ABSTRACT

Title of dissertation: THE BILINGUAL ACQUISITION OF COMPOUND WORDS AND ITS RELATION TO READING SKILLS

Chenxi Cheng, Doctor of Philosophy, 2008

Dissertation directed by: Dr. Min Wang
Department of Human Development

This study investigated how Chinese-English bilingual children process compound words in their two languages and how that processing skill in one language affects reading skill in the other language. Experiments 1 and 2 investigated the bilingual acquisition of compound words, using a lexical-decision paradigm. Each compound was composed of two constituent morphemes in the target language. The combination of the translated equivalents of the constituents formed a new translated compound word (or nonword) in the nontarget language. In both Experiments 1 and 2, when the target language was English, the lexical status of translated compounds in the nontarget language was shown to affect the accuracy of lexical decisions in the target language. When the target language was Chinese, the effect of the lexical status in English was not significant in Experiment 1 and disappeared after the effect of familiarity was controlled in Experiment 2. The results of Experiment 2 further showed that the effect of the lexical status of translated compounds was independent of semantic transparency and language

proficiency. Those results provided evidence of decomposition in both semantically transparent and semantically opaque compounds. The stronger effect from L1 to L2 than from L2 to L1 is consistent with the Revised Hierarchical Model (Kroll & Stewart, 1994).

Experiment 3 investigated the awareness of compound words and reading skills and their relationship in a group of Grade 2 and Grade 3 Chinese-English bilingual children. Comparable tasks in Chinese and English were designed to test students' morphological awareness of compounds, phonological awareness, oral vocabulary, word reading, and reading comprehension. Results of structural equation modeling showed that, within each language, compound awareness was a significant predictor for both real-word naming and reading comprehension. Across languages, English compound awareness was a significant predictor for reading comprehension in Chinese. Those results suggest that compound awareness might play a critical role in the reading development of Chinese-English bilingual children.

THE BILINGUAL ACQUISITION OF COMPOUND WORDS AND ITS

RELATION TO READING SKILLS

by

Chenxi Cheng

Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2008

Advisory Committee:

Assistant Professor Min Wang, Chair
Professor Patricia Alexander
Professor Robert DeKeyser
Professor Mariam Jean Dreher
Professor John Guthrie

Dedication

This dissertation is dedicated to my parents in Beijing, China. Without their great understanding and support the completion of the work would not have been possible.

Acknowledgements

I would like to thank my advisor, Dr. Min Wang, for her tremendous support throughout the course of the study. She has provided helpful suggestions and comments in preparing the study and continuous help in revising the dissertation. I am also grateful to professors Alexander, DeKeyser, Dreher, Guthrie, and Parault for their valuable feedback throughout the process of my dissertation.

I thank my peer graduate students of the Bilingual and Biliteracy Research Lab for their support. I especially thank Kendra Sun-Alperin for her continuous editing help on my dissertation. Many thanks also go to Chen Yang and Wei Gao for their assistance with the data collection. I would also like to thank The English Editing for International Graduate Students (EEIGS) program for their editing help.

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Chapter I: Introduction

In the age of globalization, bilingualism has expanded dramatically accompanied by an increasing need for communication in foreign languages (Committee for Economic Development, 2006). There has been a rapidly growing number of bilingual and literacy studies in the leading peer-reviewed journals in the fields of cognitive, developmental, and educational psychology. However, most of the bilingual studies have centered on bilingual speakers of two European languages, such as French and English (e.g., Deacon & Bryant, 2006; Deacon, Wade-Woolley, & Kirby, 2007; Nicoladis, 2006;), Dutch and English (e.g., Dijkstra & Van Heuven, 2002; Kroll & Stewart, 1994; Lemhöfer et al., 2008), and Spanish and English (e.g., Sunderman & Kroll, 2006). Although Chinese and English are two of the most-spoken languages in the world, only a handful of studies are devoted to Chinese-English bilingual acquisition (e.g., Wang, Perfetti, & Liu, 2005). This dissertation focuses on Chinese-English bilingual children, investigating one specific aspect of language processing—namely, morphological processing—and how children's morphological awareness contributes to their reading achievements.

Morphological processing has been at the center of the study of the mental lexicon in monolingual populations (Caramazza, Laudanna, & Romani, 1988; Plaut & Gonnerman, 2000; Rubin, Becker, & Freeman, 1979; Taft, 1994; Taft & Forster, 1975). Complex words, composed of multiple morphemes, are the target materials in studies of morphological processing. There are three ways to form complex words: inflection, derivation, and compounding. Across all languages, compounding is the most universal process of forming complex words across all languages (Dressler, 2006). The universality of compounds makes it an ideal subject for bilingual studies that require comparable materials across different languages. Even if researchers could avoid studying compounds by choosing bilinguals who speak two similar languages rich in inflectional and derivational morphology, such as French and English (e.g., Deacon & Bryant, 2006; Deacon, Wade-Woolley, & Kirby, 2007), the generalizability of their findings would be limited, since not all languages have inflectional or derivational morphology. For example, there are no inflectional words and only a limited number of derivational words in Chinese. In what follows, the definitions and types of compounds are described to provide background information. Given the richness of Chinese compounds, some of their characteristics are compared with their English counterparts.

The definition and types of compounds. A morpheme is the smallest unit in a language that can be associated with meaning and grammatical function. Morphemes can be classified as free morphemes or bound morphemes, depending on whether they can stand alone (i.e., as root words). A free morpheme is one that can stand alone as a root word (e.g., *reason* in *reasonable*). A bound morpheme cannot stand alone as a root word (e.g., *-s* in *dogs* and *cran* in *cranberry*).

Linguistically, words can be either monomorphemic words (e.g., *room*) or multimorphemic words (complex words). Complex words can be classified as inflectional words (e.g., *dogs*), derivational words (e.g., *reasonable*), and compound words (e.g., *classroom*). Inflectional morphology concerns the way in which words are modified to reflect grammatical information, such us number, tense, and gender. For example, *dog* and *dogs*, are singular and plural forms of the same word, so they have different grammatical functions. Derivational morphology concerns the principles governing the construction of new words, without reference to the specific grammatical role a word might play in a sentence. For example, the word *invisible* is derived from the word *visible*, and they share the same grammatical properties

(Crystal, 1997). The definition of compounds can be grammatical combinations of words to form new words (cf. Dressler, p 24). Different from inflectional and derivational words, which are composed of stems and affixes, prototypically a compound word is composed of two free morphemes (e.g., *classroom*). However, some compounds also contain bound morphemes (e.g., *cran* in *cranberry*) and these bound morphemes are not affixes. Although *cran* does not occur independently, it carries meaning which distinguishes the cranberry from other berries.

The most important constituent of a compound is the head. The head determines the semantic and syntactic properties of the whole compound. For example, *berry* is the head of *blueberry*; it carries the semantic and syntactic properties of the whole word. Thus, *blueberry* is a type of *berry* not a type of *blue*; it is a noun not an adjective. Based on the word class of the head, compounds can be classified as nominal (e.g., *blueberry*), verbal (e.g., air-dry), and adjective compounds (e.g., sky-blue). Given the word class of the constituent that is not the head, compounds can be further classified into more subclasses, such as noun-noun compounds (e.g., toothbrush), adjective-noun compounds (e.g., blackboard), verb-noun compounds (e.g., draw-bridge), adjective-adjective compounds (e.g., dark-blue), verb-verb compounds (e.g., stir-fry), adjective-verb compounds (e.g., dry-farm). Noun-noun compounds are the largest subclass in most languages (Dressler, 2006).

Chinese – a language of compounding. The uniqueness of the Chinese language makes it an interesting target language for testing the theories of compound processing. First, there are no inflectional words and only a few derivational words in Chinese (Packard, 2000). Therefore, it is extremely difficult to find testing materials within those two categories in Chinese. Second, most Chinese words are compound words. For example, in a corpus of 17,430 characters, around 80% of them are constituents of bisyllable compound words (Kang, Xu, & Sun, 2005). The Chinese compounding system is even more complex than when compared to other languages. Unlike English, in which most of the compound words are made up of two or more free morphemes, a large proportion of Chinese compounds are composed of bound morphemes (Myers, 2006). For example, the 机 (*ji1*, meaning *machine*) in 飞机 (*fei1 ji1*, meaning *airplane*) 洗衣机 (*xi3 yi1 ji1*, meaning *laundry machine*) and 电话机 (*dian4 hua4 ji1*, meaning *telephone*) is a bound morpheme that cannot stand alone as a root word. The richness and complexity of its compound words make Chinese an ideal language for the study of compound-word processing. Third, Chinese orthography also plays a role in the processing of compounds. English is an alphabetic orthography in which graphemes map onto phonemes. Chinese is a morphographic language, meaning the graphemes map onto morphemes that are also syllables. For example, the Chinese character 火 represents the morpheme which means fire and can be read as *huo3*. Even though the character is composed of four strokes, the strokes do not represent any meaning or sounds. Therefore, the morpheme is a very salient structure in Chinese orthography. As a result, Chinese readers might be more sensitive to morphemes than English readers.

