results of Experiment 2 did not support the decompose account (i.e., morpheme-to-word activation) of Chinese compound word representation and suggest that transparent compound words may not occupy word-level orthographic representations in the mental lexicon.

4.4 Experiment 3: Opaque untransposable words

Experiment 3 examined the influence of transposed opaque nonwords on the processing of the original words. Opaque words are more likely than transparent words to be represented as wholes in the mental lexicon. Thus, transposed opaque nonwords may be able to activate word-level orthographic representations of original words and thus produce facilitation to the processing of the original words.

4.4.1 Method

Participants

The same participants in Experiment 1 participated in this experiment.

Design

The design of this experiment was similar to that of Experiment 1.

Materials

Twenty opaque words were selected as target words. Each word (e.g., 马虎, means *careless* in English) was paired with an identical word (e.g., 马虎), a transposed nonword (e.g., 虎马), a control word (e.g., 毕竟, means *after all* in English) or a control nonword (e.g., 竟毕). For nonword targets, each one (e.g., 评昨) was also paired with an identical nonword (e.g., 评昨), a transposed nonword (e.g., 昨评), a control word (e.g., 泉水, means *spring water* in English) or a control nonword (e.g., 水泉). The linguistic characteristics of the prime words such as the frequency rank, neighborhood size, stroke number of both the initial and final characters were in Table 2-1. The arrangement of materials was similar to that of Experiment 1.

Procedure

The procedure was the same as in Experiment 1.

4.4.2 Results

Table 4- 4 RT (ms) and accuracy in Experiment 3

Condition	Normal words		Transposed nonwords	
	RT	Accuracy	RT	Accuracy
Related primed	652 (199)	.98 (.16)	742 (212)	.97 (.17)
Control primed	704(190)	.95 (.21)	759(214)	.97 (.18)

Note. Standard deviations in parentheses

Only correct responses were used for RT analysis. Reaction time that exceeded three standard deviations of each subjects was deleted. Those shorter than 300ms and longer than 1500ms were also deleted. The criteria delete about 3.2% of the total data points.

In total, 749 data points were used in RT analysis. The results (Figure 4-4) show that the main effect of word order was not significant (t=-1.13, p>.05). The main effect of relatedness was significant (t=-4.09, p<.01). The interaction between word order and relatedness was not significant (t=-1.65, p>.05). An insignificant interaction suggests that the effect produced by identical words (52ms) and that produced by transposed nonwords

(17ms) were similar. If the effect produced by transposed nonwords was insignificant, a significant interaction should have appeared[7]. Thus, the results suggest that both normal and transposed related primes facilitate target word recognition. In addition, the main effect of the stroke number of the initial character in prime words was marginally significant (t=1.79, p=.07). It suggests that the stroke number of the initial character delayed lexical responses to target words. No other effect of covariate reached statistical significance (ps>.05).

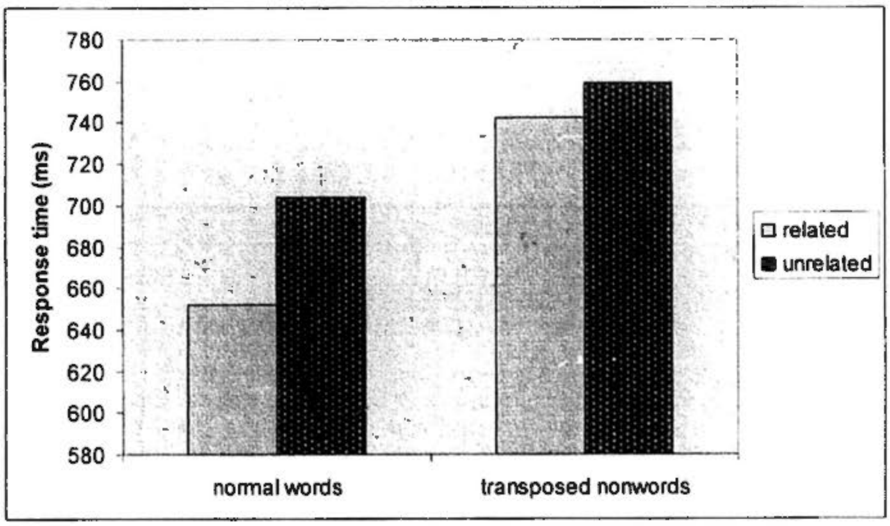

Figure 4-4 RT results of Exp 3 (opaque untransposable words)

For accuracy rate analysis, 800 data points were used. A logit mixed effect model appropriate for nominal dependent variables was adopted. It used the same predictors and covariates as in RT analysis. The results show that the main effect of the neighborhood size of the initial character in prime words was marginally significant, *odds ratio*=1.01, p=.07. It suggests that the increase of the neighborhood size of the initial character

[7] It should be noted that there is no need to conduct simple effect analysis with an insignificant interaction.

enhanced the possibility for the participants to make a correct response[8]. No other effect reached significance (*p*s>.05).

4.4.3 Discussion

The results of Experiment 3 show that both identical words and transposed opaque nonwords produced facilitation to the processing of target word, although the latter is weaker than the former (but not statistically different). It suggests that the transposed opaque nonwords could activate whole-word orthographic representation of the original words and thus produced the observed facilitation effect. This effect with opaque compound words is unlikely to be caused by morpheme-to-word activation, considering the low semantic relationship between component morphemes and opaque compound words.

4.5 Experiment 4: Binding untransposable words

Binding words are monomorphemic words and thus can only be processed as wholes. Binding words provide a unique way to test whether whole-word orthographic representation can be activated by their transposed forms. This experiment will also reveal the importance of morpheme position information in whole-word orthographic representation.

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[8] Odds ratio refers to the possibility for an initial character with larger neighborhood size to induce a correct response divided by the possibility for an initial character with smaller neighborhood size to induce a correct response. It should be noted that although this odds ratio reaches statistic significance, the size of the difference between large and small neighborhood was quite small.

4.5.1 Method

Participants

The same participants in Experiment 1 participated in this experiment.

Design

The design of this experiment was similar to that of Experiment 1.

Materials

Twenty binding words were selected as target words. Each target word (e.g., 玫瑰, means *rose* in English) was paired with an identical word (e.g., 玫瑰), a transposed nonword (e.g., 瑰玫), a control word (e.g., 滂沱, means *torrential* in English) and a control nonword (e.g., 沱滂). The linguistic characteristics of the prime words such as the frequency rank, neighborhood size, stroke number of both the initial and final characters were in Table 2-1. The arrangement of materials was similar to that of Experiment 1.

Procedure

The procedure was the same as in Experiment 1.

4.5.2 Results

Table 4- 5 RT (ms) and accuracy in Experiment 4

Condition	Normal words		Transposed nonwords	
	RT	Accuracy	RT	Accuracy
Related primed	672 (180)	.98 (.14)	761 (209)	.97 (.16)
Control primed	700 (195)	.96 (.21)	798(233)	.97 (.17)

Note. Standard deviations in parentheses

Only correct responses were used for RT analysis. Reaction time that exceeded three standard deviations of each subjects was deleted. Those shorter than 300ms and longer than 1500ms were also deleted. The criteria delete about 3.1% of the total data points.

In total, 753 data points were used in RT analysis. The results (Figure 4-5) show that the main effect of word order was significant (t=-2.19, p<.05). It suggests that normal words produced faster response than transposed nonwords. The main effect of relatedness was significant (t=-6.40, p<.01). It shows that related primes produced faster response than unrelated primes. The interaction between word order and relatedness was not significant (t=0.21, p>.05). It demonstrates that both normal and transposed related primes facilitate target word recognition. No other effect of covariate reached statistical significance (ps>.05).

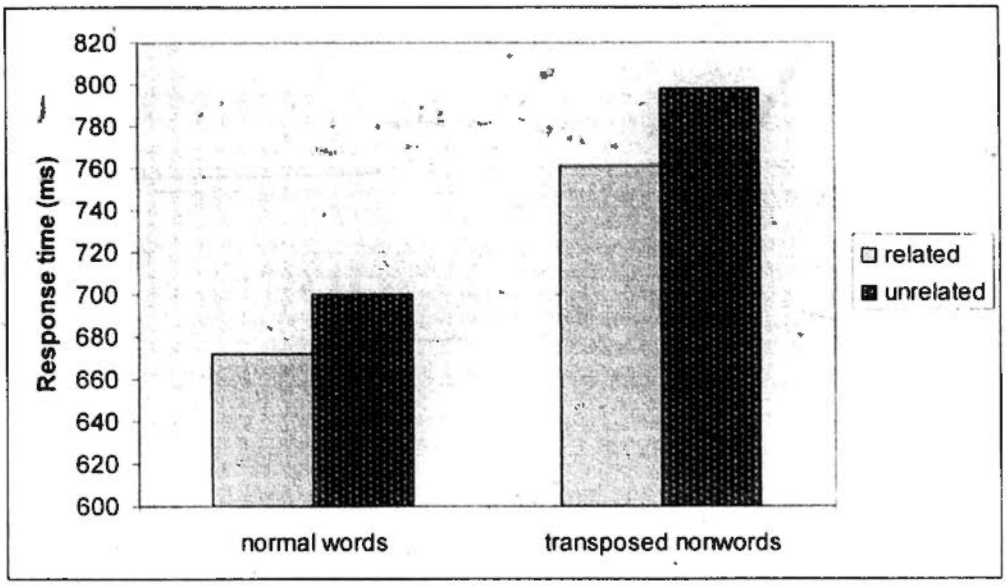

Figure 4-5 RT results of Exp 4 (binding untransposable words)

For accuracy rate analysis, 800 data points were used. A logit mixed effect model appropriate for nominal dependent variables was adopted. It used the same predictors and covariates as in RT analysis. The results show that the main effect of the stroke number of the initial character in prime words was marginally significant, *odds ratio*=1.13, p=.07. It reflects that the increase of the stroke number of the initial character enhanced the possibility for the participants to make a correct response. No other effect reached significance (ps>.05).

4.5.3 Discussion

The results of Experiment 4 show that transposed binding nonwords produced similar facilitation to the recognition of the original words as identical words. It suggests that transposed nonwords can activate word-level orthographic representation of the original words. Meanwhile, it suggests that morpheme position information was not critical in word-level orthographic representation access.

It should be noted that there is a potential challenge to the whole-word orthographic representation activation account. In the computer display of the stimuli, when the semantic radicals of the two components in a binding word were identical (e.g., 蝴蝶), the semantic radical of the prime nonword stayed on the screen and became the semantic radical of the target word. Thus, the observed facilitation may be caused by radical overlap between prime and target words.

4.6 General Discussion of Study 2

Study 2 examined orthographic representations of Chinese compound words using transposed-character similarity effect. Experiment 1 shows that prime-target pairs of transposable compound words (e.g., 领带, means *tie* in English - 带领, means *lead* in English) did not produce significant effect. It is possible to be caused by the offset between lexical competition (between prime and target words) and morpheme-to-word activation (from morphemes in prime words to target words). However, it is hard to draw conclusion about the status of orthographic representations of Chinese compound words based on this null effect. The issue was further investigated with Experiments 2 to 4. Experiment 2 shows that transparent transposed nonwords did not produce facilitation to transparent target words. This finding excludes the possibility of morpheme-to-word activation that would predict significant facilitation. Instead, the result may suggest that transparent words do not have word-level orthographic representations that can be activated by transposed nonwords. Experiment 3 shows that opaque transposed nonwords produced significant facilitation to opaque target words. This effect cannot be caused by morpheme-to-word activation because the semantic relatedness between component morphemes and opaque compound words is really low. Thus, it is most likely that the opaque transposed nonwords activate word-level orthographic representation activation of opaque target words. The results of Experiments 2 and 3 show that opaque compound words are more likely than transparent compound words to be represented as orthographic wholes in the mental lexicon[9]. In addition, Experiment 4 examined the influence of binding transposed nonwords to the processing of binding target words (e.g., 徊徘-徘徊, means *wander* in English). It provides evidence that it is possible to activate whole-word orthographic representations of Chinese two-character words by transposed nonwords. Thus, the facilitation produced by opaque transposed nonwords to opaque target words was very likely to be caused by activation of word-level orthographic representations of the opaque target words.

The present findings are consistent with Ding and Peng (2006) who also observed insignificant inhibition by transposable prime-target words. The null effect found in the present study and Ding and Peng (2006) does not necessarily contradict the interference observed by Taft, Zhu and Peng (1999). Taft et al. used a lexical decision task without primes. They found that lexical decision response was slower for transposable words (e.g.,

[9] I did not conduct a combined analysis of Experiments 2 and 3 considering the different target items used in the two experiments.

领带) than untransposable controls. They argued that transposable words suffer from competition between activation of the lexical representations of the transposed and the original words (e.g., 带领) in a lexical decision task. However, this explanation is inconsistent with the finding that words with multiple meanings are often recognized faster than single-meaning words in a lexical decision task (Jastrzembski & Stanners,1975).

The present result is consistent with Taft et al. (1999), who found that lexical decision responses to transposed nonwords (e.g., 光风) were much slower that to control nonwords that cannot be transposed to be a word (e.g., 返构). They argued that the former, but not the latter, can activate the lexical representation of their base words. This activation would induce a positive lexical decision response, causing a delay in the "no" response. In the present study, significant facilitation by transposed nonwords to opaque target words (e.g., 虎马-马虎) was observed. Facilitation was observed because a transposed nonword activates a word representation that is identical with the target word. Hence, the inhibition observed by Taft et al. (1999) and the facilitation observed in the present study are in fact quite consistent with each other and can be explained by a similar cognitive mechanism.

However, it should be noted that transposed-character nonwords used in the present study are quite different from transposed-letter nonwords used in alphabetic languages. Firstly, transposition of characters is a manipulation of morphemes that are much larger linguistic units than letters. A significant difference between morpheme and letter is that morphemes convey meanings but letters do not. Even after transposition, morphemes may send semantic cues of the whole words. It may facilitate activation of whole word representations and thus exaggerate the observed effect. Secondly, the positions of transposed characters and letters also differ. In studies with alphabetic languages, two internal letters were often transposed to get a transposed nonword. However, compound words used in the present study only have two component characters and thus the transposition occurs with initial and final characters. Position of the transposed components may have an influence on the observed effect (Johnson, Perea & Rayner, 2007). Considering these two aspects, it should be cautious to integrate present observed effect into the transposed nonword literatures.

Underlying mechanism of the observed transposed-character similarity effect

In sum, the findings of Study 2 suggest that Chinese compound words, especially the opaque ones, are likely to occupy whole word orthographic representations that can be activated by their corresponding transposed nonwords. As to the two candidate explanations for the findings of transposed compound word processing: decomposed morpheme-to-word activation and holistic activation of whole word representations, previous studies (Taft, 1985; Peng et al., 1999) assumed that it is spreading activation from morpheme-level to whole-word level that contributes to the observed effect; however, the findings of the present study support the second explanation - holistic activation of word-level orthographic representations much more.

Is it possible to explain the observed transposed character similarity effect with a decomposed account? A new lexical processing model (Taft et al., 1999; Taft & Nguyen-Hoan, 2010) argues for a decomposed account by accommodation of a 'lemma' level (see p.65). According to this model, the null effect with transposable prime-target pairs (e.g., 马上-上马, Experiment 1) may be explained by the counteraction of morpheme-to-word lemma facilitation and word lemma inhibition. Thus, our observed results may be consistent with a decomposed representation account instead of a holistic representation account. However, as I have pointed out in Discussion of Study 1 (see p.65), involvement of a lemma representation cannot exclude the existence of whole-word orthographic representation, considering that 'lemma' represents an abstract connection of form and meaning. With such a view, whole-word orthographic representation should be included into a lexical processing model. In addition, considering the present task is a lexical decision one with visual input, it is more likely that the lexical competition occurs on orthographic level instead of semantic level or lemma level. Many studies with masked priming and lexical decision task did not found significant semantic priming effect (Bueno & Frenck-Mestre, 2008; Taft & Kougious, 2004). Overall, the observed effect with transposable word pairs may be hard to explain with a lexical processing mechanism without word-level orthographic representation.

The role of morpheme position in compound words processing

The different findings observed with transparent and opaque compound words reflect that morpheme position information may take different effects in these two kinds of words. For transparent compound words, whole word meaning can be computed from the meanings of the component morphemes. Morpheme position information may be important during this process, considering that whole word meanings of transposable transparent words, such as 领带 (means *tie* in English) and 带领 (means *lead* in English), are totally different. However, due to the low relatedness between component morpheme meaning and whole word meaning in opaque compound words, meaning extraction from the first and second morphemes is not quite useful to reach whole word meaning. As a result, position information in opaque words is not that important as in transparent words. The findings of Experiments 3 and 4 may suggest that morpheme position information is not quite important for words that are represented as wholes.

Theoretically, on the one hand, the findings of transparent words are consistent with the hypothesis of the Interactive Activation Model (McClelland & Rumelhart, 1981) that component letters in words are decoded one by one, from left to right. On the other hand, the findings for opaque compound words conform to the hypothesis of the Multiple Read-out Model (Grainger & Jacobs, 1996) that asserts two simultaneous active cognitive mechanisms for visual word recognition--a global criterion and a specific criterion. According to this model, readers may make their decisions based on the global activation level of the visual input or much detailed check of the specific criterion. Researchers (e.g., De Moor, Verguts, & Brysbaert, 2005) have found that when the lexical decision task emphasize on speed, participants may rely more on the global activation level to make decisions and many errors are often produced. Conversely, if the lexical decision task emphasizes more on accuracy, participants may rely more on the specific activation of the visual input and few errors would be produced. Such findings suggest that the two mechanisms for visual word recognition are quite flexible. In our experiments, the transposed nonwords were presented on the screen very shortly (i.e., 57ms) and were forwardly masked by a series of symbols (i.e., ####). Thus, the processing situation of transposed nonwords in our experiments may be similar to tasks that emphasize on speed. As a result, considering the visual similarity between transposed words and the original words, it is quite likely for the participants to access the orthographic representation of the original words.

Further research directions

One factor that may affect compound words' whole word representation is word surface/token frequency, which refers to the total number of times a word appears in a corpus (Diependaele, Grainger, & Sandra, in press). The facilitation effect of complex words' surface frequency has been evidenced in studies both in alphabetic languages (e.g., Niswander, Pollatsek, & Rayner, 2000) and in Chinese (e.g., Yan, Tian, Bai, & Rayner, 2006). Furthermore, the influence of semantic transparency may be moderated by word surface/token frequency. Considering that opaque compound words, regardless of frequency, are more likely to occupy word level entries in the mental lexicon, the effect of word surface frequency may be much stronger for transparent words. High frequency transparent words may be more likely than low frequency transparency words to be represented as unitary units in the mental lexicon. It is possible that the reason why Experiment 2 does not reveal facilitation produced by transposed nonwords to transparent target words is that the word frequency of such words are too low. Further studies should take word frequency into consideration.

Another aspect that should be considered in future studies is whether the activation of morpheme position information is affected by the syntactic structure of Chinese compound words. The most common kinds of Chinese compound words are coordinates and subordinates. For coordinate words (e.g., 美丽), both the initial and final morphemes are morphological head of the word. The two morphemes have equal contributions to compound word meaning composition. However, subordinate compound words (e.g., 美食) have only one morphological head which is often the final morpheme. It is possible that morpheme position information matters much in subordinate than coordinate words because it is important to localize the head morpheme in subordinate words processing. Considering different roles of initial and final morphemes in coordinate and subordinate words, coordinate transposed words may be more possible to activate whole word lexical representation than the subordinate words. However, whether the two kinds of compound words represented in different ways needs further studies.

In addition, the characteristics of the control words used in the present study may have some influence on the results. For example, if a control word is quite transparent, transposed nonwords may have some semantic cues at character level. The transposed nonword '益利', for instance, conveys the meaning of 'benefit' by its component characters. Using such transposed nonwords as controls may potentially lead participants to emphasize on a decomposed processing style. Conversely, participants may emphasize more on a holistic processing style with opaque transposed nonwords as control (e.g., 活快). Other characteristics of the control nonwords/words, such as the concreteness of meaning and the number of meanings a character carries, may also have some influence on the priming effect. Further studies should take such factors into consideration.