In summary, compounding is the most widely used word-formation process across all languages (Dressler, 2006). The universality of compounding makes it an ideal subject of cross-language and bilingual research. Furthermore, given the richness of compound words in Chinese, it is critical to study compound processing in the Chinese-English bilingual population. Previous bilingual studies can be divided into two categories, based on the levels of analyses entailed. On a micro-level, some researchers have attempted to model bilingual processing using experimental methods (e.g., Dijkstra, Moscoso del Prado Martín, Schulpen, Schreuder, & Baayen, 2005;

Dijkstra & Van Heuvan, 2002; Kroll & Stewart, 1994; Lemhöfer et al., 2008). On a macro-level, some researchers have focused on the cross-language transfer of reading skills using correlational methods (e.g., Durgunoglu, 1993; Wang, Perfetti, & Liu, 2005).

For this dissertation, three experiments investigated compound processing by Chinese-English bilingual children from both levels. On a micro level, the first two experiments examined cross-language activation during the lexical processing of compounds. On a macro level, the third experiment examined the cross-language contribution of compound-word processing skill to reading acquisition. In the following sections the three experiments are discussed from both levels.

Experiments 1 and 2—Cross-language Activation during Compound Processing

The research on bilingual processing of compounds provides a special perspective for testing the models of the two fields. A common feature of the bilingual lexicon, the mental lexicon of bilingual speakers, and of compound words is that they are composed of two (or more) elements—the bilingual lexicon is composed of two languages, and compound words are composed of two or more morphemes. A key question in the area of bilingual word recognition is whether the two language systems are associated at the conceptual/semantic level (where the meanings of words are stored) or at the lexical level (where the orthographic and phonological representations are stored) or at both levels (e.g., Kroll & Stewart, 1994; Potter, So, Von Eckardt, & Feldman, 1984; Sholl, Sankaranarayanan, & Kroll, 1995).

There is an ongoing debate in the area of compound processing as to whether and how compound words are decomposed into their constituents. Furthermore, the models in compound processing differ on whether the compounds are decomposed at the lexical level or at the conceptual level (e.g., de Jong, Feldman, Schreuder, Pastizzo, & Baayen, 2002; Libben, 1998). Therefore, the studies in both fields place emphasis on the distinctions and connections between conceptual representations and lexical representations. Given these common features, in Experiments 1 and 2, the investigation on how bilinguals process compounds will provide insight into the critical issues involved in the two fields.

For example, when a Chinese-English bilingual child hears the compound word, such as *white-collar* in English, researchers of compound processing are interested in knowing whether the child can decompose the word into *white* and *collar* at the lexical level. Furthermore, researchers may also be interested in how the properties of the compounds, such as their semantic transparency (the consistency between the meaning of a compound word and its constituent morphemes) and frequency, affect the way in which compounds are processed. For example, are the semantic representations of *white* and *collar* activated as well, since *white-collar* is an opaque word its meaning cannot be inferred from the meanings of *white* and *collar*.

Researchers of bilingualism are interested in answering the question whether the translation equivalents of *white—白* and *collar—领* in Chinese are activated. Note that the combination of *白* and *领* happens to be a real Chinese compound word *白领 (whitecollar)*, these researchers may wonder whether *白* and *领* are then combined after their representations are activated in the bilingual mental lexicon, and whether *whitecollar* and *白领* are linked by the translation equivalents at the lexical level or by the shared conceptual representations at the semantic level. Conversely, if the same child hears *白领* in Chinese, which is his/her first language (L1), it is also interesting to examine whether the L2 (English) affects the L1 (Chinese) just like the L1 (Chinese) affects the L2 (English).

The specific research questions of Experiments 1 and 2 are: (a) When children process compounds in one language, is their performance affected by the lexical status of the translated compounds in the other language? (b) How does semantic transparency affect this cross-language activation? (c) Does this cross-language activation differ between bilingual children who are more proficient in their second language (L2) and those who are less proficient?

I hypothesize that the response accuracy of children's lexical judgments of compound words will be affected by the lexical status of the translated compounds in the nontarget language. This effect provides evidence of compound decomposition and cross-language activation during compound processing by bilinguals. Given the difference between semantically transparent and semantically opaque compounds in terms of the relation between the meanings of constituent morphemes and the meanings of whole compounds, I hypothesize that semantic transparency will have an effect on the lexical processing of compounds. According to the compound-processing model (Libben, 1998), both semantically transparent and opaque compounds are decomposed at the lexical level, but only transparent compounds are decomposed at the semantic level. Therefore, I hypothesize that the lexical status of translated compounds affects the response accuracy of children's lexical judgments of both transparent and opaque compounds.

Models of bilingual lexicon will be examined by comparing the magnitude of the cross-language activation effect on transparent versus opaque compounds. According to the concept association model (Potter et al., 1984), the words in L1 and L2 are associated by the shared semantic representations, and there is no link between L2 words and their translation equivalents in L1. In other words, when bilingual children hear a word in L2, they have the access to its meaning directly. The translation equivalent of the word in L1 only can be accessed with the activation of the conceptual representation.

According to the word association model (Potter et al.,1984), the words in the L1 and L2 are associated at the lexical level and there is no direct link between L2 words and the concept. When bilingual children hear a word in L2, they would not understand the meaning of the word directly. They must first activate the translation equivalent of the word in L1, through which the concept of the word could be accessed.

According to the revised hierarchical model (RHM, Kroll & Stewart, 1994), L1 and L2 words can be associated at both the lexical level and the semantic level. There is a strong lexical link from the L2 word to the L1 word and a weak link from the L1 word to the L2 word. Initially, there was no direct link between L2 words and their semantic representations. The link between L2 words and their concepts is via their L1 translation equivalents. With increased language proficiency, the link between L2 words and their semantic representations develop and the asymmetry between L1 and L2 becomes less obvious.

If the lexical status of the translated compounds has a greater effect on transparent compounds than on opaque ones, the concept association model is supported. Otherwise, the word association model or the RHM model is supported. Based on the RHM model, I hypothesize that the lexical status of the translated compounds in L1 will have an effect on lexical judgments on L2 compounds. The lexical status of the translated compounds in L2 will have little or no effect on target L1 compounds. Furthermore, the response pattern will vary for children with different levels of L1 and L2 language proficiency.

Experiment 3—Cross-language Transfer of Reading Skills

Morphological awareness refers to children's "ability to identify, reflect on, and manipulate word units that convey meaning" (Anderson & Li, 2006, p. 76). Inflectional, derivational, and compound morphology represent different aspects of morphological awareness. Evidence from previous studies supports the importance of morphological awareness in reading in both Chinese and English (e.g., Nagy, Berninger, & Abbott, 2006; Shu, McBride-Chang, Wu, & Liu, 2006). However, the studies in English have focused on inflectional and derivational morphology, which are very limited in Chinese.

Children's awareness of compound morphology, which is common in both Chinese and English, has received only limited attention in the literature. Recent research suggests that bilingual children's awareness of compound structure in one language contributes to their reading ability in another language (Wang, Cheng, & Chen, 2006). That finding revealed the importance of compound processing in Chinese-English bilingual reading acquisition.

Experiment 3 of this dissertation takes a further step in investigating the relation between compound awareness and reading skills. Comparable tasks in English and Chinese were administered to measure children's oral vocabulary, compound awareness, phonological awareness, and reading outcomes (word reading and reading comprehension). Structural equation modeling was used to address the following two questions: (a) What are the important aspects of compound awareness; and (b) is morphological awareness a significant predictor of reading outcomes within and across languages?

I hypothesize that compound awareness can be assessed via multiple tasks, each task representing a specific aspect of compound awareness. The critical aspects are children's awareness of compound structure and sensitivity to the meanings of constituent morphemes. With respect to the relationship between compound awareness and reading outcomes, I hypothesize that there is a direct link from compound awareness to reading outcomes within and across languages. This finding will support and extend the findings of Wang et al. (2006).

In summary, as the most common form of complex words across all languages, compound words are ideal ingredients for bilingual research. Given the common separation between semantic and lexical representations, investigation of compound processing in bilingual populations provides insight into both fields. Furthermore, emerging studies have provided evidence of bilingual children's cross-language transfer in compound structures. Only a handful of studies have explored compound processing by bilingual children (e.g., Nicoladis, 2002, 2003; Nicoladis & Krott, 2007, which focused on French-English). Three experiments were designed to fill a gap in literature by investigating Chinese-English bilingual children who were learning Chinese at home, while learning English at an American school. Since they learned Chinese earlier than they learned English, Chinese is considered as their first language (L1) and English as their second language (L2). Findings from this study are a first step toward our better understanding of Chinese-English bilingual children's morphological processing and its relationship to learning to read.

Definitions of Key Terms

COMPOUNDS: grammatical combinations of words to form new words (cf. Dressler, p 24). In the dissertation unless specified, compounds refer to prototypical compounds that are composed of two free morphemes.

DECOMPOSITION: the process of decomposing whole compound words into their constituent morphemes.

REAL WORD: the lexicalized words that would be found as an entry in a dictionary.

NONWORD: the words that make up by the author and could not be found as an entry in a dictionary.

SEMANTIC TRANSPARENCY: the degree of consistency between the meaning of a compound word and the meanings its constituent morphemes.

BILINGUAL LEXICON: the MENTAL LEXICON of bilingual speakers.

MENTAL LEXION: is the set of words that one uses regularly or recognizes when used by others. Psycholinguists have proposed various models for such a mental lexicon, in which words are mentally organized with respect to such features as meaning, lexical category, frequency, length, and sound" (VandenBos, 2007, p. 569).

LEXICAL LEVEL: the level in the mental lexicon where the lexical forms (e.g., orthographic and phonological representations) are stored (Kroll & Stewart, 1994, Groot & Kroll, 1997).

SEMANTIC/CONCEPT LEVEL: the level in the mental lexicon where the meanings of words are stored (Kroll & Stewart, 1994; Kroll & de Groot, 1997).

MORPHOLOGICAL AWARENESS: the ability to identify, reflect on, or manipulate word units that convey meaning (Anderson & Li, 2006, p. 76).

PHONOLOGICAL AWARENESS: the ability to perceive and manipulate the sound units of spoken words (Castles & Coltheart, 2004; Goswami & Bryant, 1990).

CROSS-LANGUAGE TRANSFER: "in second-language acquisition, the tendency to transfer the phonology, syntax, and semantics of the native language into the learning of the second language" (VandenBos, 2007, p. 523).

Chapter II: Literature Review

This literature review explores how bilingual children acquire compounds in two languages by investigating relevant work in the fields of compound processing and bilingual acquisition. I start with an overview of models and relevant studies of compound processing. Next, the literature on how children acquire compounding is reviewed. I then provide an overview of the models of the bilingual lexicon. Following a review of the empirical studies on bilingual acquisition of compounds, the role of compound awareness in reading development of bilingual children is discussed. Finally, the limitations of previous studies as well as the directions of this dissertation are outlined.

Compound Representation and Processing

The principal question in studies of compound processing is whether and how the compounds are decomposed into their constituent morphemes. Previous studies of compounds have shown that compound processing is affected by several properties of the constituent morphemes, such as semantic transparency (e.g., Libben, Gibson, Yoon, & Sandra, 2003; Zwitserlood, 1994), frequency (e.g., de Jong et al., 2002), position in the string (e.g., Kehayia et al., 1999), and headedness (e.g., Jarema et al., 1999). The results of those studies provide converging evidence that the constituents of a compound are activated during compound processing. Studies investigating those factors are discussed after a general description of relevant models.

Models in Compound Processing

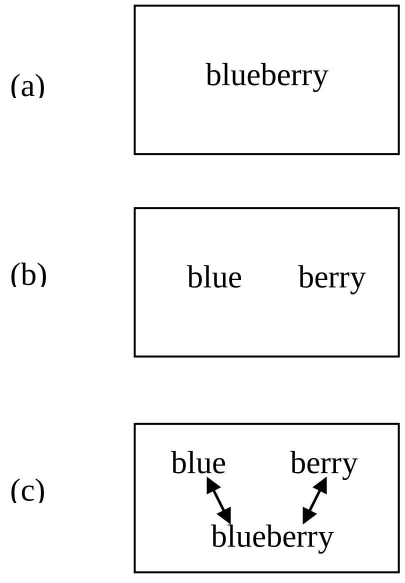
Compounds are classified as a subcategory of multimorphemic words. The general models of morphological processing can also be applied to compounds. The central question of debate among different models is whether and how an individual morpheme is represented in the brain. According to connectionist models, rather than an independent component of language, morphological structure is an emergent, inter-level representation that mediates computations between semantics and phonology (Plaut & Gonnerman, 2000).

All the models within the framework of the mental lexicon, a dictionary-like structure, agree that morphological structure is represented in the mental lexicon. However, different models hold different views on the role of decomposition in the processing of morphemes. According to the *full-listing* hypothesis, complex words have their own representation in memory; the constituent morphemes are not represented in the mental lexicon (Rubin, Becker, & Freeman, 1979). For example, according to that hypothesis, *blueberry* is represented as a whole word and the representations of *blue* and *berry* are not associated with *blueberry* (see Fig. 1a). According to the *decomposition* hypothesis, the constituent morphemes of a complex word—but not the complex words themselves—are represented in the mental lexicon. Thus, the meaning of a complex word can only be accessed by analyzing the meanings of its constituent morphemes (Taft & Forster, 1975). For example, *blueberry* does not have its own representation in the mental lexicon; its meaning is composed on-line from the meanings of *blue* and *berry* (see Fig. 1b). Both hypotheses allow for little flexibility in processing, and they have encountered difficulties in explaining some empirical data.

Most researchers support more interactive models, which propose a direct lexical route involving access to full-form representations along with a parsing route (Caramazza, Laudanna, & Romani, 1988; Taft, 1994; Verhoeven & Perfetti, 2003). According to those interactive models, the mental lexicon is the storehouse for both complex words and their constituent morphemes. The meaning of a complex word can be accessed either directly or by an analysis of the meanings of its constituent morphemes. The analysis approach is affected by the features of individual compound words and its constituent morphemes, such as frequency of the whole word, the family size of their constituent morphemes, and their semantic transparency. For example, *blueberry* has its own representation in the mental lexicon, which is associated with the representations of *blue* and *berry*. The meaning of *blueberry* can be either accessed directly as a whole word or computed from the meanings of *blue* and *berry* (see Fig. 1c). If the compound word is of high frequency, such as *blueberry*, the direct route might be faster than the parsing route.

Figure 1

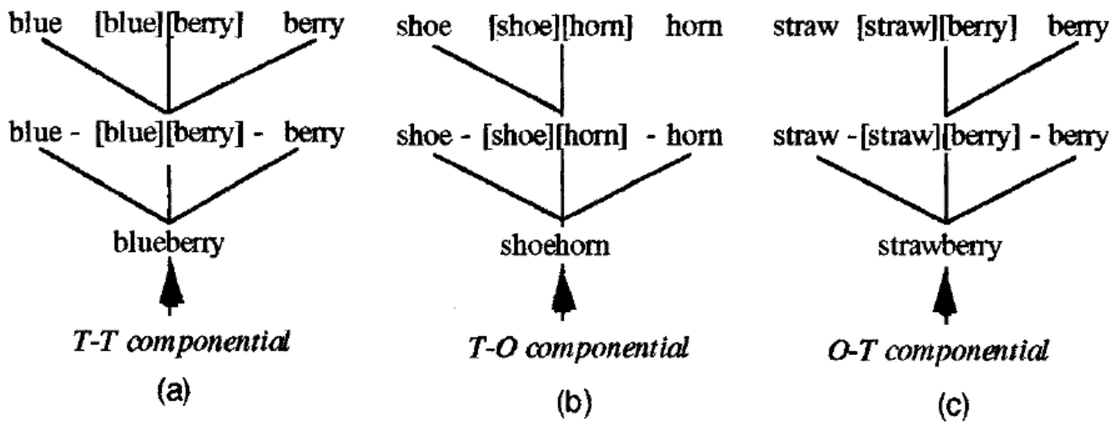
<u>The (a) full-list (b) decomposition and (c) interactive hypotheses of compounds</u>



Although the general models of morphological processing could be applied to different types of morphological processes, there are potentially significant differences in the processing of each type of complex word. Libben (1994, 1998) proposed a model especially derived for compound representation and processing (see Fig. 2). According to an interactive model, compounds are represented and processed at three levels: the stimulus level, the lexical level, and the conceptual level. The compounds are first processed as a whole at the stimulus level, which links to the identical representations of both the constituent morphemes and the whole word. Whether the constituent morphemes are linked to their representations at the conceptual level depends on their semantic transparency. Semantic transparency refers to the consistency between the meaning of a compound word and its constituent morphemes. For example, *class* and *room* in *classroom* are transparent constituents from which one can easily infer the meaning of *classroom*, but *depart* in *department* is opaque, and one cannot infer its meaning.