Conclusions

The findings of the present study reveal psychological reality of word-level orthographic representations for Chinese compound words. Different representations for transparent and opaque words are also indicated by the present study. Transparent words may be represented in a system in which morpheme positions are marked, whereas opaque words in one similar to that posited in the Multiple Read-out Model.

Chapter 5

Study 3: Activation of morpheme meanings in Chinese

5.1 Introduction

Study 3 examines how Chinese compound words are accessed. The focus is to investigate the role played by component morphemes in visual recognition of Chinese compound words.

Whether morpheme activation is morpho-orthographic or morpho-semantic is still hotly debated. Dual-route models (e.g., Schreuder & Baayen, 1995) assume that complex words are formally decomposed into morphemic units in parallel with whole word access. Supralexical model (Giraudo & Grainger, 2001) holds that morphological effect is semantically based because only root morphemes that are consistent with whole word meaning would get activation from the accessed whole word representations. To disentangle morpho-orthographic and morpho-semantic accounts, it is important to test whether the meaning of component morphemes can be activated in compound word processing.

Recent studies examining morpheme meaning activation mainly rely on semantic transparency effect in priming of derived words on their stems. If semantically transparent complex word-stem pairs (e.g. *teacher-TEACH*) produce larger priming effects than opaque pairs (e.g., *department-DEPART*), it can be argued that morpheme meanings are activated. Using such materials, no difference was found between transparent and opaque pairs under masked priming with short prime duration (<60ms) (e.g., Rastle, Davis, & New, 2004). It shows that in the early stage of compound word processing, morphological decomposition is form-driven, regardless of semantics. Conversely, significant difference was observed between transparent and opaque pairs under cross-modal priming, long term priming (i.e., with several items inserting between prime and target), unmasked visual-visual priming, and masked priming with long prime duration (e.g., Marslen-Wilson, Tyler, Waksler, & Older, 1994; Rueckl & Aicher, 2008). It shows that the meaning of component morpheme was activated in a later stage of compound word processing. Such findings may suggest that morphological processing is form-then-meaning activation.

Contrary to the prediction of the form-then-meaning hypothesis, morpho-semantic activation was also observed under masked priming paradigm, with SOA shorter than 60ms (Feldman, O'Connor, & Del Prado Martin, 2009). Similar results were also observed by Diependaele, Sandra and Grainger (2009) who proposed the Hybrid model that includes both morpho-orthographic decomposition at a sublexical level and a morpho-semantic activation at a supralexical level. However, other researchers disagree about the reliability and interpretations of such effects (Rastle & Davis, 2008; Davis & Rastle, 2010). Thus, whether morphological processing is form-then-meaning or form-with-meaning has not been yet clearly determined by semantic transparency paradigm.

The critical dispute between the form-then-meaning and form-with-meaning accounts is whether morpheme meaning activation occurs simultaneously with form activation. Considering that researchers consistently agree morpho-orthogrpahic processing occurs at the initial stage of morpheme processing, the unsolved problem is actually the time-course of morpho-semantic activation. Thus, a direct way to differentiate the above two accounts is to examine the occurrence of morpheme meaning activation in early stage of multimorphemic word processing without the contribution of form activation.

It can be accomplished with comparison between the priming effect produced by word pairs that overlap in morpheme meaning only and no other aspects {+Morph, -Ortho, -Phono, -Seman} with that produced by unrelated pairs. Dissociation of morpho-semantic overlap from other aspects is possible in Chinese. Many pairs of Chinese characters differ in visual forms and pronunciations but have almost identical meanings. For example, both 吃 / chī / and 食 / shí / mean *eat*. They can form a compound word pair 吃惊 (means *surprised* in English) and 食欲 (means *appetite* in English) which, apart from a pair of semantically related initial morphemes, have no overlap in form (orthography and phonology), or word semantics. Any priming effect between such word pairs can be attributed unequivocally to morphemic semantic activation.

The present study is the first to use Chinese compound word pairs that overlap in morpheme meaning only in a masked priming paradigm to investigate morpheme meaning activation. In the three experiments reported below, a target word was preceded by a prime that semantically overlapped with it in one morpheme, in whole word, or nothing at all. The three experiments only differed in the position of the semantically related morphemes in prime-target pairs. If the meaning of component morphemes can be activated, responses to the target words in the morpheme meaning related condition would be faster than those in the unrelated condition. The occurrence of morpheme meaning activation would rule out the dual route models that argue for form-based morphological processing (e.g., Morphological Race Model, Baayen, Dijkstra, & Schreuder, 1997). Models that assume morpho-semantic activation reflects supralexical clustering of a morphological family cannot provide a satisfactory explanation either, considering that the morpheme meaning related word pairs do not overlap in form and word meaning at all. To detect the relative speed of morpheme and word meaning activation, both short and long SOAs (60 and 200 ms) are used in the experiments. If morphological processing is form-with-meaning, morpheme meaning activation should not appear later than word meaning activation. Otherwise, if morphological processing is form-then-meaning, morpheme meaning activation may lag behind word meaning activation.

5.2 Experiment 1

5.2.1 Method

Participants

The participants were 37 (19 females) undergraduate students at the Chinese University of Hong Kong. They were native Chinese speakers, right handed, and had normal or corrected-to-normal vision. They were paid for their participation. The same group of participants took part in all the experiments.

Design and materials

This was a 3×2 within-subject design. The first factor was the semantic relationship between prime and target words (morpheme meaning related, word meaning related and unrelated). This variable was manipulated within blocks. The second factor was SOA (60ms and 200ms). This variable was manipulated between blocks.

Thirty-six target words were selected from a larger pool of 50 words. Fifty students at South China Normal University were paid to assess the degree of semantic relatedness between each of these target words and a morpheme-related word, as well as a semantically related word, with 1 representing unrelated and 9 highly related. The mean rating for word pairs that overlapped in the first morpheme only (e.g., 吃惊, means *surprise* in English-食欲, means *appetite* in English) and word meaning only (e.g., 胃口 means *appetite* in English -食欲, means *appetite* in English) was 2.2 and 7.5, respectively,

$t_{(35)}$=-32.25, p<.001.

Each of the 36 target words was paired with three different prime words, matched on word frequency (Institute of Language Teaching and Research, 1986). Among the 108 prime-probe pairs, 36 pairs contained semantically related initial morphemes but were semantically unrelated in word meaning (e.g., 吃惊, means *surprised in English*-食欲, means *appetite* in English). Another 36 pairs were related in word meaning but did not contain semantically related morphemes (e.g., 胃口, means *appetite* in English-食欲, means *appetite in English*). The rest were controls (e.g., 发愤, means *strive resolutely* in English-食欲, means *appetite* in English). All the prime and target word pairs differed in both orthography and phonology. The average word frequency for the target words, morpheme meaning related, word meaning related and control prime words were 38, 48, 44 and 44 per million, respectively. Other linguistic characteristics of prime words including the mean frequency, orthographic neighborhood size and stroke number of the initial and final morphemes were in Table 5-1.

Table 5-1 Linguistic characteristics of the stimuli used in Experiment 1-3

Linguistics characteristics	Exp1	Exp2	Exp3
Frequency rank of initial character	3478 (4592)	2546 (4326)	2866 (3814)
Frequency rank of final character	2050 (2720)	2744 (3461)	4155 (6629)
Neighborhood size of initial character	78.18 (182.63)	101.31 (123.14)	86.04 (118.09)
Neighborhood size of final character	92.69 (86.20)	83.91 (120.15)	89.06 (76.29)
Stroke number of initial character	10.97 (4.43)	9.94 (4.10)	11.01 (4.38)
Stroke number of final character	11.05 (4.21)	11.59 (4.46)	11.64 (4.24)

Note. Standard deviations in parentheses

The 108 prime-probe pairs were divided into three blocks. Each target word only appeared once in each block, preceded by a different prime word each time. The combination of target word and prime word type across blocks and participants followed a Latin-square design. In addition, each block contained the same number of nonword target trials as fillers. Totally, each subject did 216 trials under each SOA condition.

Procedure

The stimuli were presented by a computer on a 15-inch LCD. All the characters were set in 18 font of *Song Font*. The words presented at the center of the screen were approximately 2.7cm×1.3cm in size. Participants sat about 60cm from the screen. The program was compiled by E-Prime 2.0.

A forward masked priming paradigm was employed. Each trial began with a red fixation sign (font size 18) appearing at the center of the screen for 500ms. Then a pattern mask (####, font size 18) appeared on the screen for 500ms. After it disappeared, a prime word appeared at the same position for either 60 or 200ms. Then a target word appeared and remained until the participant made a lexical decision response on the keyboard. As soon as a response was detected, the target word disappeared and the participants were asked to press a key to start the next trial. The participants could choose to rest every 20 trials.

At the beginning of the experiment, the participants were given instructions regarding the procedure, followed by a practice phase, which contained 10 word-word and 10 word-nonword pairs. The practice phase was repeated until 90% accuracy was reached.

The main experiment was divided into two equal parts differing only in SOA conditions (60 or 200ms). The order of SOA conditions was counterbalanced across participants. Each part consisted of three blocks of 72 trials. The trials within a block were randomized.

5.2.2 Results and Discussion

Table 5-2 RT (ms) and accuracy in Experiment 1

	Morpheme-related		Word-related		Control	
	RT	Accuracy	RT	Accuracy	RT	Accuracy
SOA60ms	678(166)	.90(.31)	669(155)	.89(.31)	686(160)	.88(.33)
SOA200ms	707(182)	.88(.33)	701(176)	.89(.32)	727(190)	.88(.32)

Note. Standard deviations in parentheses

The mean number of practice phases for participants to reach 90% accuracy was 1.22. In reaction time (RT) analyses, only correct responses were included. RTs beyond three standard deviations were also excluded (about 3.5%). The data were analyzed with a mixed effect model, with subject and item as random intercepts. The *p*-values were estimated by the Monte Carlo Markov chain (MCMC) method (Baayen, 2008) using 10,000 samples. The semantic relationship between prime and target words, SOA and interaction of these two factors were used as predictors for log RT. The mean frequency, orthographic neighborhood size and stroke number of the initial and final morphemes were used as covariates.

In total, 6824 data points were used. The results of model 1 show that relative to controls, response latencies of target words were significantly shorter following both morpheme meaning related primes (t=-3.23, p<.01) and word meaning related primes (t=-4.42, p<.01). The short SOA (60ms) condition induced faster response to target words than the long SOA (200ms) condition (t=-6.99, p<.01). The effect of the final morpheme frequency was significant (t=2.31, p<.05). The effect of the orthographic neighborhood size of the final morpheme was significant (t=-2.13, p<.05). All the other effects were not significant (ps>.05). Further analysis shows that the priming effects produced by morpheme and word meaning related primes were not significantly different (t=1.01, p>.05). The pattern of the results is shown in Figure 5-1.

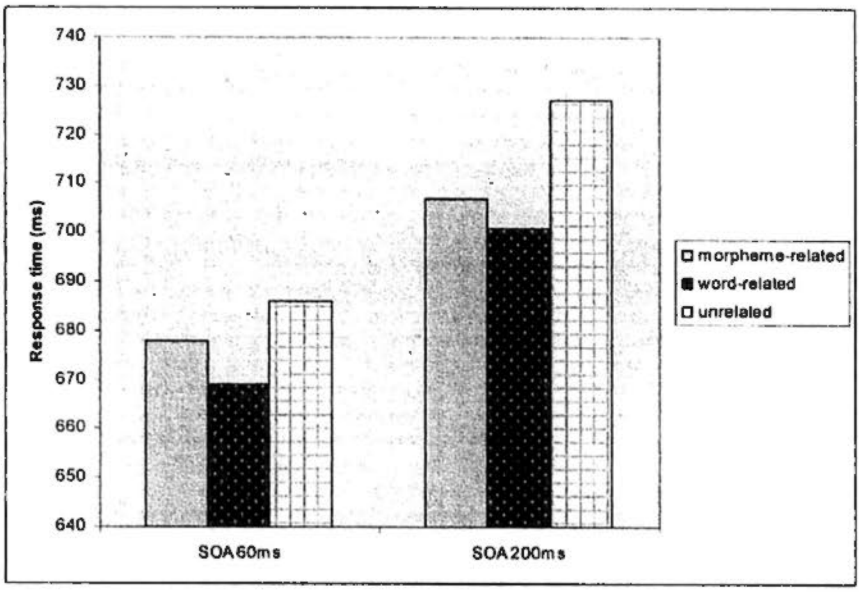

Figure 5-1 RT results of Exp1 (initial morpheme related)

For accuracy rate analysis, 7992 data points were used. A logit mixed effect models using the same predictors and covariates as in RT analysis were constructed. The results show that increase the stroke number of the initial morpheme decreased the possibility to induce a correct response (*odds ratio*=.97, p<.05). No other effect was significant (p>.05).

The results of Experiment 1 show that two words sharing a semantically related morpheme produced facilitation effect in both short and long SOA conditions. It indicates that the meaning of initial morpheme was activated quickly and facilitated compound word processing. The occurrence of morpho-semantic activation as early as 60ms SOA was consistent with the parallel dual route model but not the prefix-stripping model or the supralexical model.

5.3 Experiment 2

Experiment 2 investigated whether the meaning of the second morpheme can also be activated in compound word recognition. The results would bear on whether the two morphemes in Chinese compound words are processed in the same way.

5.3.1 Method

A new set of 108 prime-probe word pairs were selected by the same method used in experiment 1. Among them, 36 pairs shared the meaning of the second morpheme only (e.g., 金融 *financial*-强化 *reinforce*), 36 pairs shared word meaning only (e.g., 加剧 *aggravate*-强化 *reinforce*) and the rest were unrelated (e.g., 论调 *opinion*-强化 *reinforce*). Semantic relatedness was 2.1 for word pairs that contained a semantically related second morpheme only, and 7.7 for word pairs that were related in word meaning only ($t_{(35)}$ =-43.46, p<.001). The average word frequency rank for the target words, morpheme meaning related, word meaning related and control prime words were 54, 56, 52 and 59 per million, respectively. Another 108 word-nonword pairs were used as fillers. The arrangement and procedure were similar to those in experiment 1. The average frequency rank, orthographic neighborhood size and stroke number of the initial and final morphemes of the prime words in this experiment were shown in Table 5-1.

5.3.2 Results and Discussion

Table 5-3 RT (ms) and accuracy in Experiment 2

	Morpheme-related		Word-related		Control	
	RT	Accuracy	RT	Accuracy	RT	Accuracy
SOA60ms	680(167)	.86(.35)	663(150)	.86(.35)	680(151)	.84(.37)
SOA200ms	717(187)	.87(.34)	700(183)	.87(.34)	714(186)	.85(.36)

Note. Standard deviations in parentheses

The mean number of practice phases for participants to reach 90% accuracy was 1.19. About 4.05% of the RT data was excluded based on the same criterion of experiment 1. The analysis was similar to that of experiment 1.

In RT analysis, 6561 data points were used. The results show that relative to controls, response latencies of the target words were significantly shorter following word meaning related primes (t=-2.04, p<.01), but not significantly shorter following morpheme meaning related primes (t=0.65, p>.05). The short SOA (60ms) condition produced shorter response latencies to target words than the long SOA (200ms) condition ((t=-5.06, p<.01). The effect of the stroke number of the final morpheme was significant ((t=-2.16, p<.05). All the other effects were not significant (ps>.05). The pattern of the results is shown in Figure 5-2.

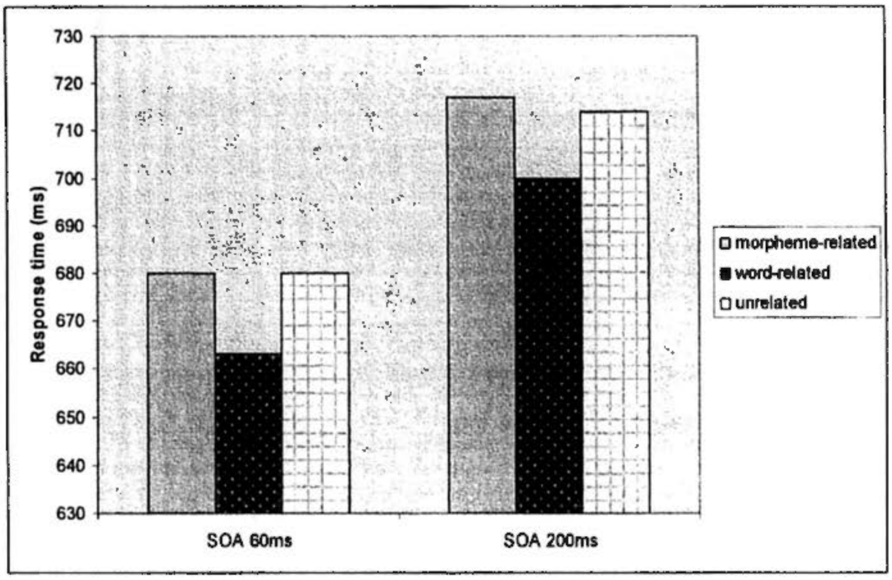

Figure 5-2 RT results of Exp2 (final morpheme related)

For accuracy rate analysis, 7992 data points were used. The results of model 1 show that relative to controls, accuracy rates of the target words were significantly higher following both morpheme meaning related primes (*odds ratio=1.36*, $p<.05$) and word meaning related primes (*odd ratio*=1.41, $p<.05$). Pairwise comparison analysis show that the effects produced by morpheme and word meaning related primes did not differ significantly ($p>.05$). The results also show that increase the stroke number of the initial morpheme decreased the possibility to induce a correct response (*odds ratio*=.08, $p<.05$). No other effects were significant (*ps*>.05). The pattern of the results is shown in Figure 5-3.

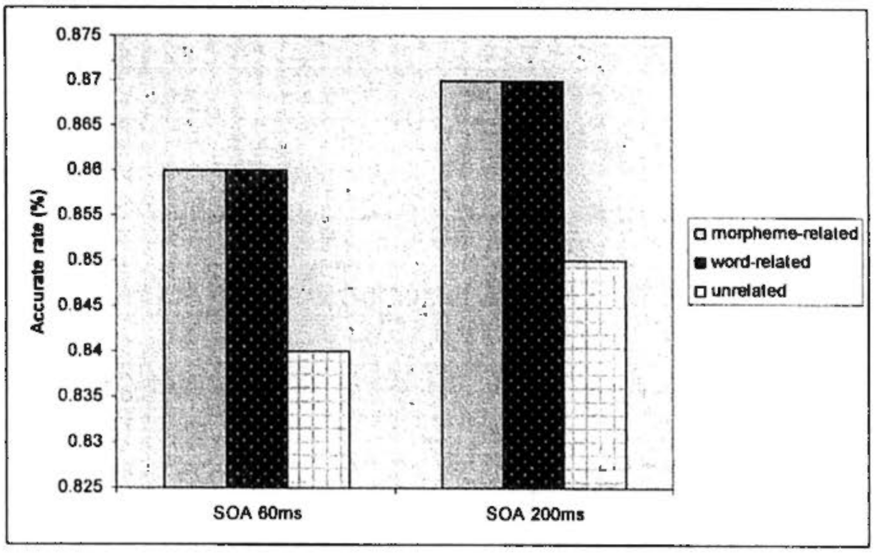

Figure 5-3 Accuracy results of Exp2 (final morpheme related)

The results of Experiment 2 show that the facilitation produced by prime-target word pairs sharing a semantically related final morpheme was detectable in response accuracy but not in response speed. It indicates that the meaning activation of the final morpheme was not quite reliable. The role played by the final morpheme in Chinese compound words seems to be quite limited. This finding may suggest that Chinese compound word recognition is serial and thus the initial morpheme gain much deeper processing than the final morpheme.

5.4 Experiment 3

Experiment 3 further examined morpheme meaning activation with prime-target word pairs sharing a semantically related morpheme at different positions (i.e., the first morpheme of a prime word was semantically related to the second morpheme of a target word, and vice versa). Priming effect would not be observed if the critical factor determining such effect is position overlap.