Figure 2

Constituency at the lexical and conceptual levels (Adapted from Libben, 1998)



According to this model, only the meanings of the whole word and transparent morphemes are activated. For example, transparent compounds, such as *blueberry*, and opaque compounds, such as *strawberry*, link to the representations of both constituents (*blue* and *berry* in *blueberry*, *straw* and *berry* in *strawberry*) and the whole word (*blueberry* and *strawberry*) at the lexical level. However, only the whole word (*blueberry* and *strawberry*) and transparent morphemes (*blue* and *berry* in *blueberry*, *berry* in *strawberry*) are linked to their representations at the conceptual level. The meaning of the opaque morpheme (*straw* in *strawberry*) is not activated. This model was very useful in interpreting findings related to the effect of semantic transparency in compound processing, which is discussed in the following section.

The Role of Semantic Transparency

Given the combinations of individual constituents' semantic transparency, compounds can be classified into four groups: TT (transparent-transparent; e.g., *blackboard*); OT (opaque-transparent; e.g., *strawberry*); TO (transparent-opaque; e.g., *jailbird*); OO (opaque-opaque; e.g., *hogwash*). Compounds can also be described as fully transparent (TT), partially transparent (OT and TO), and fully opaque (OO).

Results from previous research suggest that semantic transparency plays an important role in compound processing. The key question is whether semantically opaque compounds are processed through a morphological decomposition procedure, in other words, whether the constituents of the opaque word are activated during the processing of opaque compounds (e.g., Libben, 1998; Libben et al., 2003; Sandra, 1990; Zwitserlood, 1994).

Sandra (1990) investigated the effect of semantic transparency in Dutch speakers via a semantic priming paradigm. Results showed that semantic associates of constituents primed only semantically transparent compounds. Sandra concluded that the constituents of semantically opaque compounds are not activated, because, if the constituents were activated, a constituent semantic-priming effect should be observed. The semantic-priming paradigm used by Sandra was criticized by Libben et al. (2003), who argued that even though the constituents of opaque compounds were not activated at the semantic level, they could still be activated at the lexical level. According to Libben (1998) both transparent and opaque compounds are processed through a morphological-decomposition procedure at the lexical level. The absence of a semantic-priming effect for opaque words was because of the lack of connections between opaque compounds and their constituents at the semantic level. For example, the opaque compound *hogwash* activates the lexical representations of *hogwash*, *hog* and *wash*. The lexical representation of *hogwash* is connected to its semantic representation as a whole word, but there are no connections between the lexical representation of *hogwash* and the semantic representations of *hog* and *wash*. Even though the activation of *hog* and *wash* at the lexical level may activate their semantic representations as well, their connections with *hogwash* are indirect. That point of view has been supported in a number of studies (e.g., Libben et al., 2003; Zwitserlood, 1994).

Zwitserlood (1994) conducted two experiments to investigate the role of semantic transparency. The first experiment employed a constituent priming paradigm and found priming effects for both transparent and opaque compounds. In the second experiment, the semantic priming effect was found for only fully transparent (TT) and partially transparent compounds (TO and OT) but not for fully opaque (OO) compounds. The results of the first experiment suggest that even fully opaque compounds can be decomposed. The results of the second experiment suggest that in the processing of fully opaque compounds, the semantic representations of their constituents are not activated. Taken together, their findings imply that fully opaque compounds are decomposed at the lexical level but are not connected to the semantic representations of their constituents.

Using two different experimental paradigms, Libben et al. (2003) investigated constituent activation of the four types of compounds (TT, OT, TO and OO). There were two conditions in the first experiment. In one condition, the compounds were presented normally (i.e., *hogwash*). In the other condition, compounds were presented as two separate words (e.g., *hogwash* → *hog wash*). The authors reasoned that the influence of separation would be less for compounds that are naturally decomposed than for those that are not naturally decomposed. If the TT compounds were naturally decomposed, they should be less affected by separation than those that are not.

Contrary to their prediction, the influence of separation was greater for OT and TT compounds than for TO and OO compounds. The unexpected results might have stemmed from a flaw in the experimental design. Participants saw each compound twice, once in a normal condition and once in a split condition. Therefore, the separation effect was confounded by the repetition effect. Despite that flaw, the overall pattern of the results suggests that the reaction time of OT and TT compounds were shorter than TO and OO compounds in both conditions. Similar patterns were found in the second experiment, in which a constituent priming paradigm was employed. All types of compounds were primed by their constituent morphemes. The reaction times of OO and TO compounds were longer than those of OT and TT compounds. The results suggest that all types of compounds are decomposed to a certain degree; the degree of decomposition was smaller for compounds with an opaque head than for other compounds.

In summary, previous investigations of semantic transparency provided evidence for the morphological decomposition of compounds. Both transparent and opaque compounds are processed through a morphological decomposition procedure, but they might also be decomposed through other mechanisms. The locus and degree of decomposition are subjects for further investigation.

The Role of Other Factors

The role of morphological family size and frequency. *Morphological family* refers to the set of all the words in a language containing the same word as a given morpheme. For example, *strawberry*, *blueberry*, and *cranberry* are members of the morphological family *berry*. *Morphological family size* refers to the type count of a morphological family or the number of members in a morphological family (e.g., if there are three words containing *berry*, then the family size of *berry* is three). *Morphological family frequency* refers to the token count of a morphological family, or the sum of the frequency of each member in a morphological family (e.g., for *berry*, the morphological family frequency is the sum of the frequency of *strawberry*, *blueberry*, *cranberry*, etc.). The effect of morphological family size provides evidence of morphological decomposition (e.g., de Jong et al., 2002). If only the whole word is represented in the mental lexicon, the reaction time is not affected by morphological family size.

De Jong et al. (2002) investigated compound processing in English and Dutch, using a lexical-decision paradigm. Several measures of the morphological family were selected as predictors, such as morphological family size and morphological family frequency. The researchers also counted position-family frequency, which is the family frequency of a constituent, constrained by its position within the compound (e.g., the position-family frequency of *blue* in *blueberry* is the sum of the frequency of compounds in which *blue* is the first constituent, such as *blueberry* and *bluebird*). The results revealed that both morphological family size and the position-family frequency of the constituents affected reaction time. The mean reaction time for the stimuli with high family sizes and position-family frequencies was shorter than that for the low condition. Furthermore, position-family frequency was a better predictor of reaction time than morphological family size.

The role of position-in-string. The position of a constituent morpheme in a compound affects its processing. Studies of monomorphemic word recognition have found that the priming effect is greater when the prime and the target share the first element of the words than when they share the last element. For example, if the target is *red*, the word *rack* which shares the initial phoneme with *red* has a greater priming effect than *wood* which shares the final phoneme with red (Coltheart, Woollams, Kinoshita, & Perry, 1999). That could be explained in terms of a left to right serial procedure instead of a parallel procedure in which all the letters in a word are processed simultaneously.

Similar results were found in studies of compound words (e.g., Jarema et al., 1999; Kehayia et al., 1999). Jarema et al. (1999) found that the priming effect of the initial constituents was greater than that of the final constituents in French when the initial constituents were the head of the compound. There was no difference in the magnitude of priming between initial and final constituent in Bulgarian and English, whose heads are the final constituents. The position effect revealed that compound processing is comparable to the processing of monomorphemic words. The initial constituent activates all the words sharing the same initial substring, whether the words are right- or left-headed.