5.4.1 Method

A new set of 108 prime-probe word pairs was selected by the same method used in the previous experiments. Semantic relatedness was 2.3 for word pairs that contained a semantically related morpheme only, and 7.5 for word pairs that were related in word meaning only ($t_{(35)}=-32.25$, $p<.001$.). Among the 108 pairs of words, 36 pairs shared a morpheme on different positions. The first morpheme in prime words was semantically related to the second morpheme in the target words and vice versa (e.g., 杀菌 *sterilize*-主宰 *govern*). Thirty-six pairs were related in word meaning only (e.g., 把持 *dominate*-主宰 *govern*), and the rest were unrelated (e.g., 体味 *appreciate*-主宰 *govern*). The average word frequency rank for the target words, morpheme meaning related, word meaning related and control prime words were 69, 57, 64 and 58 per million, respectively. Another 108 word-nonword pairs were used as fillers. The arrangement and procedure were similar to those in experiment 1 and 2. The average frequency rank, orthographic neighborhood size and stroke number of the initial and final morphemes of the prime words in Experiment 3 were shown in Table 5-1.

5.4.2 Results and Discussion

Table 5-4 RT (ms) and accuracy in Experiment 3

	Morpheme-related		Word-related		Control	
	RT	Accuracy	RT	Accuracy	RT	Accuracy
SOA60ms	669(158)	.87(.34)	668(163)	.84(.35)	681(147)	.86(.35)
SOA200ms	702(180)	.86(.35)	696(183)	.87(.34)	714(171)	.85(.34)

Note. Standard deviations in parentheses

The mean number of practice phases for participants to reach 90% accuracy was 1.41. About 3.75% of the RT data was excluded. The analysis was similar to experiment 1.

For RT analysis, 6605 data points were used. The results show that relative to controls, response latencies of the target words were significantly shorter following both morpheme meaning related primes (t=-2.10, p<.05) and word meaning related primes (t=-3.70, p<.05). The short SOA (60ms) condition induced shorter response latencies to target words than the long SOA (200ms) condition (t=-5.70, p<.01). All the other effects were not significant (ps>.05). Further analysis shows that the effects produced by morpheme and word meaning related primes were not significantly different (p>.05). The pattern of results is shown in Figure 5-4.

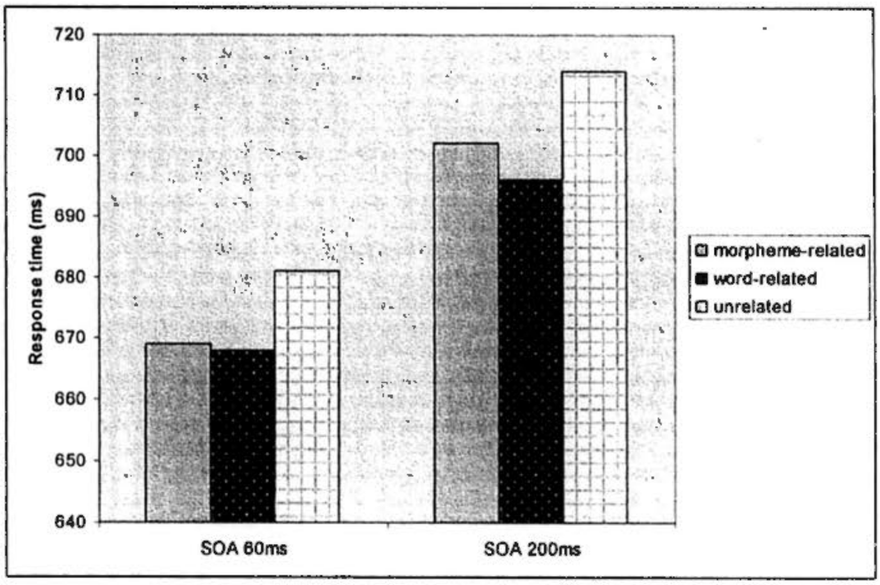

Figure 5-4 RT results of Exp 3 (cross morpheme related)

For accuracy rate analysis, 7992 data points were used. The results show that relative to controls, accuracy rates of the target words were significantly higher following word meaning related primes (*odds ratio=1.23*, $p<.05$), but not significantly higher following morpheme meaning related primes ($p>.05$). No other effects were significant ($ps>.05$). The pattern of results is shown in Figure 5-5.

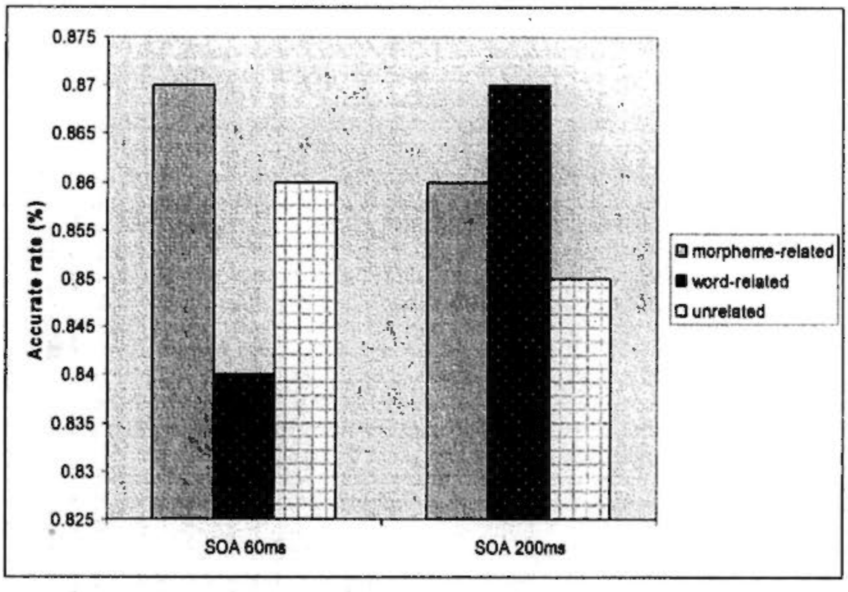

Figure 5-5 Accuracy results of Exp 3 (cross morpheme related)

Combined analyses

In the combined analyses, the data of the three experiments were aggregated to examine the effect of morpheme and word meaning related primes, and whether or not the former was affected by the position of the related morphemes. The semantic relationship between primes and targets, SOA, the related morpheme position, their interactions and target word frequency (covariate) were used as predictors in the following models. The mean frequency rank, orthographic neighborhood size and stroke number of the initial and final morphemes were used as covariates.

For RT analysis, 19990 data points were used. The results show that relative to controls, response latencies of the target words were significantly shorter following both morpheme meaning related primes (t=-2.70, p<.05) and word meaning related primes (t=-5.90, p<.05). Pairwise comparison analysis shows that the effects produced by morpheme and word meaning related primes did not differ significantly (p>.05). The priming effect brought by either initial or final related morphemes did not differ from crossed related morphemes (p>.05). However, the results revealed a significant interaction between morpheme meaning related condition and related morpheme position (t=2.15, p<.05). It shows that in the morpheme meaning related condition, initial related morphemes brought faster response to the target words than final related morphemes. All the other effects were not significant (ps>.05).

For accuracy rate analysis, 23976 data points were used. Similar analyses were done as with RT data. The results show that relative to controls, accuracy rates of the target words were significantly higher following word meaning related primes (*odds ratio*=1.40, $p<.05$) and morpheme meaning related primes (*odds ratio*=1.36, $p<.05$). The results also show that compared to initial morpheme related primes, final morpheme related primes were less likely to induce correct responses (*odds ratio*=0.76, $p<.05$). The mean frequency of the initial morpheme was also significant (*odds ratio*=1.11, $p<.05$). No other effect was significant (ps>.05).

5.5 General Discussion of Study 3

The three experiments show clearly that two-character Chinese compound words can produce priming effects even though they do not overlap in orthography, phonology or semantics, but are connected by two highly semantically related morphemes. At 60ms SOA the semantic properties of the compound constituents in the primes are accessed to a sufficient degree to spread activation to the constituent morphemes contained in the targets to facilitate lexical decisions to the latter. Our results are consistent with Feldman et al. (2009)'s finding of early semantic transparency effects. Thus, quick morphemic semantic activation may not be specific to Chinese compound words, but a universal characteristic of complex word recognition.

Generalization across languages should be taken with cautions, however, because there are important differences between the Chinese compound words used in the present study and those in studies of alphabetic languages. Firstly, the component morphemes in Chinese compound words are spatially segmented. This may facilitate fast morpho-semantic activation. Secondly, the prime and target words are both compounds, instead of derived words and their stems. Thirdly, fast morpheme meaning activation may be related to the characteristics of the Chinese language. The relationship between orthography and semantics is much closer in Chinese than in alphabetic languages.

Although the semantic transparency effect at very short SOAs has been used to argue for the form-with-meaning view and against the form-then-meaning view, it does not necessarily put the locus of morpho-semantic processing at a prelexical level. The hybrid model (Diependaele, et al., 2009) could also provide an adequate account if it is assumed that, in parallel with a decomposed input to the morpho-orthographic representations, whole-word input to a corresponding lexical form representation enables a fast activation of morpho-semantic representations at a supralexical level in the case of transparent but not opaque primes. To the extent that this activation of morpho-semantic representations via whole-word lexical form representations is very fast, semantic transparency effects, no matter how early they are detected, cannot distinguish whether morphemic semantic activation is pre- or supralexical.

Such a hybrid model or any models that posit morpheme meaning activation at a supralexical level only, may not be able to account for our findings that there are morpho-semantic priming effects between pairs of words that have no overlap in form or word semantics. Considering that opaque prime-target word pairs are not assumed to have related representations at the supralexical level, there is no reason why word pairs that share neither form nor meaning should. In that case, the morpheme meaning driven priming effects cannot be explained in terms of supralexical morpho-semantic activation.

On the other hand, a dual-route model in which the prelexical decomposition route parses a complex word into morphemic units that have both form and semantic properties is consistent with our findings of morpheme meaning driven priming effects. Although we cannot be certain that morpheme meaning activates before word meaning in our experiments because significant priming effects attributable to morpheme and word meaning related primes were both detected at 60 and 200ms SOAs, the fact that the former did not lag behind is still compatible with a prelexical account. Future experiments should use even shorter SOAs to ascertain that morpho-semantic decomposition can occur prior to whole-word access in order to locate it as prelexical.

It is worth noting that concurrent occurrence of morpheme meaning activation and whole word meaning activation may be consistent with the revised prelexical account (Taft & Nguyen-Hoan, 2010). This new model includes both 'lemma' representations of component morphemes and complex words. Considering that 'Lemma' represents abstract relationship between form and meaning, it can explain component morpheme meaning activation by activation of component morpheme lemma. Similarly, whole-word meaning activation may be explained by activation of complex words lemma.

Finally, the influence of morpheme position was also examined in the experiments. The final morpheme meaning activation was only detected by accuracy analysis but not by RT analysis. The combined RT analysis revealed that under morpheme meaning related condition, a cross related morpheme in the primes produced much faster response to the target words than a final related morpheme. The combined error analysis revealed that compared to final morpheme related primes, initial morpheme meaning related primes were more likely to help participants make a correct response. These results may imply dominance of initial morphemes in Chinese compound word recognition because the initial morpheme played important role both in the initial and crossed morpheme related condition. In contrast, Juhasz, Starr, Inhoff and Placke (2003) found more salient influence of the final (head) morpheme of English compounds. It seems that the relative importance of morpheme position may differ across languages.

To conclude, the present study provides evidence to form-with-meaning hypothesis of morphological processing because morpheme meaning activation is found to occur early in Chinese compound word recognition. These results can be explained by a dual-route model that assumes morpho-semantic activation in parallel with whole word access.

Chapter 6 General Discussion

6.1 Major Findings

The present study found that Chinese two-character compound words are likely to have word-level orthographic representations in the mental lexicon. The representation of compound words is found to be affected by semantic transparency. Transparent words are likely to be represented in a decomposed way; while opaque words are likely to be represented in a holistic way. During access of Chinese compound words, component morpheme meanings are found to be activated. The findings suggest that Chinese compound words may be represented as unitary units, but the meanings of component morphemes are activated and involved in compound word processing.

6.1.1 Orthographic representation of Chinese compound words

The first research question of the present study is whether Chinese compound words have word-level orthographic representations. The results of Studies 1 and 2 provided empirical evidence to this question. In particular, Study 1 shows that high frequency orthographic neighbors produce inhibition to low frequency target words. Considering that the orthographic neighbors used in this study are two-character compound words, the observed effect suggests that compound words are represented as orthographic wholes in the mental lexicon. It should be the lexical competition between two activated word-level orthographic representations that contributes to the observed inhibition effect. Otherwise, two compound words sharing one character with each other would facilitate each other's processing due to visual similarity. The results of Experiments 3 and 4 of Study 1 show that high frequency orthographic neighbor inhibition effect was more likely to be observed with opaque prime words (regardless of the semantic transparency of target words). Such findings suggest that high frequency opaque compound words are more likely than transparent words to be represented as orthographically unitary units.

Word-level orthographic representation was also examined in Study 2 by transposed-character similarity effect. The result of Experiment 1 of Study 2 shows that transposable compound words produced null effect on the processing of the original words (e.g., 马上-上马). It excludes the possibility of morpheme-to-word activation that would predict facilitation with transposable word pairs and indicates a possibility for holistic activation of word-level orthographic representations. The results of two follow up experiments (i.e., Experiments 2 and 3) show that transposed opaque nonwords produced facilitation to the original compound words (e.g., 虎马-马虎) but transposed transparent nonwords did not (e.g., 傲骄-骄傲). Such findings may suggest that opaque compound words are more likely to be represented as wholes than transparent words. That is because only if compound words are represented as wholes, can transposed nonwords activate word-level representations of the original words and produce facilitation to their processing.

The findings of word-level orthographic representations are consistent with the

Multi-Level Interactive Activation Model (Figure 6-1) (Taft, Liu, & Zhu, 1999). There are several orthographic representation levels in this model: the stroke level, radical level, component character (morpheme) level and compound word level, all of which are interactive to each other. Each level except the stroke level is connected to the semantic and phonological representations of the same level. The frequency with which that connection is used determines the connection strength. The most frequent link can be activated more quickly and easily. Therefore, high-frequency words are more likely (or faster) than low-frequency words to activate word-level orthographic representations.

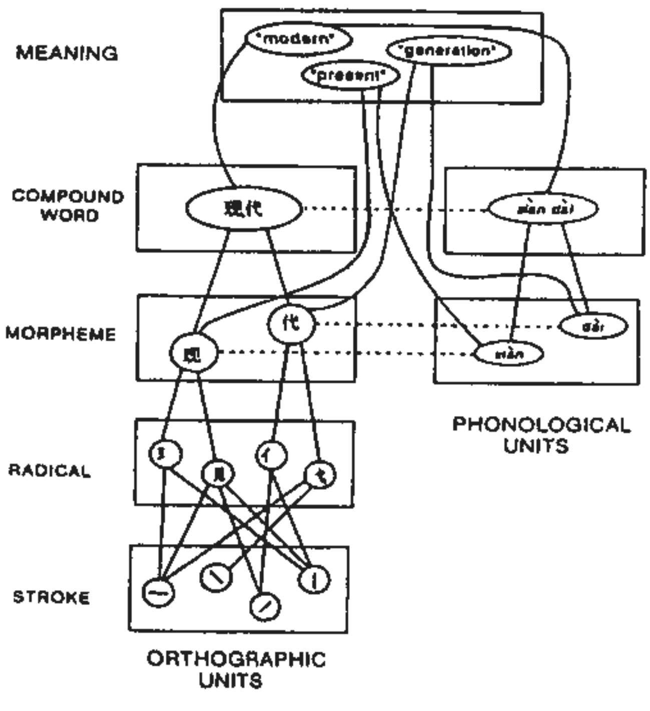

Figure 6-1 The multilevel interactive-activation framework (from Taft & Zhu, 1995)

However, the Multi-Level Interactive Activation Model seems to be unable to explain all the evidence collected in the present study. Firstly, two compound words sharing one character/morpheme (i.e., orthographic neighbors) should be positively connected in the Multi-level Interactive Activation Model. However, the results of Study 1 suggest that orthographic neighbors in Chinese are possibly negatively connected with each other and thus compete for lexical access. Secondly, morpheme position information should be important in the connection from morpheme-level to whole word level representation in the Multi-level Interactive Activation Model. However, it is found to be not quite critical for the access of whole word orthographic representation in the present study, because transposed opaque nonwords are found to activate word-level orthographic representations of the original words.

As a result, the findings of the present study may be explained by a new model. This new model holds that both word-level and character-level orthographic representations exist for Chinese compound words. It asserts that the existence of word-level orthographic representations of Chinese compound words does not falsify the existence of character-level orthographic representations. This view is consistent with the Multi-Level Interactive Activation Model (Taft, Liu, & Zhu, 1999). However, the critical difference between the new model proposed in the present study and the Multi-level Interactive Activation Model is the relationship between word-level and character-level orthographic representations. In Taft's model, word-level representations of compound words are stored at a higher level than character-level representations. It seems that word-level representation in this model is actually activated by character-level representations. However, the whole word orthographic representation proposed in the new model is stored at the same level with character-level representations. Whole word representation is activated by the visual input of the compound words as a whole. It is the total activation level of the whole words rather than independent activation of each component character that determines the activation of whole word orthographic representations.

6.1.2 Lexical representation of Chinese compound words

The findings of the present study suggest that two-character Chinese compound words are likely to be represented as orthographic wholes in the mental lexicon. Other studies suggest that Chinese compound words are likely to have whole-word phonological and semantic representations in the mental lexicon (Law, Wong, & Chiu, 2005; Zhou, et al., 1999).

Law, Wong and Chiu (2005) provided evidence for the existence of whole-word phonological representation. They asked dyslexic children to read two-character Chinese compound words containing homographic characters whose pronunciation can only be disambiguated in word context (e.g., 交易/gaau1 jik6/ & 轻易/hing1 ji6/). Law et al. (2005) found that dyslexic children can read the word as a whole correctly, despite that they did not know the meaning of the compound words. Conversely, some dyslexic patients with brain damage cannot make a correct pronunciation for characters that have more than one pronunciation in different word context (Law & Or, 2001; Weekes, Chen, & Yin, 1997; Weekes & Chen, 1999). For example, the character 茄 should be pronounced as */ke2/* in 番茄*/faan1ke2/* and */gaa1/* in 雪茄*/syut3gaa1/*. However, these dyslexic patients pronounced 茄 as */gaa1/* in 番茄 and */ke2/* in 雪茄. This result shows that the dyslexic patients could not read on word context but just randomly selected one pronunciation of the character. They are surface dyslexic patients whose direct word-level representation system has been impaired but the phonological reading route is still intact. The contrast between these two kinds of dyslexia reveals the importance of word-level phonological representations in Chinese compound word processing.

Word-level semantic representation also gets some empirical supports. With a priming paradigm, Zhou et al. (1999) found that only those compound words with the same morpheme can facilitate each other constantly (e.g., 华贵, *luxury* in English -华丽, *gorgeous* in English). Word pairs that share orthography but no semantic relatedness (e.g., 华贵, *luxury* in English -华侨, *overseas Chinese* in English) can bring facilitation with a shorter SOA but that facilitation turns into an inhibitory effect with longer SOA. The difference between the morpheme related prime-target pairs (e.g., 华贵-华丽) and the form related prime-target pairs (e.g., 华贵-华侨) lies in whole word semantic relatedness between the prime and target words. Specifically, the morpheme related prime-target pairs are semantically related to each other, but form related prime-target pairs are not. Thus, the facilitation produced by the morpheme related prime-target pairs is mainly due to whole word semantic relatedness. Based on this finding, the authors argued that there is word-level semantic representation of Chinese compound words.

On the whole, a word's representation in the mental lexicon includes three interlocking components: orthographic, phonological and semantic representations (c.f., Perfetti, et al., 2005). Thus, evidences from these three aspects are all useful to determine the status of lexical representation. The present finding of word-level orthographic representations, together with the findings of word-level phonological (Law et al., 2005) and semantic (Zhou et al., 1999) representations, support the psychological reality of holistic lexical representations of Chinese compound words.