Kehayia et al. (1999) found that the priming effect of initial constituents was greater than that of final constituents in Greek and Polish, even though the second constituent was the head. The strong effect of initial constituents in those two languages might be because of the interfixation in the two languages. The first and second constituents of compounds are usually linked by -o- in Greek and Polish. For example, the Greek compound *domatosalata* (“tomato salad”) is composed of *domat-* ,*-o-*, and *salata.* Also, the initial constituents appear as a bound stem instead of a free uninflected form in Greek. For example, *domata* (tomato) is a free morpheme but it appears as *domat-* in a compound word. Since the initial constituent appears as a bound stem while the final constituent appears as a free stem. That suggests that the association between the initial constituent and the compound might be greater than the association between the final constituent and the compound. It also suggests that the position effect in compound processing is not merely a substring effect, but also involves the activation of semantic and grammatical information, such as the interfixation in Greek and Polish compounds.

The role of headedness. Most compounds consist of a modifier and a head. In some languages, such as English, compounds are always right-headed (e.g., in the compound *bookstore*, *store* is the head and *book* is the modifier). In other languages, such as French, the compounds can be either left-headed or right-headed. Jarema et al. (1999) investigated the effects of semantic transparency, position-in-string, and headedness in French, English, and Bulgarian. In English and Bulgarian, compounds are always right-headed. In French, compounds are either right-headed or left-headed. When tested in English and Bulgarian, differential priming was not found between the initial and final constituents. The priming effect of the first constituent reflected the position-in-string effect. The priming effect of the second constituent reflected the headedness effect. By contrast, the priming effect of the first constituent was significantly greater than that of the second constituent in French when the head was the initial constituent. The results reflected combined effects of position-in-string and headedness on the initial constituent, since the first constituent had not only the advantage of position but also the function of a head.

As reviewed in the previous section on semantic transparency, Libben et al. (2003) investigated the interaction between transparency and headedness in English. Based on the transparency of the constituents, the compound words were divided into four classes: TT, OT, TO and OO compounds. The results show that the TT and OT compounds patterned together and the TO and OO compounds patterned together. Therefore, the transparency of the modifier has less impact than that of the head.

The headedness effect and the interaction between transparency and headedness suggest that, to some extent, the meaning of a compound is composed on-line. The head of a compound determines the semantic, syntactic, and morphological properties of the whole compound; therefore, the transparency of the head makes a greater contribution to the process of on-line composition.

The role of conceptual combination. Although the models of compound processing suggest that compound words are decomposed into their constituent morphemes, how the constituents are linked with each other is not shown. For example, according to Libben (1998), the compound *blueberry* is decomposed into *blue* and *berry*, but it is not clear how to form the meaning of *blueberry* from *blue* and *berry*. The research on conceptual combination provides that information and additional insight into the processing of compounding.

Conceptual combination is the process in which two or more concepts are combined to form a new concept (e.g., Gagné, 2001). Usually, the meaning of a compound can be inferred from the meaning of its constituents. A novel compound may not be treated as a word but either as a combination of two words or as a phrase. Unlike a novel monomorphemic word, the meaning of a compound can be inferred not only from its context but also from the conceptual combination of its components. For example, children need to rely on the context to understand the meaning of *berry* if they do not know the word, however they can understand the meaning of *blueberry* without the context as long as they know the meanings of *blue* and *berry*.

One theory of conceptual combination is the Competition-Among-Relations-in-Nominals (CARIN) theory (Gagné, 2001). According to the CARIN theory, conceptual combination relies on the selection of a relation that links the constituents. For example, the relation that links the constituents of *snowball* is that the noun *(ball)* MADE OF the modifier *(snow)*; the relation that links the constituents of *honeybee* is that the noun *(bee)* MAKES the modifier *(honey)*. The selection of the relation is affected by the availability of particular relations.

One working definition of *relation availability* is the frequency with which a modifier-noun has been used for a particular relation. For example, if the noun MADE OF modifier relation is more frequent for *snow* than other relations, the availability of that relation is greater than other relations for *snow*. Gagné and Shoben (1997) asked participants to judge whether provided noun-noun combinations had a sensible literal interpretation. There were three conditions in their experiment: High-High (HH), High-Low (HL) and Low-High (LH). In the HH condition, the frequency of the relation was high for both the modifier and the head noun (e.g., *mountain bird*, in which the relation is that of the noun *(bird)* is LOCATED in the modifier *(mountain)*, the relation of LOCATED is high for *mountain* as a modifier and *bird* as a noun). In the HL condition, the frequency of the required relation was high for the modifier but low for the head noun (e.g., *mountain cloud* in which the relation is also noun [*cloud*] LOCATED in modifier [*mountain*], the relation of LOCATED is high for *mountain* but low for *cloud*). In the LH condition, the frequency of the required relation was low for the modifier and high for the head noun (e.g., *mountain magazine*, in which the relation is noun [*magazine*] ABOUT modifier [*mountain*], the relation of ABOUT is low for *mountain* but high for *magazine*). The researchers found that the mean reaction times to the HH and HL combinations were shorter than those to the LH combinations. That indicates that the availability of a relation for the modifier affects the processing of conceptual combinations.

Gagné (2001) tested the effect of relation availability from a different perspective. Relation availability was defined in terms of recent usage of the relation. The availability of a recently used relation is greater than that of other relations. Pairs of novel combinations with either same modifier or head nouns were used as primes and targets. The other factor was the similarity of relations used by the prime and target combinations. For example, when the target was *student vote*, there were two priming conditions: *employee vote* which shared the same relation as the target; and *reform vote* which used a different relation from the target. The priming effect was greater for the combinations that used the same relations as the target than for the ones that used different relations. The priming effect of relational similarity was found when the target and priming had common modifiers, but no priming effect of relational similarity was found for combinations sharing the same head noun.

Novel compounds become lexicalized with repeated exposure. Evidence from previous research (e.g., Gagné & Spalding, 2004) suggests that familiar compounds are processed in a way similar to that of novel compounds. Using the experimental paradigm described above (Gagné, 2001), using familiar compound words, Gagné and

Spalding found that recent exposure to a same-relation compound (e.g., *snowfort*) facilitated the processing of a subsequent compound (e.g., *snowball*). That result indicated that relation availability not only affects the interpretation of novel combinations but also affects the processing of familiar compound words. One implication of that finding is that relation information is involved in the compound processing.

Although the above studies provided evidence for the CARIN theory, the materials used in the studies were limited in noun-noun combinations. Moreover, as proposed by Wisniewski (2000; see also Parault, Schwanenflugel, & Haverback, 2005), although the relations in most conceptual combinations can be covered by the basic relation types in the CARIN theory (e.g., Gagné & Shoben, 1997), those basic relations cannot fit into noun-noun compounds composed of two similar constituents (e.g., *whiskey beer*). In the dual-process theory, Wisniewski (1996, 1998) proposed that in addition to the relations, novel conceptual combinations could be interpreted by abstracting a property of the modifier and carrying it over to the head. For example, in *whiskey beer,* the property abstracted from *whiskey* is its flavor, which can be carried over to *beer*. By analyzing participants' interpretation of noun-noun combinations, previous studies (Wisniewski, 1996; Wisniewski & Love, 1998) showed that conceptual combinations were better interpreted with properties when the two constituents in the combination are similar. Despite the on-going debate between the proponents of the CARIN theory and those of the dual-process theory (e.g., Gagné & Spalding, 2006; Murphy & Wisniewski, 2006), studies of conceptual combination have provided insights into how compound processing might be affected by the semantic properties of the constituents, such as relation availability and properties of the constituents.

Auditory and visual processing of compounds. Most of the previously mentioned experimental studies used the visual stimuli of compounds (e.g., Jarema et al., 1999; Libben et al., 2003; Kehayia et al., 1999; Sandra, 1990 Zwitserlood, 1994). However, auditory processing of compounds might be different from visual processing. The spoken form and written form of compounds differ in two aspects. First, the two constituent morphemes are presented simultaneously in written form, but presented sequentially in spoken form. Second, in written form there may be a space or hyphen between the two constituent morphemes.