6.1.3 Morphological processing of Chinese compound words

The dispute of recent studies on morphological processing is around form-then-meaning and form-with-meaning accounts. One way to resolve this debate is to examine whether component morpheme meanings are activated at an early stage of compound word processing. Therefore, the second research question of the present study is whether morpheme meanings are activated in Chinese compound word processing and its time course. Study 3 aims to test morpheme meaning activation in Chinese compound words processing by distinguishing the influence of form from meaning. To accomplish this goal, prime-target pairs that contained a pair of semantically related morphemes but did not relate to each other in orthography, phonology, and whole-word meaning. The priming effect produced by such prime-target pairs can only be attributed to component morpheme meaning activation in prime and target words. The results of Study 3 show that component morpheme meaning activation was observable at the first 60ms of word processing. This finding is more consistent with the form-with-meaning account than the form-then-meaning account.

The finding of morpheme meaning activation in compound word processing is consistent with a decomposed account of word access. It is not difficult to reconcile holistic representation with decomposed access of Chinese compound words, considering the findings of Study 3. The results show simultaneous appearance of word meaning activation and component morpheme meaning activation. It is possible that component morpheme meaning activation occurs at the same time with or even after whole word meaning access if morpho-semantic processing is quite fast. However, the supralexical locus of morpheme meaning activation has been ruled out in Study 3 (see p. 121). Thus, the findings of Study 3 are most compatible with a dual-route model that assumes parallel activation of morpheme and whole word meaning activation. From this perspective, there may be two routes for whole word access: morpheme access route and direct word access route. These two routes may take place simultaneously in compound words processing to accelerate the speed of word access. Furthermore, in view of the findings of Studies 1 and 2, the importance of the two routes may differ for transparent and opaque words. The morpheme access route may be heavily relied on during transparent words access; while direct word access route is much more emphasized during opaque word access.

6.2 Contributions of the present research

The present study reveals that Chinese two-character compound words are represented as holistic units in the mental lexicon. It suggests that our mental representation system may conform more to the principle of processing efficiency than storage efficiency. Representing compound words as holistic units in the mental lexicon inevitably requires repeated representation of component characters contained in different words. Such representation needs more storage capacity than representing compound words as component characters. However, such representation may accelerate word access speed by direct match between visual input and the corresponding lexical representation in the mental lexicon.

As to the morphological processing in compound word recognition, Study 3 reveals the existence of early morpheme meaning activation by an innovative method. It also shows the relative speed of morphological decomposition route and whole word access route by a comparison between morpho-semantic effect and whole word semantic effect. The results are useful for distinguishing among different morphological processing models. The occurrence of morpho-semantic activation within short prime duration is consistent with early decomposition accounts and the connectionist account but not the late decomposition accounts. The relative speed of morpheme and word meaning activation support the parallel dual route model and the connectionist model rather than the supra-lexical model and the hybrid model.

6.3 Limitations and directions for further research

Firstly, although the present study used several potential influential factors as covariates in the statistical analyses, such factors (e.g., frequency, neighborhood size and stroke number of initial and final characters) may have interaction effect with the independent variables. The implication and validity of the present study are limited without investigation of such possible interactions. Further studies may try to test such interactions in order to clarify the picture of cognitive processing of Chinese compound words more clearly.

Secondly, although both Study 1 and Study 2 made use of experimental paradigms used in studies of alphabetic languages and obtained similar result patterns, it should be cautious to generalize the findings to other languages. Specifically, the orthographic neighbors in Study 1 and the transposed nonwords in Study 2 are quite different from those used in alphabetic languages. Although the priming effects observed were significant, their magnitude was much smaller than that observed with alphabetic languages. Differences between materials may be the reason.

Thirdly, as pointed out in the General Discussion of Study 1, mental representation of Chinese compound words may be malleable. Repeated processing of two-character words in daily reading may help to shape word-level representations in the mental lexicon. This hypothesis is consistent with the high plasticity of the human memory system. However, to draw such a conclusion needs more developmental evidence. Further research may investigate the existence and developmental trend of word-level orthographic representations for Chinese compound words with participants of different age groups.

Fourthly, the results of the present study are drawn from behavioral experiments with brief presentations of compound words. It may be not considered a natural context for compound word processing. A more natural way to examine the processing of compound words is in normal reading. Eye movement studies can accomplish this goal by monitoring participants' eye movement indicators when they are reading sentences or texts. Results from eye movement studies would provide more evidence to the existence of whole word orthographic representations of Chinese compound words.

Last but not least, a recent discovery of visual word form area (VWFA) by neuropsychologists provides a neural basis for the orthographic representation. Researchers using brain imaging techniques have localized a region in the fusiform gyrus that responds specifically to visual words (McCandliss, Cohen, & Dehaene, 2003). McCandliss et al. (2003) found that VWFA shows larger activation to words than to nonsense letter strings. The hypothesis that VWFA corresponds to whole word recognition is further supported by studies of patients with brain damage. Researchers found that lesions in this brain area are associated with letter-by-letter reading strategy (Gaillard, Naccache, & Pinel, 2006). Thus, if two-character Chinese compound words are represented as wholes, neural activation of VWFA by real compound words should differ from that of two-character nonwords. Whether this is the case or not needs further research.

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APPENDICES

Appendix 1 Stimuli used in Exp 1a (Study 1)

No	Target		Orthographic word neighbor		Word control		Orthographic nonword neighbor	Nonword control
1	lùtú 路途	Road	shíxiàn 实现	To achieve	lùxiàn 路线	Route	lùlián 路怜	shíxún 实询
2	wěngù 稳固	Firm	shùlín 树林	Forest	wěndìng 稳定	Stable	wěnjiū 稳究	shùbǔ 树补
3	xiàoliào 笑料	Jokes	tànqì 叹气	Sigh	xiàohuà 笑话	Joke	xiàoxì 笑细	tànmiè 叹灭
4	bàokǎo 报考	Apply	wūyún 乌云	Dark clouds	bàokān 报刊	Press	bàomiè 报蔑	wūfù 乌父
5	qǐlì 起立	Stand up	suǒwèi 所谓	The so-called	qǐyì 起义	Uprising	qǐbǐ 起比	suǒzhèn 所赈
6	jiǎnlüè 简略	Brief	shíjì 实际	Actual	jiǎnzhí 简直	Simply	jiǎnxián 简贤	shíyóu 实犹
7	qiàqiǎo 恰巧	Happened	shénqíng 神情	Look	qiàdàng 恰当	Appropriate	qiàyú 恰余	shénshuò 神硕
8	tǎnrán 坦然	Calm	shāqiū 沙丘	Dune	tǎnkè 坦克	Tanks	tǎnmài 坦麦	shāchì 沙赤
9	zhāozhì 招致	Incur	pífū 皮肤	Skin	zhāohū 招呼	Call	zhāozhǒng 招肿	píchāo 皮朝
10	zhǐshǐ 指使	Instigate	nèiróng 内容	Content	zhǐdǎo 指导	Guide	zhǐluó 指罗	nèiháo 内豪
11	qīnjìn 亲近	Close	lǐngyù 领域	Field	qīnqi 亲戚	Relatives	qīnzhì 亲智	lǐngzhān 领粘
12	yímín 移民	Immigration	jiēshi 结实	Solid	yídòng 移动	Mobile	yímáng 移芒	jiéhu 结忽
13	chūsè 出色	Excellent	rújīn 如今	Today	chūfā 出发	Starting	chūshí 出石	rújiǎ 如甲
14	gòusī 构思	Idea	shèyǐng 摄影	Photography	gòuzào 构造	Construction	gòupàn 构判	shèxī 摄膝
15	zhōngshēng 终生	Lifelong	shīfù 师傅	Master	zhōngyú 终于	Finally	zhōngquǎn 终犬	shīqiāng 师腔
16	jíqiè 急切	Urgent	tiányě 田野	Field	jímáng 急忙	Hastily	jíhuān 急欢	tiánjuān 田捐
17	yùqī 预期	Expected	xiāngxìn 相信	I believe	yùbèi 预备	Preparation	yùyáo 预肴	xiāngkuò 相括
18	fēnpài 分派	Assignment	xìngzhì 性质	Nature	fēnxī 分析	Analysis	fēnguài 分怪	xìngzhě 性者
19	zénàn 责难	Censure	xuānchuán 宣传	Publicity	zérèn 责任	Responsibility	zédào 责到	xuānfàn 宣犯
20	kāimíng 开明	Enlightened	yāoqiú 要求	Requirements	kāishǐ 开始	Start	kāihóng 开红	yàotuǒ 要妥
21	liúlì 流利	Fluent	zāinàn 灾难	Disaster	liúdòng 流动	Mobile	liúyǔ 流羽	zāixú 灾徐
22	bànlǐ 办理	For	shēngyīn 声音	Sound	bànfǎ 办法	Approach	bànjīng 办经	shēngdì 声帝
23	jǐnkuài 尽快	As soon as possible	nǎozi 脑子	Brain	jǐnguǎn 尽管	Although	jǐndēng 尽登	nǎoguǎng 脑广
24	pànjué 判决	Judgment	qūzhé 曲折	Tortuous	pànduàn 判断	Judge	pànzhū 判诸	qūchǎo 曲吵
25	kùnjìng 困境	Dilemma	lìyòng 利用	Use	kùnnan 困难	Difficult	kùnqiān 困铅	lìníng 利宁
26	wènhòu 问候	Greetings	kěyǐ 可以	Can	wèntí 问题	Problem	wènbàng 问磅	kěmǎ 可马
27	biàngù 变故	Accident	guīdìng 规定	Provisions	biànhuà 变化	Change	biànyè 变业	guīmǔ 规姆
28	shōufù 收复	Recover	jiàngshuǐ 降水	Precipitation	shōushi 收拾	Pack	shōuyán 收研	jiàngyǐ 降已

Appendix 2 Stimuli used in Exp 1b (Study 1)

No	Target		Orthographic word neighbor		Word control		Orthographic nonword neighbor	Nonword control
1	lùtú 路途	Road	yīnmóu 阴谋	Conspiracy	qiántú 前途	Future	péntú 盆途	chímóu 驰谋
2	wěngù 稳固	Firm	yìhuì 议会	Parliament	wángù 顽固	Stubborn	xiàngù 限固	yòuhuì 幼会
3	xiàoliào 笑料	Jokes	xiǎnglè 享乐	Pleasure	yùliào 预料	Expected	jiéliào 桔料	sūlè 苏乐
4	bàokǎo 报考	Apply	shāngyè 商业	Business	sīkǎo 思考	Thinking	suīkǎo 虽考	méngyè 萌业
5	qǐlì 起立	Stand up	kèrén 客人	Guests	dúlì 独立	Independent	jiānglì 将立	mòrén 茉人
6	jiǎnlüè 简略	Brief	miànjī 面积	Area	zhànlüè 战略	Strategy	lǜlüè 律略	wénjī 蚊积
7	qiàqiǎo 恰巧	Happened	pāidǎ 拍打	Pat	língqiǎo 灵巧	Dexterity	xìngqiǎo 杏巧	wǎngdǎ 往打
8	tǎnrán 坦然	Calm	piàoliang 漂亮	Beautiful	suīrán 虽然	Although	shuǎrán 耍然	zhàngliàng 障亮
9	zhāozhì 招致	Incur	qínglǎng 晴朗	Sunny	xìngzhì 兴致	Interest	cúnzhì 存致	tǎlǎng 塔朗
10	zhǐshǐ 指使	Instigate	shǎoshù 少数	Few	jíshǐ 即使	Even if	bàishǐ 败使	kěshù 可数
11	qīnjìn 亲近	Close	tóngyì 同意	Agree	fùjìn 附近	Near	zhàngjìn 帐近	gèyì 各意
12	yímín 移民	Immigration	zhuīqiú 追求	Pursuit	gōngmín 公民	Citizens	àimín 艾民	tuìqiú 退求
13	chūsè 出色	Excellent	fēnpèi 分配	Distribution	liǎnsè 脸色	Look	dànsè 弹色	ruòpèi 若配
14	gòusī 构思	Idea	wánchéng 完成	Complete	yìsi 意思	Mean	sèsī 瑟思	kùchéng 库成
15	zhōngshēng 终生	Lifelong	wàibian 外边	Outside	wèishēng 卫生	Health	gēshēng 戈生	réngbiān 仍边
16	jíqiè 急切	Urgent	shǒushù 手术	Surgery	qīnqiè 亲切	Cordial	quánqiè 泉切	zhǐshù 止术
17	yùqī 预期	Expected	shātān 沙滩	Beach	rìqī 日期	Date	máoqī 毛期	zhétān 折滩
18	fēnpài 分派	Assignment	róngyù 荣誉	Honor	bāngpài 帮派	Gang	wèipài 胃派	ángyù 昂誉
19	zénàn 责难	Censure	róngjiě 溶解	Dissolve	kǔnàn 苦难	Suffering	niànnàn 念难	bēijiě 碑解
20	kāimíng 开明	Enlightened	qīngxiàng 倾向	Tendency	biǎomíng 表明	That	jìmíng 季明	jiǎnxiàng 捡向
21	liúlì 流利	Fluent	luòtuó 骆驼	Camel	quánlì 权利	Right	hànlì 汗利	xìtuó 系驼
22	bànlǐ 办理	For	liángshi 粮食	Food	dàolǐ 道理	Reason	bǎnlǐ 版理	zhìshí 稚食
23	jǐnkuài 尽快	As soon as possible	mìfēng 蜜蜂	Bee	yúkuài 愉快	Happy	dùkuài 渡快	yuànfēng 愿蜂
24	pànjué 判决	Judgment	jūnduì 军队	Army	jiānjué 坚决	Firm	tūnjué 吞决	shìduì 示队
25	kùnjìng 困境	Dilemma	lìyì 利益	Interest	huánjìng 环境	Environment	nújìng 奴境	shāyì 纱益
26	wènhòu 问候	Greetings	jiàoshī 教师	Teachers	qìhòu 气候	Climate	mùhòu 木候	āishī 挨师
27	biàngù 变故	Accident	lèixíng 类型	Type	yuángù 缘故	Reason	pínggù 凭故	lǎnxíng 览型
28	shōufù 收复	Recover	měngliè 猛烈	Violent	chóngfù 重复	Repeat	jiāngfù 姜复	jìliè 济烈

Appendix 3 Stimuli used in Exp 2a (Study 1)

No	Target		Orthographic word neighbor		Word control		Orthographic nonword neighbor	Nonword control
1	lùtú 路途	Road	lùxiàn 路线	Route	shíxiàn 实现	To achieve	lùxiàn 路限	shíxiàn 实限
2	wěngù 稳固	Firm	wěndìng 稳定	Stable	shùlín 树林	Forest	wěndìng 稳订	shùlín 树临
3	xiàoliào 笑料	Jokes	xiàohuà 笑话	Joke	tànqì 叹气	Sigh	xiàohuà 笑画	tànqì 叹弃
4	bàokǎo 报考	Apply	bàokān 报刊	Press	wūyún 乌云	Dark clouds	bàokān 报堪	wūyún 乌匀
5	qǐlì 起立	Stand up	qǐyì 起义	Uprising	suǒwèi 所谓	The so-called	qǐyí 起宜	suǒwèi 所未
6	jiǎnlüè 简略	Brief	jiǎnzhí 简直	Simply	shíjì 实际	Actual	jiǎnzhí 简侄	shíjì 实记
7	qiàqiǎo 恰巧	Happened	qiàdàng 恰当	Appropriate	júbù 局部	Local	qiàdàng 恰荡	júbù 局步
8	tǎnrán 坦然	Calm	tǎnkè 坦克	Tanks	shāqiū 沙丘	Dune	tǎnkè 坦刻	shāqiū 沙秋
9	zhāozhì 招致	Incur	zhāohū 招呼	Call	pífū 皮肤	Skin	zhāohū 招忽	pífū 皮敷
10	zhǐshǐ 指使	Instigate	zhǐdǎo 指导	Guide	nèiróng 内容	Content	zhǐdǎo 指岛	nèiróng 内茸
11	qīnjìn 亲近	Close	qīnqi 亲戚	Relatives	lǐngyù 领域	Field	qīnqì 亲器	lǐngyù 领玉
12	yímín 移民	Immigration	yídòng 移动	Mobile	jiēshí 结实	Solid	yídòng 移冻	jiēshí 结时
13	jiējì 接济	Financial aid	jiējìn 接近	Close	rújīn 如今	Today	jiējìn 接晋	rújīn 如金
14	gòusī 构思	Idea	gòuzào 构造	Construction	shèyǐng 摄影	Photography	gòuzào 构燥	shèyǐng 摄颖
15	zhōngshēng 终生	Lifelong	zhōngyú 终于	Finally	shīfu 师傅	Master	zhōngyú 终鱼	shīfù 师富
16	dòngtīng 动听	Sounds	dòngyuán 动员	Mobilization	tiányě 田野	Field	dòngyuán 动原	tiányě 田冶
17	yùqī 预期	Expected	yùbèi 预备	Preparation	xiāngxìn 相信	I believe	yùbèi 预背	xiāngxìn 相衅
18	fēnpài 分派	Assignment	fēnxī 分析	Analysis	xìngzhì 性质	Nature	fēnxī 分希	xìngzhì 性治
19	zénàn 责难	Censure	zérèn 责任	Responsibility	xuānchuán 宣传	Publicity	zérèn 责认	xuānchuán 宣船
20	kāimíng 开明	Enlightened	kāishǐ 开始	Start	yāoqiú 要求	Requirements	kāishǐ 开使	yāoqiú 要囚
21	liúlì 流利	Fluent	liúdòng 流动	Mobile	dānwu 耽误	Delay	liúdòng 流洞	dānwù 耽物
22	jīyā 积压	Backlog	jījí 积极	Positive	liánxì 联系	Contact	jījí 积吉	liánxì 联戏
23	míngkuài 明快	Bright	míngquè 明确	Clear	nǎozi 脑子	Brain	míngquè 明却	nǎozī 脑资
24	pànjué 判决	Judgment	pànduàn 判断	Judge	qūzhé 曲折	Tortuous	pànduàn 判段	qūzhé 曲辙
25	kùnjìng 困境	Dilemma	kùnnan 困难	Difficult	tàiyáng 太阳	Sun	kùnnán 困男	tàiyáng 太扬
26	wènhòu 问候	Greetings	wèntí 问题	Problem	kěyǐ 可以	Can	wèntí 问鼐	kěyǐ 可已
27	biàngù 变故	Accident	biànhuà 变化	Change	guīdìng 规定	Provisions	biànhuà 变话	guīdìng 规订
28	shōufù 收复	Recover	shōushi 收拾	Pack	yídòng 移动	Mobile	shōushí 收时	yídòng 移冻

Appendix 4 Stimuli used in Exp 2b (Study 1)

No	Target		Orthographic word neighbor		Word control		Orthographic nonword neighbor	Nonword control
1	lùtú 路途	Road	qiántú 前途	Future	yīnmóu 阴谋	Conspiracy	qiántú 钱途	yīnmóu 音谋
2	wěngù 稳固	Firm	wángù 顽固	Stubborn	yìhuì 议会	Parliament	wángù 完固	yìhuì 益会
3	xiàoliào 笑料	Jokes	yùliào 预料	Expected	xiǎnglè 享乐	Pleasure	yùliào 愈料	xiǎnglè 想乐
4	bàokǎo 报考	Apply	sīkǎo 思考	Thinking	shāngyè 商业	Business	sīkǎo 斯考	shāngyè 伤业
5	qǐlì 起立	Stand up	dúlì 独立	Independent	kèrén 客人	Guests	dúlì 读立	kèrén 课人
6	jiǎnlüè 简略	Brief	zhànlüè 战略	Strategy	zhújiàn 逐渐	Gradually	zhànlüè 栈略	zhújiàn 竺渐
7	qiàqiǎo 恰巧	Happened	língqiǎo 灵巧	Dexterity	zájiāo 杂交	Hybrid	língqiǎo 玲巧	zájiāo 砸交
8	yīnxiǎn 阴险	Insidious	yīnmóu 阴谋	Conspiracy	pífū 皮肤	Skin	yīnmóu 因谋	pífū 脾肤
9	zhāozhì 招致	Incur	xìngzhì 兴致	Interest	qínglǎng 晴朗	Sunny	xìngzhì 姓致	qínglǎng 擎朗
10	zhǐshǐ 指使	Instigate	jíshǐ 即使	Even if	míngzì 名字	Name	jíshǐ 及使	míngzì 明字
11	qīnjìn 亲近	Close	fùjìn 附近	Near	tóngyì 同意	Agree	fùjìn 副近	tóngyì 童意
12	yímín 移民	Immigration	gōngmín 公民	Citizens	zhuīqiú 追求	Pursuit	gōngmín 弓民	zhuīqiú 锥求
13	hūyìng 呼应	Echo	hūxī 呼吸	Respiratory	dòngzuò 动作	Action	hūxī 忽吸	dòngzuò 冻作
14	gòusī 构思	Idea	yìsi 意思	Mean	wánchéng 完成	Complete	yìsī 忆思	wánchéng 玩成
15	zhōngshēng 终生	Lifelong	wèishēng 卫生	Health	duìdài 对待	Treatment	wèishēng 为生	duìdài 队待
16	jíqiè 急切	Urgent	qīnqiè 亲切	Cordial	shǒushù 手术	Surgery	qīnqiè 钦切	shǒushù 首术
17	chéngjiāo 成交	Turnover	chénggōng 成功	Success	bìyào 必要	Necessary	chénggōng 呈功	bìyào 泌要
18	zuìzhèng 罪证	Evidence	zuìzhuàng 罪状	Counts	róngyù 荣誉	Honor	zuìzhuàng 醉状	róngyù 融誉
19	yùnfèi 运费	Freight	yùnshū 运输	Transportation	shēnkè 深刻	Deep	yùnshū 孕输	shēnkè 伸刻
20	wēiwàng 威望	Prestige	wēixié 威胁	Threat	qīngxiàng 倾向	Tendency	wēixié 危胁	qīngxiàng 清向
21	liúlì 流利	Fluent	quánlì 权利	Right	luòtuo 骆驼	Camel	quánlì 泉利	luòtuo 落驼
22	bànlǐ 办理	For	dàolǐ 道理	Reason	liángshi 粮食	Food	dàolǐ 到理	liángshi 梁食
23	jǐnkuài 尽快	As soon as possible	yúkuài 愉快	Happy	mìfēng 蜜蜂	Bee	yúkuài 鱼快	mìfēng 觅蜂
24	pànjué 判决	Judgment	jiānjué 坚决	Firm	jūnduì 军队	Army	jiānjué 间决	jūnduì 均队
25	kùnjìng 困境	Dilemma	huánjìng 环境	Environment	lìyì 利益	Interest	huánjìng 桓境	lìyì 丽益
26	wènhòu 问候	Greetings	qìhòu 气候	Climate	jiàoshī 教师	Teachers	qìhòu 弃候	jiàoshī 轿师
27	biàngù 变故	Accident	yuángù 缘故	Reason	lèixíng 类型	Type	yuángù 元故	lèixíng 累型
28	shōufù 收复	Recover	chóngfù 重复	Repeat	lǚxíng 旅行	Travel	chóngfù 虫复	lǚxíng 屡行

Appendix 5-1 Stimuli used in Exp 3 (TT) (Study 1)

No	Target		Orthographic word neighbor		Word control		Orthographic nonword neighbor	Nonword control
1	jǔlì 举例	Example	jǔbàn 举办	Held	xìnhào 信号	Signal	jǔbàn 举华	xìnhào 信浩
2	bèirù 被褥	Bedding	bèipò 被迫	Forced	biǎoyǎn 表演	Performance	bèipò 被魄	biǎoyǎn 表眼
3	huífù 回复	Reply	huíyì 回忆	Memories	jìfēng 季风	Monsoon	huíyì 回易	jìfēng 季丰
4	bùpǐ 布匹	Cloth	bùzhì 布置	Layout	sǔnshī 损失	Loss	bùzhì 布致	sǔnshī 损施
5	huòchuán 货船	Cargo ship	huòbì 货币	Currency	wěndìng 稳定	Stable	huòbì 货毕	wěndìng 稳订
6	jīliú 激流	Torrent	jīliè 激烈	Intense	qūbié 区别	Difference	jīliè 激猎	qūbié 区憋
7	cāoláo 操劳	Physical exertion	cāozuò 操作	Operation	dìtú 地图	Map	cāozuò 操坐	dìtú 地涂
8	yīngyǔ 英语	English	yīngyǒng 英勇	Heroic	tiáoyuē 条约	Treaty	yīngyǒng 英永	tiáoyuē 条曰
9	xīnhūn 新婚	Wedding	xīnxiān 新鲜	Fresh	cānguān 参观	Visit	xīnxiān 新先	cānguān 参关
10	jiàngwēn 降温	Cool	jiàngdī 降低	Lower	cǎodì 草地	Lawn	jiàngdī 降滴	cǎodì 草帝
11	guānglǎn 光缆	Cable	guāngmíng 光明	Bright	chuàngzuò 创作	Creation	guāngmíng 光鸣	chuàngzuò 创坐
12	hézòu 合奏	Ensemble	hélǐ 合理	Reasonable	děngdài 等待	Wait	hélǐ 合李	děngdài 等带
13	wúxiào 无效	Invalid	wúxiàn 无限	Unlimited	běnshēn 本身	Itself	wúxiàn 无现	běnshēn 本伸
14	hūyìng 呼应	Echo	hūxī 呼吸	Respiratory	jiànkāng 健康	Health	hūxī 呼希	jiànkāng 健抗
15	xiāngróng 相容	Compatibility	xiāngtóng 相同	Same	zhǔnquè 准确	Accurate	xiāngtóng 相童	zhǔnquè 准却
16	jiěsàn 解散	Dissolve	jiěshì 解释	Explained	jìlǜ 纪律	Discipline	jiěshì 解试	jìlǜ 纪虑
17	ānyì 安逸	Easy	ānpái 安排	Arrangements	tuīdòng 推动	Promote	ānpái 安牌	tuīdòng 推冻
18	chéndiàn 沉淀	Precipitation	chénzhòng 沉重	Heavy	chūfā 出发	Starting	chénzhòng 沉众	chūfā 出法
19	yǎnbiàn 演变	Evolution	yǎnyuán 演员	Actor	hēi'àn 黑暗	Dark	yǎnyuán 演原	hēi'àn 黑案
20	yándōng 严冬	Winter	yánsù 严肃	Serious	hǎiyáng 海洋	Marine	yánsù 严素	hǎiyáng 海扬
21	yùnfèi 运费	Freight	yùnyòng 运用	Use	gǔdài 古代	Ancient	yùnyòng 运咏	gǔdài 古待
22	huāndù 欢度	Celebrate	huānyíng 欢迎	Welcome	duìzhǎng 队长	Captain	huānyíng 欢萤	duìzhǎng 队掌
23	yīcì 依次	Turn	yīkào 依靠	Depend	xiāomiè 消灭	Eliminate	yīkào 依拷	xiāomiè 消蔑
24	tíwèn 提问	Questions	tígōng 提供	Provide	chéngdù 程度	Level	tígōng 提宫	chéngdù 程杜
25	wēiguān 微观	Micro	wēixiào 微笑	Smile	gǒnggù 巩固	Consolidation	wēixiào 微校	gǒnggù 巩顾
26	xìngjí 性急	Impatience	xìngzhì 性质	Nature	shìwù 事物	Things	xìngzhì 性致	shìwù 事误
27	yǒuzhù 有助	Help	yǒuguān 有关	For	yǒuguān 有关	For	yǒuguān 有观	yǒuguān 有冠
28	fùyìn 复印	Photocopying	fùzá 复杂	Complex	gōngjù 工具	Tools	fùzá 复砸	gōngjù 工据
29	zhǎngshēng 掌声	Applause	zhǎngwò 掌握	Master	tiělù 铁路	Railway	zhǎngwò 掌沃	tiělù 铁璐
30	wàitào 外套	Coat	wàiguó 外国	Foreign	fùzé 负责	Responsible	wàiguó 外郭	fùzé 负泽
31	zhǐzé 指责	Accused	zhǐdǎo 指导	Guide	nèiróng 内容	Content	zhǐdǎo 指倒	nèiróng 内融
32	yǐnyòng 引用	Quote	yǐnqǐ 引起	Cause	zhōuwéi 周围	Around	yǐnqǐ 引启	zhōuwéi 周唯
33	wénjìng 文静	Gentle and quiet	wénxué 文学	Literature	chuàngzào 创造	Create	wénxué 文穴	chuàngzào 创皂
34	hòumǔ 后母	Stepmother	hòulái 后来	Later	zhìdù 制度	System	hòulái 后睐	zhìdù 制杜
35	zhèngmén 正门	Main entrance	zhèngquè 正确	Correct	rènwu 任务	Task	zhèngquè 正雀	rènwu 任雾
36	tóngděng 同等	Same	tóngshí 同时	At the same time	cuòwù 错误	Error	tóngshí 同石	cuòwù 错物

Appendix 5-2 Stimuli used in Exp 3 (OT) (Study 1)

No	Target		Orthographic word neighbor		Word control		Orthographic nonword neighbor	Nonword control
1	dǎobì 倒闭	Collapse	dǎoméi 倒霉	Bad luck	zīgé 资格	Qualification	dǎoméi 倒眉	zīgé 资隔
2	chōuchá 抽查	Checks	chōuxiàng 抽象	Abstract	zhèngjīng 正经	Serious	chōuxiàng 抽向	zhèngjīng 正京
3	huāmì 花蜜	Nectar	huāshēng 花生	Peanut	xíngli 行李	Luggage	huāshēng 花升	xíngli 行礼
4	tiānfù 天赋	Talent	tiānzhēn 天真	Naive	míxìn 迷信	Superstition	tiānzhēn 天针	míxìn 迷锌
5	guānshuì 关税	Tariff	guānhuái 关怀	Care	fēngqì 风气	Atmosphere	guānhuái 关槐	fēngqì 风器
6	mímáng 迷茫	Confused	míxìn 迷信	Superstition	bèixīn 背心	Vest	míxìn 迷锌	bèixīn 背新
7	shīsàn 失散	Separated	shīwàng 失望	Disappointed	xiàyóu 下游	Downstream	shīwàng 失妄	xiàyóu 下由
8	qián'é 前额	Forehead	qiánxiàn 前线	Front	kuàihuó 快活	Happy	qiánxiàn 前限	kuàihuó 快或
9	huómái 活埋	Buried alive	huópō 活泼	Lively	guāngxiàn 光线	Light	huópō 活颇	guāngxiàn 光献
10	xuémíng 学名	Scientific name	xuéwèn 学问	Learning	tǐxì 体系	System	xuéwèn 学纹	tǐxì 体戏
11	yíngdì 营地	Camp	yíngyǎng 营养	Nutrition	géwài 格外	Particularly	yíngyǎng 营仰	géwài 格歪
12	chūshòu 出售	Sale	chūshēn 出身	Birth	chūshēn 出身	Birth	chūshēn 出深	chūshēn 出申
13	máshéng 麻绳	Hemp rope	máfan 麻烦	Trouble	cóngshì 从事	In	máfán 麻凡	cóngshì 从视
14	zhěngshù 整数	Integer	zhěngfēng 整风	Rectification	fādá 发达	Developed	zhěngfēng 整蜂	fādá 发答
15	rèlèi 热泪	Tears	rènao 热闹	Lively	làngfèi 浪费	Waste	rènào 热挠	làngfèi 浪废
16	kèzhàn 客栈	Inn	kèqi 客气	Polite	yàojǐn 要紧	Critical	kèqì 客弃	yàojǐn 要仅
17	tiānchuāng 天窗	Skylight	tiānrán 天然	Natural	guǎngbō 广播	Radio	tiānrán 天冉	guǎngbō 广剥
18	xiǎnlù 显露	Revealed	xiǎnrán 显然	Obviously	shǒuduàn 手段	Means	xiǎnrán 显冉	shǒuduàn 手断
19	duìhuà 对话	Dialogue	duìxiàng 对象	Object	zhàopiàn 照片	Photos	duìxiàng 对项	zhàopiàn 照骗
20	zhǔtǐ 主体	Subject	zhǔzhāng 主张	Advocate	chéngjiù 成就	Achievement	zhǔzhāng 主章	chéngjiù 成旧
21	wùzhǒng 物种	Species	wùlǐ 物理	Physics	wénjiàn 文件	File	wùlǐ 物李	wénjiàn 文贱
22	tèchǎn 特产	Specialty	tèwù 特务	Spy	xìbāo 细胞	Cells	tèwù 特误	xìbāo 细宝
23	xiānxíng 先行	In advance	xiānjìn 先进	Advanced	qíngxíng 情形	Case	xiānjìn 先晋	qíngxíng 情行
24	zhuānkē 专科	Specialist	zhuānmén 专门	Specialized	xiǎoxīn 小心	Careful	zhuānmén 专问	xiǎoxīn 小欣
25	jiāyóu 加油	Oil	jiāgōng 加工	Processing	lǎobǎn 老板	Boss	jiāgōng 加基	lǎobǎn 老般
26	biāobǎng 标榜	Flaunt	biāozhǔn 标准	Standard	guānxīn 关心	Concern	biāozhǔn 标淳	guānxīn 关欣
27	miànzhào 面罩	Face mask	miànjī 面积	Area	yǎnguāng 眼光	Vision	miànjī 面基	yǎnguāng 眼广
28	běnsè 本色	Character	běnlái 本来	Originally	gōngfu 工夫	Work	běnlái 本赖	gōngfu 工伏
29	zhíshuǎng 直爽	Straightforward	zhíjiē 直接	Directly	chuántǒng 传统	Traditional	zhíjiē 直阶	chuántǒng 传筒
30	mùlù 目录	Directory	mùdì 目的	Objective	jīnglǐ 经理	Manager	mùdì 目帝	jīnglǐ 经李
31	zīzhù 资助	Funding	zīliào 资料	Information	bǎozhèng 保证	Guarantee	zīliào 资撩	bǎozhèng 保挣
32	zìlì 自立	Independence	zìyóu 自由	Free	ménkǒu 门口	Door	zìyóu 自犹	ménkǒu 门扣
33	suǒshǔ 所属	Belongs	suǒwèi 所谓	The so-called	jùtǐ 具体	Specific	suǒwèi 所卫	jùtǐ 具梯
34	jiǎnyì 简易	Simple	jiǎnzhí 简直	Simply	jīhuì 机会	Opportunities	jiǎnzhí 简执	jīhuì 机慧
35	fāngxíng 方形	Square	fāngzhēn 方针	Policy	jīguān 机关	Authority	fāngzhēn 方珍	jīguān 机冠
36	yuánzhù 原著	Original	yuánzé 原则	Principles	shuǐpíng 水平	Level	yuánzé 原择	shuǐpíng 水屏

Appendix 5-3 Stimuli used in Exp 3 (TO) (Study 1)

No	Target		Orthographic word neighbor		Word control		Orthographic nonword neighbor	Nonword control
1	qiángbào 强暴	Violent	qiángdù 强度	Strength	dòngzuò 动作	Action	qiángdù 强杜	dòngzuò 动坐
2	biǎobái 表白	Confession	biǎoyǎn 表演	Performance	fánghù 防护	Protection	biǎoyǎn 表眼	fánghù 防互
3	jiāodào 交道	Dealings	jiāoyì 交易	Transactions	gǎiliáng 改良	Improved	jiāoyì 交义	gǎiliáng 改凉
4	fēnhóng 分红	Dividend	fēnxī 分析	Analysis	gōngjù 工具	Tools	fēnxī 分西	gōngjù 工聚
5	jiějì 接济	Financial aid	jiēchù 接触	Contact	jiànkāng 健康	Health	jiēchù 接畜	jiànkāng 健抗
6	jìndù 进度	Progress	jìngōng 进攻	Attack	shèbèi 设备	Equipment	jìngōng 进弓	shèbèi 设背
7	rènmìng 任命	Appointed	rènwu 任务	Task	shǐyòng 使用	Use	rènwù 任物	shǐyǒng 使泳
8	běnfèn 本分	Sub	běnshēn 本身	Itself	shùliàng 数量	Quantity	běnshēn 本深	shùliàng 数[illegible]
9	lǎoliàn 老练	Experienced	lǎorén 老人	Elderly	tiělù 铁路	Railway	lǎorén 老仁	tiělù 铁录
10	tánxīn 谈心	Talk	tánpàn 谈判	Negotiations	tuīguǎng 推广	Promotion	tánpàn 谈盼	tuīguāng 推光
11	tiáolǐ 条理	Coherent	tiáoyuē 条约	Treaty	wěndìng 稳定	Stable	tiáoyuē 条曰	wěndìng 稳订
12	tōngróng 通融	Accommodation	tōngxùn 通讯	Communications	xiāngfǎn 相反	On the contrary	tōngxùn 通汛	xiāngfán 相烦
13	tóuhào 头号	Top	tóunǎo 头脑	Mind	xuěhuā 雪花	Snowflake	tóunǎo 头瑙	xuěhuá 雪划
14	tóubèn 投奔	Defected	tóurù 投入	Input	yáchǐ 牙齿	Teeth	tóurù 投濡	yáchǐ 牙尺
15	tuīduàn 推断	Infer	tuīdòng 推动	Promote	yǒuxiào 有效	Effective	tuīdòng 推洞	yǒuxiào 有校
16	wēiwàng 威望	Prestige	wēixié 威胁	Threat	bǎojiàn 宝剑	Sword	wēixié 威邪	bǎojiàn 宝件
17	xiànyǎn 现眼	Disgraced	xiànshí 现实	Reality	duìzhǎng 队长	Captain	xiànshí 现识	duìzhǎng 队掌
18	xiāoqiǎn 消遣	Pastime	xiāomiè 消灭	Eliminate	gǒnggù 巩固	Consolidation	xiāomiè 消蔑	gǒnggù 巩故
19	yìqì 意气	Emotional	yìshí 意识	Consciousness	xiānghù 相互	Mutual	yìshí 意食	xiānghù 相户
20	zhāopái 招牌	Sign	zhāohu 招呼	Call	jìlǜ 纪律	Discipline	zhāohù 招恕	jìlǜ 纪率
21	zhēnkōng 真空	Vacuum	zhēnlǐ 真理	Truth	jiǎnchá 检查	Check	zhēnlǐ 真李	jiǎnchá 检茶
22	zhōudào 周到	Thoughtful	zhōuwéi 周围	Around	zhǐchū 指出	That	zhōuwéi 周唯	zhǐchū 指初
23	bùluò 部落	Tribe	bùmén 部门	Departments	qízhōng 其中	Which	bùmén 部闷	qízhōng 其终
24	cǎotú 草图	Sketch	cǎodì 草地	Lawn	chuàngzuò 创作	Creation	cǎodì 草递	chuàngzuò 创座
25	chūqì 出气	Outlet	chūfā 出发	Starting	guānzhòng 观众	Audience	chūfá 出伐	guānzhòng 观种
26	chuàngjǔ 创举	Pioneering	chuàngzào 创造	Create	jiānchí 坚持	Persist	chuàngzào 创燥	jiānchí 坚迟
27	cuòluò 错落	Scattered	cuòwù 错误	Error	wánquán 完全	Completely	cuòwù 错务	wánquán 完泉
28	dàoxiè 道谢	Thank	dàolù 道路	Road	liánxì 联系	Contact	dàolù 道录	liánxì 联戏
29	duìzhào 对照	Control	duìdài 对待	Treatment	xiànzhì 限制	Limit	duìdài 对带	xiànzhì 限至
30	fàngfēng 放风	Spread rumors	fàngdà 放大	Enlarge	yǎnyuán 演员	Actor	fàngdà 放搭	yǎnyuán 演元
31	gǎikǒu 改口	Changed to	gǎishàn 改善	Improve	zhǔnquè 准确	Accurate	gǎishàn 改汕	zhǔnquè 准雀
32	gǔbǎn 古板	Old-fashioned	gǔdài 古代	Ancient	yǔnxǔ 允许	Allowed	gǔdài 古带	yǔnxǔ 允续
33	hǎitáng 海棠	Begonia	hǎiyáng 海洋	Marine	yùnyòng 运用	Use	hǎiyáng 海杨	yùnyǒng 运咏
34	hēibāng 黑帮	Gang	hēi'àn 黑暗	Dark	zhúbù 逐步	Gradually	hēiàn 黑案	zhúbù 逐部
35	jiǎndiǎn 检点	Indecent	jiǎnyàn 检验	Test	láidào 来到	To	jiǎnyàn 检焰	láidào 来稻
36	jiànwài 见外	See outside	jiànmiàn 见面	Meet	xíngwéi 行为	Behavior	jiànmiàn 见觅	xíngwéi 行维