There is limited previous research on comparing the compound processing in the two different types of modalities. Koester, Gunter, Wagner, and Friederici (2004) used auditory stimuli to investigate the decomposition of compounds. Both the primes, which were syntactically related to one of the constituent morphemes, and the targets, which were the compound words, were presented orally. The priming effects were found for both constituents. Results indicated that the underlying mechanisms of auditory and visual processing of compounds are similar, at least in adult populations.

To summarize, empirical evidence suggests that both the whole word and its constituents have their own representations in the mental lexicon. Whether and how compound words are decomposed during the processing is affected by many factors, such as semantic transparency, morphological family size and frequency, position-in-string, headedness, and conceptual combination. The effects of frequency and position-in-string reflect the role of the lexical properties of the constituents in compound processing. The effects of semantic transparency, headedness, and conceptual combination reflect how semantic properties affect participants' understanding of compounds. The aforementioned studies were mainly conducted on adult participants; in the following section, the review is focused on children.

Children's Acquisition of Compounds

Children as young as two years old comprehend and produce novel compounds (e.g., Nicoladis, 2006). When children first learn a novel compound they may treat it as two words. When children gradually learn compounding rule, they become aware that there is a head and a modifier in a compound word, and the related rules to interpret novel compounds.

Children may also create some novel compounds. For example, a *feather* might be called *'bird hair.'* How children create compounds may provide some insight into their knowledge of and creative use of compounding rules. There is limited research on children's acquisition of compounds compared to that of adults. Researchers have addressed children's acquisition of compounds in terms of the effects of productivity of compounds in a language (e.g., Clark, 1998; Clark et al., 1985; Nicoladis, 1999) and headedness of compounds (e.g., Nicoladis, 2003b).

The Role of Productivity

The productivity of compounds varies among languages. Previous research suggests that productivity affects children's acquisition of compounds. If children are exposed to a language in which compounds are frequent, they acquire compounds earlier and produce more of them than the children who learn a language containing fewer compounds (e.g., Clark, 1998; Clark et al., 1985; Nicoladis, 1999).

The influence of compound productivity in English has been compared to that of French. Compound nouns are more frequent and prolific in English than in French. English-speaking children as young as two-and-a-half years old understand and produce novel compounds (Clark et al., 1985). Compared to English-speaking children, French-speaking children rarely produce novel compounds to express novel concepts (Clark, 1998). In a case study, a French-speaking child began to produce novel compounds after age three (Nicoladis, 1999). In an experimental study, Parault et al. (2005) investigated six- and nine-year-old children's understanding of noun-noun combinations by manipulating the similarities between the two constituents. The results indicated that children had more difficulty than adults in interpreting high-similar combinations using the proper strategy (e.g., interpreting high-similar combinations by carrying the properties of the modifier to the head). The use of similar noun-noun combinations in children's literature was also investigated and found to be very limited. Those results revealed the impact of language exposure on children's acquisition of compounds.

Besides the productivity of the whole compound words, the productivity of the constituent morphemes also affects children's acquisition of compounds (e.g., Krott & Nicoladis, 2005; Nicoladis & Krott, 2007). The productivity of constituent morphemes is represented by two aspects: the frequency and the morphological family size. The morphological family size refers to the number of compound words sharing the same constituent morpheme. Krott and Nicoladis (2005) investigated the influence of the family size of the constituents of compounds in a group of English-speaking children. In their study children were asked to explain a list of compound words that varied in their family size.

Results showed that children were more likely to include a constituent morpheme in their explanation when the constituent had a high family size. The family size had a greater effect on the modifiers of the compounds than on the heads of the compounds. When taking frequency effect into consideration, both family size and frequency affected children's use of the head. However, children's use of the modifier was only affected by family size. Their finding suggests that the productivity of the constituent morphemes affects children's understanding of the compound words. Children may rely on the compound words that share the same constituent in their vocabulary to interpret the meanings of the compound words and the constituent morphemes. Children can understand a constituent morpheme better if they know more words that share the same constituents.

These findings received further support from Nicoladis and Krott (2007) in a group of French-speaking children. Interestingly, most of the children who participated in this study also spoke English. Therefore the children were actually English-French bilingual children with French as their first language. To demonstrate that the findings of their study could be generalized to monolingual French speaking children, the researchers included children's English oral vocabulary and English word family size into their analyses. They found that English oral vocabulary was not correlated with children's performance in French. Since the English word family size was highly correlated with the French family size, it is impossible to differentiate whether the effects they found were related to the English or French family size. Regardless of this critical confound, their results did demonstrate the role of productivity in children's acquisition of compounds.

In summary, the effect of productivity suggests that there exists an influence of exposure on children's acquisition of compounds. As children increasingly encounter compound words, they are more likely to use compounds in their own speech. Furthermore, children are more likely to use the constituent morphemes that have high family sizes. Compounds are highly productive in Chinese; however, there is no systematic investigation on how early Chinese children can understand and produce compounds. For this reason it is important to investigate Chinese children's acquisition of compounds.

Even though the effect of productivity could be inferred by comparing results of different studies on the age of acquisition among languages with different levels of productivity, it is possible that the observed differences were because of other factors, such as bias in sampling, cultural differences, etc. To reach more significant conclusions, future research needs to be based on the same sample. That could be achieved by studying bilingual children who are simultaneously learning two languages having different levels of productivity.

The Role of Headedness

In order to understand a compound such as *bookshop*, children need to know that *bookshop* is a kind of shop instead of a kind of book. In other words, children need to be aware of the headedness of compounds, even though they might not explicitly know the definition of modifier and head. Clark et al. (1985) investigated children's understanding of novel compounds. Children were asked to point out correct picture of novel compounds (e.g., 'apple-knife') from four choices (e.g., knife, apple, apple tree, egg beater). If the children understood 'apple knife' to be a kind of knife, they would choose knife. The results showed that children made correct choices as young as three years old.

Nicoladis (2003b) investigated three- and four-year-old children's understanding of novel compounds (e.g., *sunbag*). In her study, children were given four pictures representing: the head alone (e.g., bag), the modifier alone (e.g., sun), the two objects juxtaposed (e.g., sun surrounded by a bag), and the two objects interacting (e.g., sun on bag). Children were asked to choose the picture that best represented the novel compound. The results suggest that the children understood that a compound refers to interacting objects or at least to two objects. The study was not designed to test children's awareness of headedness; there was no reverse order distracter (e.g., the sun with a bag on it). Therefore, the researcher could not determine whether children knew that the two objects in the compounds were not equal. Although the study did not focus on headedness, the pattern of children's errors made did not show a head preference–the rates at which they chose a head or a modifier were equal. That result indicates that, in the preschool years, children's knowledge of the structure of compound nouns is still developing. As convergent evidence, Parault et al. (2005) also found that second graders still have difficulty interpreting noun-noun combinations with similar constituents.

The Bilingual Lexicon

A key question in research on bilingualism is how the information for the two languages is represented in a bilingual mental lexicon. More specifically, the debate among different model makers is whether or not the two languages share an integrated lexicon. Models like the bilingual interactive activation Model (BIA) support an integrated bilingual lexicon in which the lexical access is non-selective (Dijkstra & Van Heuven, 1998). Models like the revised hierarchical model (RHM) suggest that the two languages may have both shared semantic representation and separated lexical representation (Kroll and Stewart, 1994).