Appendix 5-4 Stimuli used in Exp 3 (OO) (Study 1)

No	Target		Orthographic word neighbor		Word control		Orthographic nonword neighbor	Nonword control
1	qīnxìn 亲信	Trusted	qīnqiè 亲切	Cordial	duìxiàng 对象	Cordial	qīnqiè 亲怯	duìxiàng 对伥
2	bǎozhòng 保重	Take care	bǎozhèng 保证	Guarantee	zīliào 资料	Guarantee	bǎozhèng 保郑	zīliào 资敹
3	chéngjiàn 成见	Prejudice	chéngjiù 成就	Achievement	lìchǎng 立场	Achievement	chéngjiù 成旧	lìchǎng 立敞
4	dāngchǎng 当场	On the spot	dāngrán 当然	Of course.	yìjiàn 意见	Of course,	dāngrán 当冉	yìjiàn 意贱
5	gōngzhěng 工整	Neat	gōngfu 工夫	Work	guānxīn 关心	Work	gōngfū 工付	guānxīn 关新
6	jīzhì 机智	Witty	jīhuì 机会	Opportunities	xiāoxi 消息	Opportunities	jīhuì 机汇	xiāoxī 消希
7	jīngjì 经纪	Brokers	jīnglǐ 经理	Manager	biāozhǔn 标准	Manager	jīnglǐ 经李	biāozhǔn 标淳
8	lěngqīng 冷清	Deserted	lěngquè 冷却	Cooling	dǎoméi 倒霉	Cooling	lěngquè 冷雀	dǎoméi 倒枚
9	shǒutóu 手头	Hand	shǒuduàn 手段	Means	tiānrán 天然	Means	shǒuduàn 手断	tiānrán 天冉
10	shuǐxiān 水仙	Narcissus	shuǐpíng 水平	Level	xiànxiàng 现象	Level	shuǐpíng 水屏	xiànxiàng 现向
11	tǐwèi 体味	Appreciate	tǐxì 体系	System	xuéwèn 学问	System	tǐxì 体戏	xuéwěn 学稳
12	xìjié 细节	Details	xìbāo 细胞	Cells	tèwù 特务	Cells	xìbǎo 细宝	tèwù 特勿
13	xiǎoqi 小气	Stingy	xiǎoxīn 小心	Careful	zhuānmén 专门	Careful	xiǎoxīn 小欣	zhuānmèn 专问
14	yàohài 要害	Vital	yàojǐn 要紧	Critical	kèqi 客气	Critical	yàojǐn 要锦	kèqì 客弃
15	zhàoliào 照料	Care	zhàopiàn 照片	Photos	běnlǐng 本领	Photos	zhàopiàn 照骗	běnlíng 本凌
16	chōngdòng 冲动	Impulse	chōngtū 冲突	Conflict	chōuxiàng 抽象	Conflict	chōngtū 冲秃	chōuxiàng 抽向
17	dòngtīng 动听	Sounds	dòngyuán 动员	Mobilization	yíngyǎng 营养	Mobilization	dòngyuán 动元	yíngyǎng 营仰
18	fēngmiàn 封面	Cover	fēngjiàn 封建	Feudal	shēngmìng 生命	Feudal	fēngjiàn 封件	shēngmìng 生鸣
19	guǎngkuò 广阔	Expansive	guǎngbō 广播	Radio	xiǎnrán 显然	Radio	guǎngbō 广波	xiǎnrán 显冉
20	jímù 极目	Jimu	jíqí 极其	Extremely	chūshēn 出身	Extremely	jíqí 极齐	chūshēn 出深
21	jiāngjiù 将就	Will	jiāngjūn 将军	General	dǎsuan 打算	General	jiāngjūn 将君	dǎsuàn 打蒜
22	jièguāng 借光	Excuse me	jièkǒu 借口	Excuse	shénsè 神色	Excuse	jièkǒu 借叔	shénsè 神涩
23	jìnqǔ 进取	Aggressive	jìnhuà 进化	Evolution	géwài 格外	Evolution	jìnhuà 进话	géwāi 格歪
24	làngmàn 浪漫	Romantic	làngfèi 浪费	Waste	yàojǐn 要紧	Waste	làngfèi 浪肺	yàojǐn 要锦
25	mǎhu 马虎	Careless	mǎshàng 马上	Immediately	yuánzé 原则	Immediately	mǎshàng 马尚	yuánzé 原泽
26	méndì 门第	Door No.	ménkǒu 门口	Door	jīguān 机关	Door	ménkòu 门扣	jīguān 机观
27	qíngdiào 情调	Sentiment	qíngxing 情形	Case	xiānjìn 先进	Case	qínghāng 情行	xiānjìn 先晋
28	wénpíng 文凭	Diploma	wénjiàn 文件	File	mǎnzú 满足	File	wénjiàn 文键	mǎnzú 满卒
29	xiàchǎng 下场	End	xiàyóu 下游	Downstream	bèixīn 背心	Downstream	xiàyóu 下由	bèixīn 背欣
30	xiànyǎn 现眼	Disgraced	xiànxiàng 现象	Phenomenon	mǎshàng 马上	Phenomenon	xiànxiàng 现向	mǎshàng 马尚
31	xíngjìng 行径	Act	xíngli 行李	Luggage	huāshēng 花生	Luggage	hánglǐ 行理	huāshēng 花升
32	yìqì 意气	Emotional	yìwèi 意味	Mean	dǎting 打听	Mean	yìwèi 意位	dǎtīng 打厅
33	chéngyǔ 成语	Idiom	chéngfèn 成分	Components	huópo 活泼	Components	chéngfèn 成奋	huópō 活颇
34	chōukòng 抽空	Find time	chōuxiàng 抽象	Abstract	zhèngjīng 正经	Abstract	chōuxiàng 抽项	zhèngjīng 正精
35	chuánzhēn 传真	Fax	chuántǒng 传统	Traditional	jiāgōng 加工	Traditional	chuántǒng 传桶	jiāgōng 加弓
36	dǎyìn 打印	Print	dǎting 打听	Inquire about	nǎojīn 脑筋	Inquire about	dǎtīng 打厅	nǎojīn 脑今

Appendix 6-1 Stimuli used in Exp 4 (TT) (Study 1)

No	Target		Orthographic word neighbor		Word control		Orthographic nonword neighbor	Nonword control
1	yōuyì 优异	Excellent	chāyì 差异	Differences	zhǎyǎn 眨眼	Wink	chāyì 插异	zhàyǎn 乍眼
2	zhǎngshēng 掌声	Applause	liánshēng 连声	Repeatedly	chuǎnqì 喘气	Pant	liánshēng 怜声	chuànqì 串气
3	jiàngwēn 降温	Cool	tǐwēn 体温	Body temperature	fēngbào 风暴	Storm	tǐwēn 钵温	fēngbào 蜂暴
4	yùgǎn 预感	Premonition	mǐngǎn 敏感	Sensitive	xiānhóng 鲜红	Red	mǐngǎn 闽感	xiānhóng 先红
5	miánxiàn 棉线	Cotton	zhíxiàn 直线	Straight line	lànghuā 浪花	Spray	zhíxiàn 执线	lánghuā 郎花
6	chéngfǎ 乘法	Multiplication	héfǎ 合法	Legitimate	chuāngkǒu 窗口	Window	héfǎ 和法	chuāngkǒu 疮口
7	chuàngyè 创业	Entrepreneurship	zhíyè 职业	Professional	yànhuì 宴会	Banquet	zhíyè 值业	yànhuì 艳会
8	qīngxìn 轻信	Readily believe	tōngxìn 通信	Communications	jiāoyì 交易	Transactions	tǒngxìn 桶信	jiāoyì 娇易
9	piànjú 骗局	Fraud	quánjú 全局	Global	hēibǎn 黑板	Blackboard	quánjú 权局	hēibǎn 嘿板
10	yǐnyòng 引用	Quote	fèiyòng 费用	Fees	qīngzǎo 清早	Morning	fèiyòng 废用	qīngzǎo 轻早
11	jiǎnjié 简洁	Concise	chúnjié 纯洁	Pure	gǎiliáng 改良	Improved	chúnjié 醇洁	gāiliáng 该良
12	dìngjū 定居	Settlement	línjū 邻居	Neighbors	rèdài 热带	Tropical	línjū 临居	rědài 惹带
13	shūtǎn 舒坦	Comfortable	píngtǎn 平坦	Flat	dàhǎi 大海	Sea	píngtǎn 屏坦	dǎhǎi 打海
14	yǎnbiàn 演变	Evolution	shìbiàn 事变	Incident	jǔbàn 举办	Held	shìbiàn 示变	jǔbàn 沮办
15	gēshǒu 歌手	Singer	wòshǒu 握手	Shake hands	biǎoyǎn 表演	Performance	wòshǒu 卧手	biāoyǎn 标演
16	kèyú 课余	After school	shèngyú 剩余	Remaining	guǐdào 轨道	Track	shèngyú 胜余	guǐdào 鬼道
17	jiětǐ 解体	Disintegration	qìtǐ 气体	Gas	tánpàn 谈判	Negotiations	tītǐ 梯体	tánpàn 坛判
18	xiūfù 修复	Repair	chóngfù 重复	Repeat	jìfēng 季风	Monsoon	chóngfù 虫复	jìfēng 寄风
19	huífù 回复	Reply	chóngfù 重复	Repeat	tóunǎo 头脑	Mind	chóngfù 虫复	tóunǎo 投脑
20	chuàngshǐ 创始	Founding	yuánshǐ 原始	Original	fánghù 防护	Protection	yuánshǐ 袁始	fánghù 房护
21	hūyìng 呼应	Echo	gōngyìng 供应	Supply	tuīguǎng 推广	Promotion	gōngyìng 蚣应	tuìguǎng 退广
22	cūyě 粗野	Rough	tiányě 田野	Field	bǎojiàn 宝剑	Sword	tiányě 甜野	bǎojiàn 保剑
23	bǎoyǎng 保养	Maintenance	yíngyǎng 营养	Nutrition	sǔnshī 损失	Loss	yǐngyǎng 颖养	sǔnshī 笋失
24	jǔlì 举例	Example	bǐlì 比例	Ratio	huòbì 货币	Currency	bǐlì 彼例	huòbì 祸币
25	wénjìng 文静	Gentle and quiet	ānjìng 安静	Quiet	wěndìng 稳定	Stable	ànjìng 岸静	wéndìng 闻定
26	sòngbié 送别	Farewell	qūbié 区别	Difference	jīliè 激烈	Intense	qūbié 屈别	jīliè 基烈
27	wēiguān 微观	Micro	cānguān 参观	Visit	xīnxiān 新鲜	Fresh	cānguān 餐观	xīnxiān 辛鲜
28	yōudài 优待	Preferential treatment	děngdài 等待	Wait	hélǐ 合理	Reasonable	dēngdài 灯待	hélǐ 何理
29	qínkuài 勤快	Diligent	yúkuài 愉快	Happy	tōngxùn 通讯	Communications	yúkuài 鱼快	tóngxùn 童讯
30	yuánxíng 原形	Original shape	dìxíng 地形	Terrain	cǐwài 此外	In addition	dìxíng 第形	cìwài 刺外
31	zhǐzé 指责	Accused	fùzé 负责	Responsible	wàiguó 外国	Foreign	fùzé 赴责	wāiguó 歪国
32	xiāngróng 相容	Compatibility	nèiróng 内容	Content	zhǐdǎo 指导	Guide	něiróng 馁容	zhǐdǎo 纸导
33	zhèngmén 正门	Main entrance	bùmén 部门	Departments	qízhōng 其中	Which	bùmén 布门	qízhōng 旗中
34	zhǔtǐ 主体	Subject	shēntǐ 身体	Body	chuàngzào 创造	Create	shēntǐ 深体	zhuàngzào 幢造
35	huāndù 欢度	Celebrate	zhìdù 制度	System	búduàn 不断	Continuously	zhìdù 致度	bùduàn 布断
36	xiàonéng 效能	Performance	kěnéng 可能	May	wánquán 完全	Completely	kènéng 客能	wánquán 玩全

Appendix 6-2 Stimuli used in Exp 4 (OT) (Study 1)

No	Target		Orthographic word neighbor		Word control		Orthographic nonword neighbor	Nonword control
1	yàoxìng 药性	Potency	suǒxìng 索性	Simply	zìyǎn 字眼	Simply	suǒxìng 所性	zìyǎn 自眼
2	mùcǎo 牧草	Pasture	qǐcǎo 起草	Drafting	zìzhòng 自重	Drafting	qǐcǎo 扫草	zìzhòng 字重
3	qīnyuán 亲缘	Affinity	juéyuán 绝缘	Insulation	dāndiào 单调	Insulation	juéyuán 决缘	dāndiào 丹调
4	xiānxíng 先行	In advance	liúxíng 流行	Pop	tèsè 特色	Pop	liúxíng 刘行	tèsè 忑色
5	miànzhào 面罩	Face mask	lǒngzhào 笼罩	Enveloped	tóujī 投机	Enveloped	lǒngzhào 降罩	tóujī 头机
6	bèimiàn 背面	Back	tǐmiàn 体面	Decent	yǎnxià 眼下	Decent	tǐmiàn 斡面	yǎnxià 演下
7	tèchǎn 特产	Specialty	pòchǎn 破产	Bankruptcy	kǒutóu 口头	Bankruptcy	pòchǎn 魄产	kōutóu 抠头
8	shílì 实力	Strength	chīlì 吃力	Difficult	dǎoméi 倒霉	Difficult	chīlì 痴力	dǎoméi 导霉
9	chámíng 查明	Identify	yīngmíng 英明	Wise	lěngquè 冷却	Wise	yīngmíng 婴明	lèngquè 愣却
10	zuòshì 做事	Work	běnshì 本事	Ability	chōngtū 冲突	Ability	bènshì 笨事	chōngtū 充突
11	běnsè 本色	Character	shénsè 神色	Look	jièkǒu 借口	Look	shěnsè 沈色	jièkǒu 界口
12	língjī 灵机	Lingji	dòngjī 动机	Motivation	chōuxiàng 抽象	Motivation	dòngjī 冻机	chóuxiàng 愁象
13	péitóng 陪同	Accompany	hétong 合同	Contract	xíngli 行李	Contract	hétong 何同	xíngli 形李
14	shūshēng 书生	Scholar	huāshēng 花生	Peanut	tiānzhēn 天真	Peanut	huàshēng 划生	tiānzhēn 添真
15	biànxīn 变心	Cease to be faithful	bèixīn 背心	Vest	xiàyóu 下游	Vest	bèixīn 倍心	xiàyóu 夏游
16	fùhuó 复活	Resurrection	kuàihuó 快活	Happy	qiánxiàn 前线	Happy	kuàihuó 侩活	qiánxiàn 钱线
17	qīngjīn 青筋	Blue veins	nǎojīn 脑筋	Brains	chéngběn 成本	Brains	náojīn 挠筋	chéngběn 程本
18	guàniàn 挂念	Miss	guānniàn 观念	Concept	dòngyuán 动员	Concept	guānniàn 关念	dòngyuán 冻员
19	suíshēn 随身	Portable	chūshēn 出身	Birth	qíyú 其余	Birth	chūshēn 初身	jìyú 骑余
20	miǎnfèi 免费	Free	xiāofèi 消费	Consumer	jíqí 极其	Consumer	xiāofèi 萧费	jíqí 吉其
21	zhídá 直达	Direct	fādá 发达	Developed	cóngshì 从事	Developed	fǎdá 法达	cōngshì 匆事
22	biǎogé 表格	Form	yángé 严格	Strictly	yàojǐn 要紧	Strictly	yángé 言格	yàojǐn 耀紧
23	yīlǐng 衣领	Collar	běnlǐng 本领	Ability	qǐtú 企图	Ability	bēnlǐng 奔领	qǐtú 启图
24	shīzú 失足	Slip	mǎnzú 满足	Meet	wénjiàn 文件	Meet	mǎnzú 瞒足	wénjiàn 闻件
25	gūsuàn 估算	Estimate	dǎsuàn 打算	Going	lìchǎng 立场	Going	dásuàn 达算	lìchǎng 粒场
26	bìngpái 并排	Side by side	ānpái 安排	Arrangements	xìbāo 细胞	Arrangements	ǎnpái 俺排	xìbāo 戏胞
27	gōngwù 公务	Official business	tèwù 特务	Spy	niánjì 年纪	Spy	tèwù 忑务	zhānjì 粘纪
28	fāngxíng 方形	Square	qíngxíng 情形	Case	xiānjìn 先进	Case	qíngxíng 擎形	xiānjìn 鲜进
29	shǎnguāng 闪光	Flash	yǎnguāng 眼光	Vision	miànjī 面积	Vision	yǎnguāng 演光	miánjī 绵积
30	wàilái 外来	Foreign	běnlái 本来	Originally	zhíjiē 直接	Originally	bēnlái 奔来	zhíjiē 执接
31	wúguān 无关	Independent	jīguān 机关	Authority	jīhuì 机会	Authority	jīguān 基关	jīhuì 基会
32	tíngxī 停息	Stop	xiāoxi 消息	News	jīguān 机关	News	xiāoxi 诮息	jīguān 基关
33	dàxiàng 大象	Elephant	xiànxiàng 现象	Phenomenon	mǎshàng 马上	Phenomenon	xiànxiàng 线象	máshàng 麻上
34	hēibái 黑白	Black and White	míngbai 明白	Understand	shuǐpíng 水平	Understand	míngbái 铭白	shuìpíng 税平
35	hǎnjiàn 罕见	Rare	yìjiàn 意见	Comments	dāngrán 当然	Comments	yìjiàn 易见	dǎngrán 党然
36	lìfǎ 立法	Legislation	fāngfǎ 方法	Methods	fāngmiàn 方面	Methods	fāngfǎ 芳法	fāngmiàn 芳面

Appendix 6-3 Stimuli used in Exp 4 (TO) (Study 1)

No	Target		Orthographic word neighbor		Word control		Orthographic nonword neighbor	Nonword control
1	shùnyǎn 顺眼	Pleasing to the eye	zhǎyǎn 眨眼	Pleasing to the eye	chāyì 差异	Differences	zhǎyǎn 闸眼	chāyì 插异
2	qiángbào 强暴	Violent	fēngbào 风暴	Violent	tǐwēn 体温	Body temperature	fēngbào 丰暴	tǐwēn 蹄温
3	fēnhóng 分红	Dividend	xiānhóng 鲜红	Dividend	mǐngǎn 敏感	Sensitive	xiānhóng 先红	mǐngǎn 闽感
4	tiānhuā 天花	Smallpox	lànghuā 浪花	Smallpox	héfǎ 合法	Legitimate	lǎnghuā 朗花	héfǎ 河法
5	gǎikǒu 改口	Changed to	chuāngkǒu 窗口	Changed to	zhíxiàn 直线	Straight line	chuāngkǒu 疮口	zhíxiàn 执线
6	yìqì 意气	Emotional	chuǎnqì 喘气	Emotional	zhíyè 职业	Professional	chuànqì 串气	zhíyè 植业
7	liúfàng 流放	Exile	kāifàng 开放	Exile	quánjú 全局	Global	kǎifàng 凯放	quánjú 泉局
8	gǔbǎn 古板	Old-fashioned	hēibǎn 黑板	Old-fashioned	tōngxìn 通信	Communications	hēibǎn 嘿板	tǒngxìn 统信
9	dúshǒu 毒手	Murderous	fàngshǒu 放手	Murderous	jiāoyì 交易	Transactions	fángshǒu 坊手	jiāo yì 娇易
10	xiānghuì 相会	Meet	yànhuì 宴会	Meet	fèiyòng 费用	Fees	yànhuì 验会	fèiyòng 肺用
11	chízǎo 迟早	Sooner or later	qīngzǎo 清早	Sooner or later	chúnjié 纯洁	Pure	qīngzǎo 轻早	chúnjié 唇洁
12	biǎobái 表白	Confession	cāngbái 苍白	Confession	gǎiliáng 改良	Improved	cāngbái 沧白	gàiliáng 钙良
13	hǎidài 海带	Kelp	rèdài 热带	Kelp	línjū 邻居	Neighbors	rědài 惹带	línjū 林居
14	lǎoliàn 老练	Experienced	shúliàn 熟练	Experienced	píngtǎn 平坦	Flat	shúliàn 赎练	píngtǎn 凭坦
15	nǎohǎi 脑海	Mind	dàhǎi 大海	Mind	shìbiàn 事变	Incident	dāhǎi 搭海	shìbiàn 势变
16	tóuhào 头号	Top	xìnhào 信号	Top	jǔbàn 举办	Held	xìnhào 蚌号	jūbàn 狙办
17	jiāodào 交道	Dealings	guǐdào 轨道	Dealings	tánpàn 谈判	Negotiations	guǐdào 诡道	tánpàn 坛判
18	fàngfēng 放风	Spread rumors	jìfēng 季风	Spread rumors	bèipò 被迫	Forced	jìfēng 寄风	bèipò 倍迫
19	gōngzhěng 工整	Neat	wánzhěng 完整	Neat	fánghù 防护	Protection	wánzhěng 丸整	fánghù 房护
20	tánxīn 谈心	Talk	shāngxīn 伤心	Talk	xuěhuā 雪花	Snowflake	shāngxīn 觞心	xuèhuā 血花
21	màoshī 冒失	Bold	sǔnshī 损失	Bold	yíngyǎng 营养	Nutrition	sǔnshī 笋失	yíngyǎng 莹养
22	cǎotú 草图	Sketch	dìtú 地图	Sketch	yīngyǒng 英勇	Heroic	dìtú 第图	yìngyǒng 应勇
23	zhōudào 周到	Thoughtful	láidào 来到	Thoughtful	xiāngfǎn 相反	On the contrary	làidào 赖到	xiāngfǎn 香反
24	jiànwài 见外	See outside	cǐwài 此外	See outside	dìxíng 地形	Terrain	cíwài 慈外	dìxíng 第形
25	jìndù 进度	Progress	chéngdù 程度	Progress	wēixiào 微笑	Smile	chéngdù 城度	wēixiào 威笑
26	dúwù 读物	Books	shìwù 事物	Books	xìngzhì 性质	Nature	shìwù 市物	xìngzhì 杏质
27	niánguān 年关	Year	yǒuguān 有关	Year	yǒuguān 有关	For	yǒuguān 友关	yǒuguān 友关
28	jiǎndiǎn 检点	Indecent	quēdiǎn 缺点	Indecent	xiānghù 相互	Mutual	quèdiǎn 却点	xiānghù 乡互
29	rìshí 日食	Solar eclipse	liángshí 粮食	Solar eclipse	fùzá 复杂	Complex	liángshí 梁食	fùzá 负杂
30	tiáolǐ 条理	Coherent	zhēnlǐ 真理	Coherent	lǎorén 老人	Elderly	zhēnlǐ 珍理	láorén 劳人
31	rènmìng 任命	Appointed	shēngmìng 生命	Appointed	dàolù 道路	Road	shēngmìng 声命	dàolù 盗路
32	kàngtǐ 抗体	Antibody	shēntǐ 身体	Antibody	chuàngzào 创造	Create	shēntǐ 深体	chuǎngzào 闯造
33	wēiwàng 威望	Prestige	xīwàng 希望	Prestige	hòulái 后来	Later	xīwàng 牺望	hòulái 厚来
34	tuīduàn 推断	Infer	búduàn 不断	Infer	zhìdù 制度	System	bùduàn 布断	zhìdù 志度
35	jiàoliàng 较量	Contest	lìliàng 力量	Contest	rènwu 任务	Task	lìliàng 利量	rènwù 刃务
36	běnfèn 本分	Sub	bùfen 部分	Sub	cuòwù 错误	Error	bùfèn 布分	cuòwù 挫误

Appendix 6-4 Stimuli used in Exp 4 (OO) (Study 1)

No	Target		Orthographic word neighbor		Word control		Orthographic nonword neighbor	Nonword control
1	lìsuǒ 利索	Agile	xiànsuǒ 线索	Clue	zhōudào 周到	Thoughtful	xiànsuǒ 陷索	zhōudào 州到
2	qìsè 气色	Color	tèsè 特色	Features	mǎhu 马虎	Careless	tèsè 忑色	mǎhǔ 蚂虎
3	bǎozhòng 保重	Take care	zìzhòng 自重	Weight	qǐcǎo 起草	Drafting	zìzhòng 字重	qǐcǎo 启草
4	shāyǎn 沙眼	Trachoma	zìyǎn 字眼	Words	suǒxìng 索性	Simply	zìyǎn 自眼	suǒxìng 锁性
5	dīxià 低下	Low	yǎnxià 眼下	Now	juéyuán 绝缘	Insulation	yǎnxià 演下	juéyuán 决缘
6	qíngdiào 情调	Sentiment	dāndiào 单调	Monotonous	liúxíng 流行	Pop	dāndiào 丹调	liúxíng 留行
7	zhuǎnjī 转机	Transfer	tóujī 投机	Speculative	lǒngzhào 笼罩	Enveloped	tóujī 头机	lǒngzhào 陇罩
8	fēngtóu 风头	Thunder	kǒutóu 口头	Oral	pòchǎn 破产	Bankruptcy	kǒutóu 抠头	pòchǎn 迫产
9	tǐgé 体格	Physique	zīgé 资格	Qualification	běnshì 本事	Ability	zīgé 兹格	běnshì 奔事
10	yuèjīng 月经	Menstrual	zhèngjīng 正经	Serious	dǎoméi 倒霉	Bad luck	zhèngjīng 郑经	dǎoméi 岛霉
11	qīnxìn 亲信	Trusted	míxìn 迷信	Superstition	guānhuái 关怀	Care	míxìn 弥信	guānhuái 观怀
12	xiǎoqì 小气	Stingy	fēngqì 风气	Atmosphere	shīwàng 失望	Disappointed	fēngqì 封气	shīwàng 诗望
13	chōngdòng 冲动	Impulse	zhǔdòng 主动	Active	xiàyóu 下游	Downstream	zhǔdòng 煮动	xiàyóu 夏游
14	bùjǐng 布景	Scenery	guāngjǐng 光景	Scene	kuàihuó 快活	Happy	guāngjǐng 逛景	kuàihuó 侩活
15	jìmù 极目	Jimu	mángmù 盲目	Blindness	qiánxiàn 前线	Front	mángmù 芒目	qiánxiàn 钱线
16	jiǎoběn 脚本	Script	chéngběn 成本	Cost	nǎojīn 脑筋	Brains	chéngběn 程本	nǎojīn 瑙筋
17	tǐwèi 体味	Appreciate	yìwèi 意味	Mean	yìwèi 意味	Mean	yìwèi 义味	yìwèi 义味
18	dòngtīng 动听	Sounds	dǎting 打听	Inquire about	dǎting 打听	Inquire about	dǎtīng 搭听	dǎtīng 搭听
19	zhènxiàn 阵线	Front	guāngxiàn 光线	Light	huópō 活泼	Lively	guǎngxiàn 广线	huópō 或泼
20	páiwài 排外	Xenophobic	géwài 格外	Particularly	chéngfèn 成分	Components	géwài 隔外	chéngfèn 程分
21	lǐngshì 领事	Consular	cóngshì 从事	In	fādá 发达	Developed	cóngshì 慧事	fādá 乏达
22	lántú 蓝图	Blueprint	qǐtú 企图	Attempt	běnlǐng 本领	Ability	qǐtú 启图	běnlǐng 奔领
23	jiāngjiù 将就	Will	chéngjiù 成就	Achievement	chéngjiù 成就	Achievement	chéngjiù 程就	chéngjiù 程就
24	páichǎng 排场	Ostentation and extravagance	lìchǎng 立场	Position	dǎsuan 打算	Going	lìchǎng 俐场	dāsuàn 搭算
25	xiàchǎng 下场	End	lìchǎng 立场	Position	ānpái 安排	Arrangements	lìchǎng 历场	ānpái 鞍排
26	jīngjì 经纪	Brokers	niánjì 年纪	Older	tèwù 特务	Spy	zhānjì 粘纪	tèwù 忑务
27	liúyì 留意	Note	gùyì 故意	Deliberately	xìbāo 细胞	Cells	gùyì 顾意	xìbāo 戏胞
28	kāimíng 开明	Enlightened	cōngmíng 聪明	Smart	qíngxíng 情形	Case	cōngmíng 慧明	qíngxíng 擎形
29	gǔbǎn 古板	Old-fashioned	lǎobǎn 老板	Boss	jiāgōng 加工	Processing	láobǎn 劳板	jiāgōng 家工
30	diǎnxin 点心	Dessert	guānxīn 关心	Concern	biāozhǔn 标准	Standard	guānxīn 观心	biāozhǔn 镖准
31	ěrguāng 耳光	Box on the ear	yǎnguāng 眼光	Vision	miànjī 面积	Area	yǎnguāng 演光	miánjī 棉积
32	zhàoliào 照料	Care	zīliào 资料	Information	zìyóu 自由	Free	zīliào 滋料	zìyóu 字由
33	kàngtǐ 抗体	Antibody	jùtǐ 具体	Specific	jiǎnzhí 简直	Simply	jùtǐ 聚体	jiǎnzhí 减直
34	lìxī 利息	Interest	xiāoxi 消息	News	xiāoxi 消息	News	xiāoxī 萧息	xiāoxī 萧息
35	yuǎnjiàn 远见	Vision	yìjiàn 意见	Comments	yìjiàn 意见	Comments	yíjiàn 宜见	yíjiàn 宜见
36	fēngmiàn 封面	Cover	fāngmiàn 方面	Respect	fāngfǎ 方法	Methods	fāngmiàn 芳面	fángfǎ 防法

Appendix 7 Stimuli used in Exp 1 (Study 2)

No	Target		Identical word		control word		transposed words		control transposed word	
1	xíngxiàng 形象	Image	xíngxiàng 形象	Image	mìfēng 蜜蜂	Bee	xiàngxíng 象形	Pictographic	fēngmì 蜂蜜	Honey
2	cuòguò 错过	Miss	cuòguò 错过	Miss	huàtú 画图	Paint	guòcuò 过错	Fault	túhuà 图画	Picture
3	gōngguān 公关	PR	gōngguān 公关	PR	gùshì 故事	Story	guāngōng 关公	Guan	shìgù 事故	Accident
4	rénqíng 人情	Human	rénqíng 人情	Human	xǐhuan 喜欢	Like	qíngrén 情人	Lover	huānxǐ 欢喜	Joy
5	xìnggǎn 性感	Sexy	xìnggǎn 性感	Sexy	niúnǎi 牛奶	Milk	gǎnxìng 感性	Sensibility	nǎiniú 奶牛	Dairy cow
6	fāchū 发出	Issued	fāchū 发出	Issued	gēchàng 歌唱	Singing	chūfā 出发	Starting	chànggē 唱歌	Singing
7	zìsī 自私	Selfish	zìsī 自私	Selfish	huàbǐ 画笔	Brush	sīzì 私自	Privately	bǐhuà 笔画	Stroke
8	xiàtái 下台	Step down	xiàtái 下台	Step down	kēxué 科学	Science	táixià 台下	Audience	xuékē 学科	Subject
9	zǒngguī 总归	Is always	zǒngguī 总归	Is always	nǚér 女儿	Daughter	guīzǒng 归总	Belongs	érnǚ 儿女	Sons and daughters
10	hǎokàn 好看	Good-looking	hǎokàn 好看	Good-looking	shēngchǎn 生产	Production	kànhǎo 看好	Optimistic	chǎnshēng 产生	Produce
11	shíxiàn 实现	To achieve	shíxiàn 实现	To achieve	cǎisè 彩色	Color	xiànshí 现实	Reality	sècǎi 色彩	Color
12	mǎshàng 马上	Immediately	mǎshàng 马上	Immediately	gōngrén 工人	Workers	shàngmǎ 上马	Launched	réngōng 人工	Artificial
13	qiántí 前提	Premise	qiántí 前提	Premise	huǒchái 火柴	Match	tíqián 提前	Advance	cháihuǒ 柴火	Firewood
14	jiànwén 见闻	Knowledge	jiànwén 见闻	Knowledge	cháhuā 茶花	Camellia	wénjiàn 闻见	Smell	huāchá 花茶	Scented tea
15	jiēba 结巴	Stammer	jiēba 结巴	Stammer	yáshuā 牙刷	Toothbrush	bājie 巴结	Fawn	shuāyá 刷牙	Brushing
16	qìrén 气人	Angry	qìrén 气人	Angry	rénshēng 人生	Life	rénqì 人气	Popularity	shēngrén 生人	Stranger
17	píbāo 皮包	Briefcase	píbāo 皮包	Briefcase	fēngshàn 风扇	Fan	bāopí 包皮	Foreskin	shànfēng 扇风	Fan
18	shànghǎi 上海	Shanghai	shànghǎi 上海	Shanghai	qínggǎn 情感	Emotional	hǎishàng 海上	Sea	gǎnqíng 感情	Feelings
19	xūxīn 虚心	Modesty	xūxīn 虚心	Modesty	dàilǐng 带领	Led	xīnxū 心虚	Diffident	lǐngdài 领带	Tie
20	jiéqì 节气	Solar Terms	jiéqì 节气	Solar Terms	fāhuī 发挥	Play	qìjié 气节	Integrity	huīfā 挥发	Volatile

Appendix 8 Stimuli used in Exp 2 (Study 2)

No	Target		Identical word		transposed word	control word		control nonword
1	jiāoào 骄傲	Proud	jiāoào 骄傲	Proud	àojiāo 傲骄	zhuānyè 专业	Professional	yèzhuān 业专
2	mǐnjié 敏捷	Agile	mǐnjié 敏捷	Agile	jiémǐn 捷敏	biāoyǔ 标语	Slogan	yǔbiāo 语标
3	jìmò 寂寞	Lonely	jìmò 寂寞	Lonely	mòjì 寞寂	dìlǐ 地理	Geography	lǐdì 理地
4	yánsù 严肃	Serious	yánsù 严肃	Serious	sùyán 肃严	duìzhǎng 队长	Captain	chángduì 长队
5	qíngyuàn 情愿	Prefer	qíngyuàn 情愿	Prefer	yuànqíng 愿情	shèshī 设施	Facilities	shīshè 施设
6	tānwū 贪污	Corruption	tānwū 贪污	Corruption	wūtān 污贪	shìchá 视察	Inspection	cháshì 察视
7	qīngshòu 清瘦	Meager	qīngshòu 清瘦	Meager	shòuqīng 瘦清	shūtōng 疏通	Dredge	tōngshū 通疏
8	diāoxiè 凋谢	Wither	diāoxiè 凋谢	Wither	xièdiāo 谢凋	shùkòng 数控	NC	kòngshù 控数
9	sànluò 散落	Scattered	sànluò 散落	Scattered	luòsàn 落散	sōngchí 松弛	Relaxation	chísōng 弛松
10	xiànmù 羡慕	Envy	xiànmù 羡慕	Envy	mùxiàn 慕羡	gàilùn 概论	Introduction	lùngài 论概
11	chéngnuò 承诺	Commitment	chéngnuò 承诺	Commitment	nuòchéng 诺承	jùhuì 聚会	Party	huìjù 会聚
12	kāngfù 康复	Rehabilitation	kāngfù 康复	Rehabilitation	fùkāng 复康	pínghuá 平滑	Smooth	huápíng 滑平
13	yuēshù 约束	Constraints	yuēshù 约束	Constraints	shùyuē 束约	píngpàn 评判	Judge	pànpíng 判评
14	bìmiǎn 避免	Avoid	bìmiǎn 避免	Avoid	miǎnbì 免避	xiānghù 相互	Mutual	hùxiāng 互相
15	yóulǎn 游览	Tour	yóulǎn 游览	Tour	lǎnyóu 览游	shūbāo 书包	Schoolbag	bāoshū 包书
16	wēnnuǎn 温暖	Warm	wēnnuǎn 温暖	Warm	nuǎnwēn 暖温	jiàngdī 降低	Lower	dījiàng 低降
17	zhěngqí 整齐	Neat	zhěngqí 整齐	Neat	qízhěng 齐整	qīnqi 亲戚	Relatives	qīqīn 戚亲
18	yōuchóu 忧愁	Troubled	yōuchóu 忧愁	Troubled	chóuyōu 愁忧	fēngxiǎn 风险	Risk	xiǎnfēng 险风
19	xiūlǐ 修理	Repair	xiūlǐ 修理	Repair	lǐxiū 理修	jiājǐn 加紧	Step up	jǐnjiā 紧加
20	fùguì 富贵	Wealth	fùguì 富贵	Wealth	guìfù 贵富	jiànxì 间隙	Gap	xìjiàn 隙间

Appendix 9 Stimuli used in Exp 3 (Study 2)

No	Target		Identical word		transposed word	control word		control nonword
1	mǎhu 马虎	Careless	mǎhu 马虎	Careless	hǔmǎ 虎马	jiǎngjiū 讲究	Stress	jiūjiǎng 究讲
2	bēnbō 奔波	Rush	bēnbō 奔波	Rush	bōbēn 波奔	rùshǒu 入手	Start	shǒurù 手入
3	tǎnbái 坦白	Frank	tǎnbái 坦白	Frank	báitǎn 白坦	duànyán 断言	Assertion	yánduàn 言断
4	jiǎnzhí 简直	Simply	jiǎnzhí 简直	Simply	zhíjiǎn 直简	fāngzhēn 方针	Policy	zhēnfāng 针方
5	gāncuì 干脆	Altogether	gāncuì 干脆	Altogether	cuìgān 脆干	guāngjǐng 光景	Scene	jǐngguāng 景光
6	kuàihuó 快活	Happy	kuàihuó 快活	Happy	huókuài 活快	yàobù 要不	Or	bùyào 不要
7	hóngchén 红尘	Red Dust	hóngchén 红尘	Red Dust	chénhóng 尘红	màoshi 冒失	Bold	shīmào 失冒
8	dǎsuan 打算	Going	dǎsuan 打算	Going	suàndǎ 算打	piàoliang 漂亮	Beautiful	liàngpiào 亮漂
9	fēngqù 风趣	Humor	fēngqù 风趣	Humor	qùfēng 趣风	guòshī 过失	Fault	shīguò 失过
10	tǐmiàn 体面	Decent	tǐmiàn 体面	Decent	miàntǐ 面体	fēnggé 风格	Style	géfēng 格风
11	duānxiáng 端详	Looked	duānxiáng 端详	Looked	xiángduān 详端	dǎfa 打发	Send	fādǎ 发打
12	shīyì 失意	Frustrated	shīyì 失意	Frustrated	yìshī 意失	lǎoliàn 老练	Experienced	liànlǎo 练老
13	sǐbǎn 死板	Rigid	sǐbǎn 死板	Rigid	bǎnsǐ 板死	làngmàn 浪漫	Romantic	mànlàng 漫浪
14	fūqiǎn 肤浅	Shallow	fūqiǎn 肤浅	Shallow	qiǎnfū 浅肤	lìsuǒ 利索	Agile	suǒlì 索利
15	qīngchūn 青春	Youth	qīngchūn 青春	Youth	chūnqīng 春青	fēngqì 风气	Atmosphere	qìfēng 气风
16	miáotiáo 苗条	Slim	miáotiáo 苗条	Slim	tiáomiáo 条苗	duōkuī 多亏	Thanks	kuīduō 亏多
17	chōuxiàng 抽象	Abstract	chōuxiàng 抽象	Abstract	xiàngchōu 象抽	běnshi 本事	Ability	shìběn 事本
18	guǒduàn 果断	Decisive	guǒduàn 果断	Decisive	duànguǒ 断果	fēngdù 风度	Demeanor	dùfēng 度风
19	guānjiàn 关键	Key	guānjiàn 关键	Key	jiànguān 键关	géwài 格外	Particularly	wàigé 外格
20	fēngwèi 风味	Flavor	fēngwèi 风味	Flavor	wèifēng 味风	huógāi 活该	Deserve	gāihuó 该活

Appendix 10 Stimuli used in Exp 4 (Study 2)