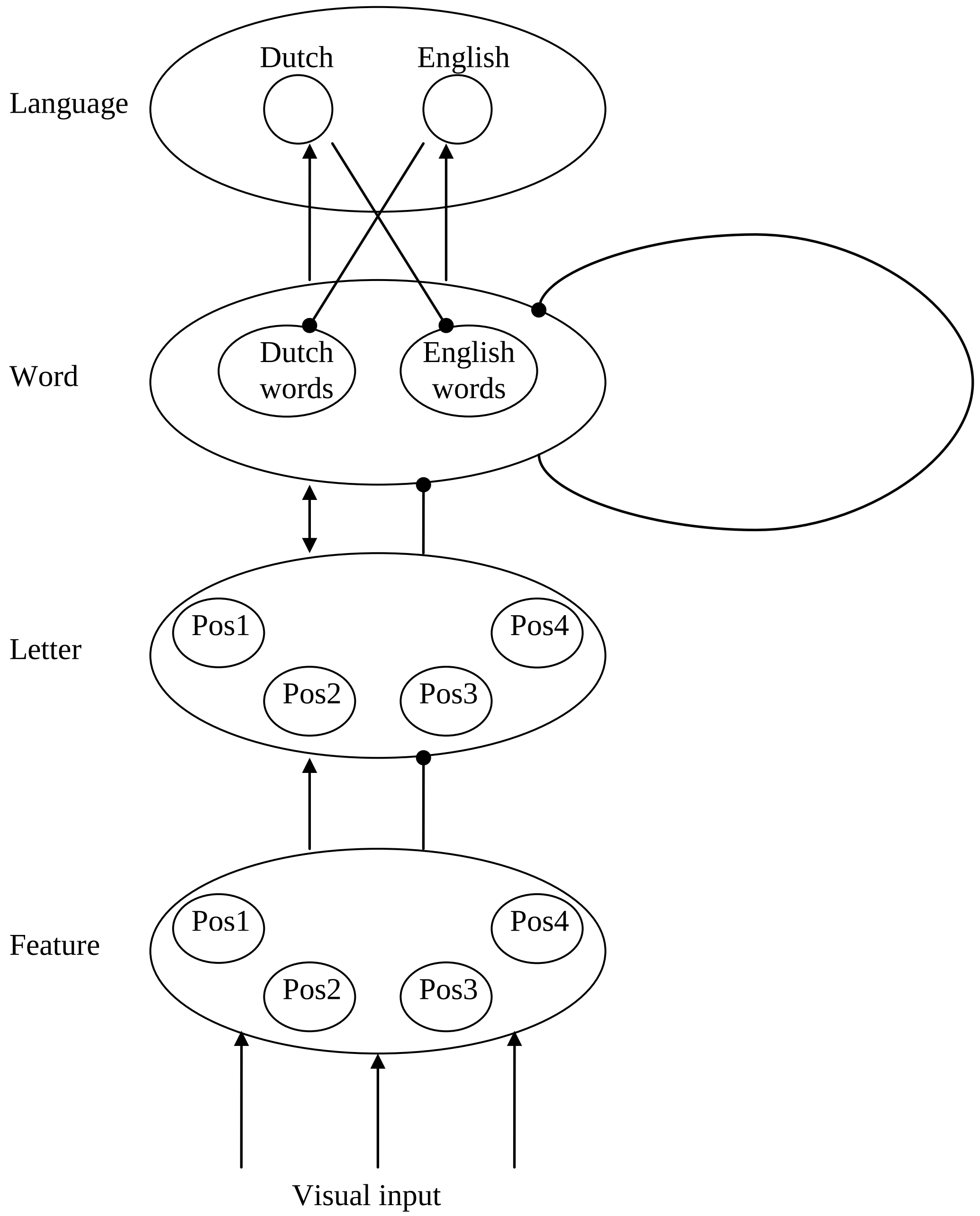
Bilingual Interactive Activation Model

Based on the interactive activation model of word recognition (McClellan & Rumelhart, 1981), Dijkstra and Van Heuven (1998; 2002) proposed a bilingual interactive activation model (BIA; see Figure 3.) and an extended version, BIA+. The basic assumption of the BIA model is that bilinguals' two languages share a common lexicon. In other words, lexical access is non-selective. When the features of the input are shared by choices in both languages, all of them are activated. For example, when a French-English speaker reads the letter *T*, the corresponding representation of *T* is activated in both French and English. A set of letters is then activated; and, in turn word units are activated simultaneously in both languages. Competing alternatives are inhibited among cognates in two languages at the word level. The activation of word units in either language stimulates the corresponding language node. The activation of language nodes then, as if competing, inhibits the activation of word units in the other language by inhibitory connections. The BIA model includes only orthographic representations. In BIA+, Dijkstra and Van Heuven (2002), extended BIA by incorporating phonological and semantic representations. BIA+ also specifies a control mechanism, which is beyond the scope of the present review.

As a computational model, BIA simulates a number of empirical findings, such as inter-lingual *orthographic neighborhood effects* (van Heuven, Dijkstra, & Grainger, 1998). Orthographic neighbors are a group of words differing by a single letter (e.g., *cat* and *hat* are neighbors of *bat*). Some words in similar languages, such as Dutch and English, have orthographic neighbors in both languages. By manipulating the number of orthographic neighbors of target words in both languages, van Heuven et al. (1998) found that the number of orthographic neighbors in Dutch affected the reaction time for target words in English. Although the BIA model can account for empirical findings on proficient bilinguals, it does not incorporate the processes of L2 learning (French & Jacquet, 2004). Compared to the BIA model, the revised hierarchical model puts more emphases on L2 acquisition (Kroll & Stewart, 1994)

Figure 3

Bilingual interaction activation (BIA) model (Adapted from Dijkstra, Van Heuven, and Gainger, 1998)



Word Association Model, Concept Association Model, and Revised Hierarchical Model

The mental lexicon can be divided into lexical and semantic levels. Phonological and orthographic information is stored at the lexical level (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). Word meanings are stored at the semantic level. Given that the same concept can be expressed in different forms across languages, most of the bilingual models suggest that the two languages have shared semantic representations but separate lexical representations. The main difference among these models is how words in an L2 are mapped to their respective meanings. According to the word association model (See Fig. 4a), words in L2 are linked to their translation equivalents in L1, and there are no direct links between L2 words and their meanings. Consequently, L2 words access their meanings via their L1 translation equivalents. According to the concept association model (See Fig. 4b), however, L2 words are directly linked to concepts; there are no direct links between L2 words and their translation equivalents in L1; and L2 words access their meanings directly, without the activation of their translation equivalents in L1.

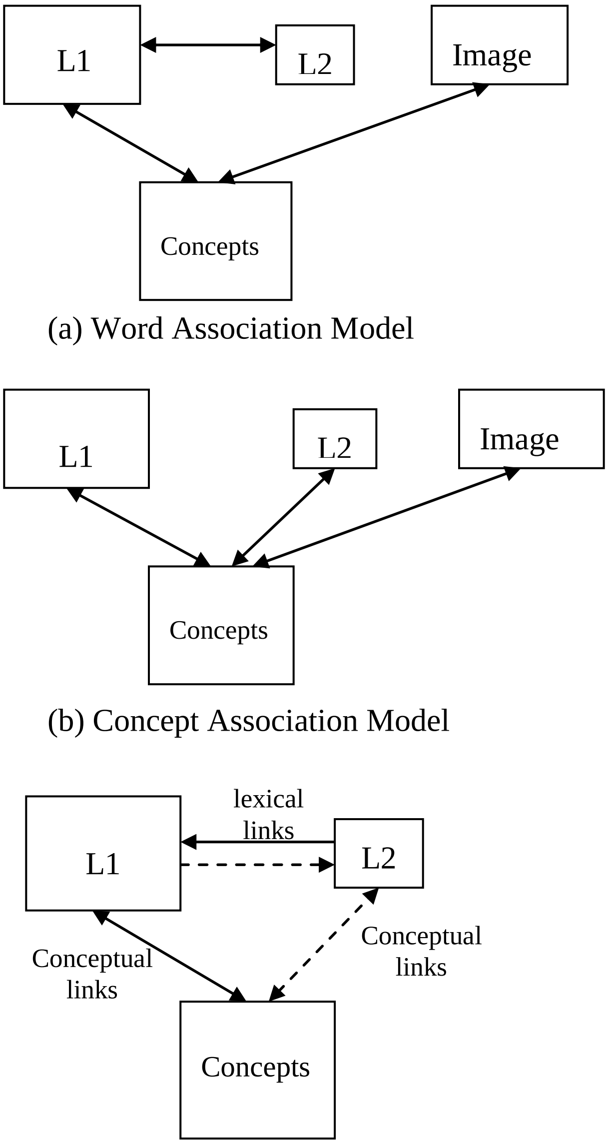
Potter et al. (1984) tested the two models by contrasting bilinguals' performance on a translation task from L1 to L2 and a picture-naming task in L2. The word association model hypothesizes that translation from L1 to L2 is faster than naming a picture in L2. Since there is a direct link between L1 and L2 words, translation from L1 to L2 does not need to activate the shared meanings of those words. By contrast, naming a picture in L2, one not only needs to access the L1 word but also to go through the links between image to concepts and between concepts to the L1 word. The concept association model hypothesizes that performance of the two tasks is similar: since both the L1 word and the image need to be mediated by concepts in order to access the L2 word. Participants showed similar performance on a translation task and a picture-naming task, which is consistent with the concept association model. Potter et al. found similar results for both proficient and less proficient L2 learners, but their results were challenged by other studies. Kroll and Curley (1988), for example, tested beginning learners with very low L2 proficiency and found that translation was faster than picture naming for beginning learners.