No	Target		Identical word		transposed word	control word		control nonword
1	méiguī 玫瑰	Rose	méiguī 玫瑰	Rose	guīméi 瑰玫	pāngtuó 滂沱	Torrential	duòpāng 沱滂
2	pútáo 葡萄	Grapes	pútáo 葡萄	Grapes	táopú 萄葡	fēnfù 吩咐	Commanded	fùfēn 咐吩
3	tǎntè 忐忑	Perturbed	tǎntè 忐忑	Perturbed	tètǎn 忑忐	jiǎohuá 狡猾	Cunning	huájiǎo 猾狡
4	lājī 垃圾	Garbage	lājī 垃圾	Garbage	jīlā 圾垃	húdié 蝴蝶	Butterfly	diéhú 蝶蝴
5	hǔpò 琥珀	Amber	hǔpò 琥珀	Amber	pòhǔ 珀琥	pángbó 磅礴	Majestic	bópáng 礴磅
6	páihuái 徘徊	Wander	páihuái 徘徊	Wander	huáipái 徊徘	biānfú 蝙蝠	Bat	fúbiān 蝠蝙
7	qiūyǐn 蚯蚓	Earthworm	qiūyǐn 蚯蚓	Earthworm	yǐnqiū 蚓蚯	chóuchú 踌躇	. Hesitate	chúchóu 躇踌
8	pīngpāng 乒乓	Table Tennis	pīngpāng 乒乓	Table Tennis	pāngpīng 乓乒	pīlì 霹雳	Thunderbolt	lìpī 雳霹
9	qíqū 崎岖	Rugged	qíqū 崎岖	Rugged	qūqí 岖崎	lángbèi 狼狈	Embarrassed	bèiláng 狈狼
10	wānyán 蜿蜒	Wind	wānyán 蜿蜒	Wind	yánwān 蜒蜿	kēngqiāng 铿锵	Common Sense	qiāngkēng 锵铿
11	chōngjǐng 憧憬	Look forward to	chōngjǐng 憧憬	Look forward to	jǐngchōng 憬憧	láodao 唠叨	Nag	dāolao 叨唠
12	fěibàng 诽谤	Defamation	fěibàng 诽谤	Defamation	bàngfěi 谤诽	dīngzhǔ 叮嘱	Told	zhǔdīng 嘱叮
13	miǎntiǎn 腼腆	Shy	miǎntiǎn 腼腆	Shy	tiǎnmiǎn 腆腼	pánghuáng 彷徨	Wandering	huángpáng 徨彷
14	jìliǎng 伎俩	Trick	jìliǎng 伎俩	Trick	liǎngjì 俩伎	gǎnlǎn 橄榄	Olives	lǎngǎn 榄橄
15	qiáocuì 憔悴	Languish	qiáocuì 憔悴	Languish	cuìqiáo 悴憔	kēdǒu 蝌蚪	Tadpole	dǒukē 蚪蝌
16	qiǎngbǎo 襁褓	Infant	qiǎngbǎo 襁褓	Infant	bǎoqiǎng 褓襁	púfú 匍匐	Creeping	fúpú 匐匍
17	yānzhī 胭脂	Rouge	yānzhī 胭脂	Rouge	zhīyān 脂胭	ménglóng 朦胧	Hazy	lóngméng 胧朦
18	mǎnǎo 玛瑙	Agate	mǎnǎo 玛瑙	Agate	nǎomǎ 瑙玛	pánshān 蹒跚	Stumble	shānpán 跚蹒
19	ē nuó 婀娜	Graceful	ē nuó 婀娜	Graceful	nà ē 娜婀	mòlì 茉莉	Jasmine	lìmò 莉茉
20	gāngà 尴尬	Awkward	gāngà 尴尬	Awkward	gàgān 尬尴	mùxu 苜蓿	Alfalfa	xumù 蓿苜

Appendix 11 Stimuli used in Exp 1 (Study 3)

No	Target		Morpheme meaning related prime		Word meaning related prime		Unrelated prime	
1	kàntòu 看透	See through	jiànwén 见闻	Knowledge	lǐngwù 领悟	Comprehend	fēichuán 飞船	Spaceship
2	wánměi 完美	Perfect	zhōngguī 终归	After all	yuánmǎn 圆满	Complete	yúnquè 云雀	Skylark
3	zújì 足迹	Footprint	jiǎoběn 脚本	Script	xíngzōng 行踪	Whereabouts	zìfù 自负	Conceited
4	quèyuè 雀跃	Jump for joy	niǎolèi 鸟类	Birds	huānhū 欢呼	Cheer	juéduàn 决断	Decision
5	mángdòng 盲动	Rash	xiāchě 瞎扯	Gab	qīngshuài 轻率	Lightly	shùkòng 数控	NC
6	miànyì 面议	Negotiable	liǎnpáng 脸庞	Face	shāngquè 商榷	Discussion	shuǐliàng 水量	Water
7	shíyù 食欲	Appetite	chījīng 吃惊	Surprise	wèikǒu 胃口	Appetite	fāfèn 发愤	Energies
8	dàyì 大意	Effect	jùxiǎng 巨响	Loud	gàilùn 概论	Introduction	mǎxì 马戏	Circus
9	xíngzōng 行踪	Whereabouts	zǒudú 走读	Attend a day school	xiàluò 下落	Whereabouts	xízuò 习作	Project
10	bēnbō 奔波	Rush	pǎodiào 跑掉	Run away	cāoláo 操劳	Physical exertion	pēngtiáo 烹调	Cook
11	héshàn 和善	Kind	yǔqí 与其	Its	wēnqíng 温情	Tender feeling	shēngxué 升学	Careers
12	wòfáng 卧房	Bedroom	tǎngyǐ 躺椅	Deck chair	qǐnshì 寝室	Room	jiànxì 间隙	Gap
13	wǎnqī 晚期	Advanced	yèxiào 夜校	Night school	mòliǎo 末了	At the end	jiāngshān 江山	Country
14	sǐdí 死敌	Mortal enemy	wángguó 亡国	Subjugation	duìtóu 对头	Head	lǎnduò 懒惰	Lazy
15	hàixiū 害羞	Shy	shāngbīng 伤兵	Wounded	miǎntiǎn 腼腆	Shy	lànmàn 烂漫	Brilliant
16	jìcè 计策	Plan	suànzhàng 算账	Afterwards	móulüè 谋略	Strategy	xiǎngyǒu 享有	Enjoy
17	kuàiyì 快意	Fiat	sùlǜ 速率	Rate	shūtan 舒坦	Comfortable	táicí 台词	Lines
18	shuǎlài 耍赖	Shamelessly	wánwù 玩物	Plaything	sāpō 撒泼	Sapo	huífù 回复	Reply
19	qiānniàn 牵念	Qian Nian	lāchě 拉扯	Pull	diànjì 惦记	Misses	liúxīng 流星	Meteor
20	diūrén 丢人	Lose face	rēngdiào 扔掉	Throw away	chūchǒu 出丑	Fool	túshā 屠杀	Massacre
21	dīluò 低落	Low	ǎixiǎo 矮小	Short and small	xiāochén 消沉	Depressed	hōngzhà 轰炸	Bombing
22	hǎoxiào 好笑	Funny	jiāhuà 佳话	Story	pěngfù 捧腹	Laugh	sāngrèn 桑葚	Mulberry
23	lěngqīng 冷清	Deserted	hánsuān 寒酸	Shabby	xiāotiáo 萧条	Depression	jījiǎo 犄角	Horn
24	jiǎnjié 简洁	Concise	lüèwēi 略微	Slightly	jīngliàn 精炼	Refining	qíqū 崎岖	Rugged
25	shěngde 省得	Save	jiǎnpǔ 俭朴	Frugal	yǐmiǎn 以免	To avoid	nǎoguā 脑瓜	Their heads
26	xīyǒu 稀有	Rare	shūsàn 疏散	Evacuation	hǎnjiàn 罕见	Rare	xúnchá 巡查	Inspect
27	wēncún 温存	Gentle	nuǎnqì 暖气	Heating	héshàn 和善	Kind	rìchéng 日程	Schedule
28	dòngxī 洞悉	Insight	xuéwèi 穴位	Acupuncture point	kànchuān 看穿	See through	wàitào 外套	Coat
29	tǎnshuài 坦率	Frank	píngxī 平息	Calm	lěiluò 磊落	Upright	sīliang 思量	Consider
30	bǎngjià 绑架	Kidnap	kǔnzā 捆扎	Banding	jiéchí 劫持	Hijack	gōngpú 公仆	Public servant
31	xiūshì 修饰	Modified	bǔjǐ 补给	Supply	zhuāngbàn 装扮	Dress up	héshān 河山	Heshan
32	wèijià 未嫁	Unmarried	méifǎ 没法	Can not	dàizì 待字	To be the word	kuànggōng 旷工	Absenteeism
33	qīngmù 倾慕	Adore	xiéshè 斜射	Oblique fire	zhōngqíng 钟情	Love	lǜshī 律师	Lawyer
34	pǐndé 品德	Morality	chángshì 尝试	Try	cāoshǒu 操守	Code of Conduct	jì'ér 继而	Then
35	gǎnzǒu 赶走	Drive away	zhuījiū 追究	Investigate	qūzhú 驱逐	Expel	tǐyàn 体验	Experience
36	shēngyù 声誉	Reputation	yīnxìn 音信	News	wēiwàng 威望	Prestige	zàngsòng 葬送	Ruin

Appendix 12 Stimuli used in Exp 2 (Study 3)

No	Target		Morpheme meaning related prime		Word meaning related prime		Unrelated prime	
1	fēngguāng 风光	Scene	liáoliàng 嘹亮	Loud	jǐngguān 景观	Landscape	nèizàng 内脏	Visceral
2	dǐxì 底细	Bottom line	yòuxiǎo 幼小	Young	nèiqíng 内情	Inside information	qǔxiào 取笑	Tease
3	guànjūn 冠军	Champions	guānbīng 官兵	Men	áotóu 鳌头	Ngau Tau	huǒjiàn 火箭	Rocket
4	cíbēi 慈悲	Mercy	jié'āi 节哀	Grief	héshàn 和善	Kind	línglì 伶俐	Clever
5	sīniàn 思念	Miss	xuāndú 宣读	Read	diànjì 惦记	Misses	jiāchù 家畜	Livestock
6	zhàoguǎn 照管	Care	chǔzhì 处治	Treatment	liàolǐ 料理	Cuisine	zhèngwù 政务	Chief
7	péiběn 赔本	A loss	huàcè 画册	Picture album	kuīsǔn 亏损	Loss	jǔshì 举世	Universally
8	chīxiāng 吃香	Popular	liúfāng 流芳	Liufang	rèmén 热门	Top	mùyù 沐浴	Bathe
9	xiāngguān 相关	Related	fēngbì 封闭	Closed	shèjí 涉及	Involved	kuángwàng 狂妄	Presumptuous
10	shànjǔ 善举	Charity	hōngtái 哄抬	Bid up	hǎoshì 好事	Good deed	wěizhèng 伪证	Perjury
11	quánpán 全盘	Overall	xiǎodié 小碟	Saucer	yībìng 一并	Be	yóuzhōng 由衷	Sincere
12	yědì 野地	Wild	zhuólù 着陆	Landing	huāngjiāo 荒郊	Wilderness	xuémíng 学名	Scientific name
13	zhōngzhǐ 终止	Termination	tiáotíng 调停	Mediate	wánjié 完结	End	xùnměng 迅猛	Rapid
14	zhuàngkuò 壮阔	Magnificent	xīnkuān 心宽	Heart width	xióngwěi 雄伟	Majestic	xiūcháng 修长	Slender
15	àomàn 傲慢	Arrogant	jiǎnhuǎn 减缓	Slow down	zìfù 自负	Conceited	jìngzhǐ 静止	Still
16	sīlù 思路	Ideas	hòudào 厚道	Kind	tóuxù 头绪	Clue	làngmàn 浪漫	Romantic
17	qiánghuà 强化	Strengthen	jīnróng 金融	Finance	jiājù 加剧	Exacerbate	lùndiào 论调	Argument
18	shuāiluò 衰落	Fading	ěrzhuì 耳坠	Earring	tuíbài 颓败	Decadent	yèyóu 夜游	Night
19	xuànyào 炫耀	Show off	xiězhào 写照	Portrayal	màinòng 卖弄	Show off	méirén 媒人	Matchmaker
20	shèngjì 胜迹	Famous historical site	shānghén 伤痕	Injuries	xiānjìng 仙境	Fairyland	màoshèng 茂盛	Lush
21	pǐpèi 匹配	Match	bāngchèn 帮衬	Use the service	kànghéng 抗衡	Contend	gāoshēn 高深	Advanced
22	xièjué 谢绝	Decline	mǐnmiè 泯灭	Devoid of	wǎncí 婉辞	Euphemism	pāimài 拍卖	Auction
23	luòkōng 落空	Fall	chéngxū 乘虚	Cheng Xu	pàotāng 泡汤	Bathing	fāngyuán 方圆	Radius
24	shèngxíng 盛行	Popular	chūzǒu 出走	Flee	shíxīng 时兴	Fashion	fēnjū 分居	Separation
25	tuīchí 推迟	Postpone	zǎowǎn 早晚	Sooner or later	yánqī 延期	Extension	yáowàng 遥望	Look into the distance
26	yíwù 贻误	Bungle	guòcuò 过错	Fault	tuōyán 拖延	Delay	shīpéi 失陪	Excuse me
27	fúruǎn 服软	Soft services	qīngróu 轻柔	Soft	rèncuò 认错	Mistaken identity	shuìyī 睡衣	Pajamas
28	liúliàn 留恋	Nostalgia	nì'ài 溺爱	Spoil	bùshě 不舍	Dismay	shāngōu 山沟	Ravine
29	zhuóyuè 卓越	Excellent	quányù 痊愈	Recovered	jiéchū 杰出	Outstanding	lèyì 乐意	Happy
30	guānglín 光临	Presence	qīnjìn 亲近	Close	huìgù 惠顾	Patronage	sūxǐng 苏醒	Wake
31	huánjī 还击	Fight back	tuīqiāo 推敲	Scrutiny	fǎnpū 反扑	Counterattack	xǔyuàn 许愿	Wishing
32	kuānróng 宽容	Tolerant	wàimào 外貌	Appearance	liàngjiě 谅解	Understanding	zhǔtǐ 主体	Subject
33	chéngzhì 惩治	Punish	zhěnliáo 诊疗	Treatment	chǔfá 处罚	Punishment	yándòng 岩洞	Cave
34	háomài 豪迈	Bold	héngkuà 横跨	Across	bēnfàng 奔放	Unrestrained	lǚxíng 履行	Performance
35	chācuò 差错	Error	huāngmiù 荒谬	Absurd	shǎnshī 闪失	Accident	kēshuì 瞌睡	Doze
36	guībǎo 瑰宝	Treasures	kǎobèi 拷贝	Copy	zhēnpǐn 珍品	Treasure	shāngtǎo 商讨	Discuss

Appendix 13 Stimuli used in Exp 3 (Study 3)

No	Target		Morpheme meaning related prime		Word meaning related prime		Unrelated prime	
1	sòngbié 送别	Farewell	juānzèng 捐赠	Donate	jiànxíng 饯行	Farewell	tǐzhì 体制	System
2	qióngjìn 穷尽	End	qīngpín 清贫	Poor	zhǐjìng 止境	End	tiàozǎo 跳蚤	Flea
3	wènhòu 问候	Greetings	tànxún 探询	Inquire	qǐngàn 请按	Press	xībié 惜别	Farewell
4	cángnì 藏匿	Hide	shǎnduǒ 闪躲	Dodge	qiánfú 潜伏	Latency	tèdìng 特定	Specific
5	cǎijí 采集	Acquisition	wénzhāi 文摘	Digest	sōuluó 搜罗	Collecting	zhǎnxiàn 展现	Show
6	luòmò 落寞	Lonely	kōngjiàng 空降	Airborne	gūjì 孤寂	Lonely	qiánchéng 虔诚	Sincere
7	cúnxīn 存心	Deliberately	huángchǔ 皇储	Crown Prince	xùyì 蓄意	Deliberate	xísú 习俗	Custom
8	chuándá 传达	Convey	yóudì 邮递	Mail	tōngbào 通报	Bulletin	xiǎnyào 险要	Advantageous
9	jībài 击败	Beat	yìdá 一打	Dozen	zhòngchuāng 重创	Hit	guīfàn 规范	Specifications
10	cuòjué 错觉	Illusion	yánwù 延误	Delay	huànjìng 幻境	Fantasy	yuánzhōu 圆周	Circumference
11	xuánlǜ 旋律	Melody	zhōuzhuǎn 周转	Turnover	yuèzhāng 乐章	Movement	yīcì 依次	Turn
12	bǎikuò 摆阔	Parade one's wealth	fāfàng 发放	Grant	xuànyào 炫耀	Show off	juéduàn 决断	Decision
13	kuāzhāng 夸张	Exaggeration	shèngzàn 盛赞	Praised	chuīniú 吹牛	Brag	xuānzhàn 宣战	Declaration of war
14	duōxīn 多心	Suspicious	kèyú 课余	After school	cāiyí 猜疑	Suspicion	nàozhōng 闹钟	Alarm Clock
15	shǐmìng 使命	Mission	zhuānyòng 专用	Special	zhòngrèn 重任	Responsibility	xiàoyì 笑意	Smile
16	guǎngkuò 广阔	Expansive	yuānbó 渊博	Erudite	kōngkuàng 空旷	Open	zōngsè 棕色	Brown
17	chénshì 尘世	Earth	pàohuī 炮灰	Cannon fodder	rénjiān 人间	World	lěngkù 冷酷	Grim
18	děngcì 等次	Other times	kuǎndài 款待	Hospitality	shùnxù 顺序	Order	míngkè 铭刻	Engraved
19	zhīfù 支付	Payment	yìngchēng 硬撑	Teeth	jiǎonà 缴纳	Pay	tóuzhì 投掷	Throwing
20	kèbó 刻薄	Mean	bīngdiāo 冰雕	Ice	jiānsuān 尖酸	Tart	pèngmiàn 碰面	Meet
21	qiáoqǐ 翘企	Eagerly look forward to	zhàntái 站台	Site	rèwàng 热望	Aspire	wànnéng 万能	Universal
22	míngshèng 名胜	Scenic	yíngyú 赢余	Surplus	jǐngdiǎn 景点	Attractions	zǒngliàng 总量	Total
23	zhǔzǎi 主宰	Dominate	shājūn 杀菌	Bactericidal	bǎchí 把持	Control	tǐwèi 体味	Appreciate
24	yízài 一再	Again	yòuxiǎng 又想	Want to	lǚcì 屡次	Repeatedly	yúchì 鱼翅	Fin
25	shīlì 失利	Failure	yìchù 益处	Benefits	kuìbài 溃败	Defeat	xīxiào 嬉笑	Laughing
26	tānwū 贪污	Corruption	zānghuà 脏话	Bad language	qīntūn 侵吞	Embezzle	xìshù 系数	Coefficient
27	qiángzhì 强制	Force	zàojiù 造就	Bring up	bīpò 逼迫	Force	rényān 人烟	Densely
28	tāntú 贪图	Covet	huàbǎn 画板	Sketchpad	míliàn 迷恋	Obsession	lǐngshì 领事	Consular
29	qiángshèng 强盛	Powerful and prosperous	wàngjì 旺季	Busy season	fánróng 繁荣	Prosperity	wéinán 为难	Difficult
30	tuīcí 推辞	Decline	lípǔ 离谱	Outrageous	huíjué 回绝	Rebuff	miǎoshì 藐视	Defy
31	pòxiǎo 破晓	Dawn	dǒngshì 懂事	Sensible	límíng 黎明	Dawn	jìtuō 寄托	Sustenance
32	shuāibài 衰败	Decay	shūchū 输出	Output	mòluò 没落	Decline	wàiháng 外行	Layman
33	dàoxiè 道谢	Thank	diāolíng 凋零	Dying	chóubào 酬报	Reward	guójì 国际	International
34	yònggōng 用功	Diligent	jìxiào 绩效	Performance	qínfèn 勤奋	Diligent	nǚgōng 女工	Women
35	pínhán 贫寒	Poor	lěngdàn 冷淡	Cold	kùnkǔ 困苦	Hardship	lǒngzhào 笼罩	Enveloped
36	wúliáo 无聊	Bored	tánxiào 谈笑	Laughing	méiqù 没趣	Dull	xínghào 型号	Model