Given the differences between beginning L2 learners and proficient bilinguals, Kroll and Stewart (1994) proposed the revised hierarchical model, in which both word and concept associations are allowed (See Fig. 4c). In order to acquire the meaning of a new word in L2, learners must depend on the translation equivalent of the word in their L1. Thus, there is a strong lexical link mapping L1 to L2 and a weak link mapping L2 to L1. Initially, there was no link between L2 and concepts, but the link begins to develop with increasing L2 proficiency. The strength of links becomes more balanced when L2 proficiency improves.

One important implication of the revised hierarchical model is the asymmetric link between L1 and L2. On one hand, translation from an L2 to an L1 is faster than translation from an L1 to an L2. On the other hand, the semantic-priming effect on an L1 is stronger than on an L2. Another implication of the revised hierarchical model is that the asymmetric link between an L1 and an L2 would be more obvious on less-proficient L2 learners than on more-balanced bilinguals. Mixed results were found in previous research on this issue. Although the asymmetric link between L1 and L2 has been evidenced in some studies (e.g., Kroll & Stewart, 1994; Sholl, Sankaranarayanan, & Kroll, 1995), other studies have found similar linking strengh in both directions of translation (e.g., La Heij, Kerling, & Van der Velden, 1996).

Figure 4

<u>Word association model, concept association model, and revised hierarchical model (adapted from Kroll and Stewart, 1994)</u>



(a) Word Association Model

(b) Concept Association Model

(c) Revised Hierarchical Model

Emerging Studies on Bilingual Acquisition of Compound Words

The various studies of monolingual populations have shown that compound processing is affected by many factors, such as semantic transparency (e.g., Libben et al., 2003), morphological family size and frequency (e.g., de Jong et al., 2002), and headedness (e.g., Krott & Nicoladis, 2005), etc. These factors that affect monolingual compound processing might also affect bilingual compound processing. One way of investigating compound processing in bilingual children is to manipulate these factors in the two languages simultaneously. For example, a morpheme and its translation equivalent may have different family sizes in the two languages. If the family sizes in both languages affects compound recognition in their L2 or L1, this will be an indication of activation of both languages in bilingual word recognition.

Very limited studies have directly investigated the role of the aforementioned factors in bilingual acquisition. Nicoladis and Krott (2007) investigated the influence of the family size of the constituents of compounds in a group of French-English children. Although their focus was on the French instead of bilingual acquisition of compounds, their findings might shed some light on research on bilingual children. Consistent with their findings in a previous study on English-speaking children (Krott & Nicoladis, 2005), family size had a greater effect on the modifier than on the head. Since the positions of the modifier and the head in compounds are different in French and English (French compounds are left-headed), their results indicated that the effect of the family size was independent of the position of the constituents in compounds. Therefore, the function of a constituent in compounds may be more important than its position. However, it is unclear in this study whether it was the French or the English family size that affected children's performance. It would be interesting in the future research to investigate whether family sizes in both languages jointly affect children's acquisition of compound words.

Few studies have directly investigated the bilingual acquisition of compounds. Structures of compounds vary from language to language. For example, noun-noun compounds are always right-headed in English (e.g., policeman) and left-headed in

French (e.g., home-orchestre, ‘man orchestra’, which means a man who plays several musical instruments). How do bilingual children simultaneously acquire the contrasting structures of compounds in two languages? Nicoladis (2002) addressed this question. A group of French-English bilingual children and a group of English monolingual children were tested in both compound production and comprehension. In the compound-production task, children were consecutively shown two pictures of multiple objects (e.g., a picture of cherries and a picture of bowls) and then were asked to name, in English, a third picture, which was a combination of the previous two pictures (e.g., bowls decorated with cherries). The French-English bilingual children produced more reversed noun-noun compounds (e.g., *bowl cherry* for the picture of bowls decorated with cherries) than English monolingual children. The result might have been caused by the influence of French upon English.

In the compound-comprehension task, children were asked to choose which one picture (out of four) that best represented a given novel compound (e.g., *rabbit car*). The four pictures showed: a target, in which the head and modifier were combined by carrying the properties of the modifier over to the head (e.g., a car with rabbit ears and tails); the modifier (a rabbit); the head (a car); and the modifier and head appearing together instead of being combined (e.g., a car next to a rabbit). Results showed that the children were able to choose the correct answer most of the time; they were more likely to choose the picture of the composition distracter than that of the modifier and the head. There were no differences in the comprehension task between bilingual and monolingual children. That might have been because of the insensitivity of their task design in detecting the children’s understanding of the position of the head. There was no distracter, which could have been a reversed combination of the modifier and the head (e.g., pictures of a car and a rabbit).

In another study, Nicoladis (2003) investigated cross-linguistic transfer in *deverbal compounds* by English-French bilingual children. Deverbal compounds are compounds derived from verbs. Deverbal compounds take the form object-verb-er (OV, e.g., *screwdriver*) in English and take the form verb-object (VO, e.g., *taille-crayon* 'sharpen-pencil' means 'pencil sharpener') in French. The children were tested in both French and English. In the compound-production task, children were asked to name pictures of machines that were acting on objects (e.g., a machine juggling suns was used to suggest the target compound *sun juggler*.) French-English bilingual children produced more VO compounds than either English or French monolingual children. That showed the impact of both languages on bilingual children. The VO structure was transferred from French to English. Compared to French monolingual children, bilingual children had had more exposure to deverbal compounds, which are relatively infrequent in French.

In the compound comprehension task, children were asked to choose the picture that best represented a given novel compound (e.g., *can crusher*) from four pictures. There were no differences in performance on the comprehension task between the bilingual and monolingual groups. The author concluded that cross-language transfer is a phenomenon of production, rather than of comprehension. However, similar to the study conducted by Nicoladis (2002), the lack of performance differences between bilingual and monolingual children in the comprehension task might reflect insensitivity in the task design. To capture the difference between object-verb-er compounds in English and verb-object compounds in English, the comprehension task needs to include both types. To make the task more sensitive to detecting cross-language transfer, children could be asked to choose the picture for an ungrammatical verb-object compound (e.g., *wash dish* for *dish-washer*) instead of a grammatical object-verb-er compound (e.g., *dish-washer*). Bilingual children might then show a better understanding of the ungrammatical form than English monolingual children.

In summary, the results of the two studies provide evidence of bilingual children's cross-language transfer of compound word structures. Although such transfers were observed only in a production task, it would be premature to conclude that cross-language transfer is a phenomenon of production only given the limitations in the design of the comprehension task. Further research is needed to reveal the mechanism of cross-language transfer.

In the aforementioned literature, I have concentrated on how compounds are represented and processed at the micro-level (within a compound word). A complete framework for the bilingual acquisition of compounds should include studies at both the micro-level and macro-level, i.e., general knowledge about compound words and the relationship between that knowledge and other aspects of languages and reading skill. Moreover, given the fact that most of L2 learners acquire their L2 language and writing skills simultaneously, the processes of bilingual acquisition and biliteracy development are intertwined and interactive. Therefore, the following section shifts my focus from word-level processing to a general awareness of compounds and its effect on reading achievement.

Compound Awareness and Reading Development

"Morphological awareness" refers to children's ability to identify, reflect on, and manipulate the morphemic structure of words (Anderson & Li, 2006, p.76; Carlisle, 1995, p. 194). Children's awareness of compound structure is one aspect of morphological awareness. Given the lack of a clear distinction among compound awareness, derivational awareness, and inflectional awareness, the literature on morphological awareness and reading development will be reviewed first. Following that general review is a detailed review of a particular study on bilingual children. The limitations of existing studies and directions for future research are also outlined.

Morphological Awareness Versus Phonological Awareness

The importance of phonemic awareness in learning to read English has been demonstrated in numerous studies (e.g., Badian, 1998; de Jong & van der Leij, 2002; see also Ehri et al., 2001, for a review). However, the role of morphological awareness in reading development is less understood. Since the same morphemes also share the same or similar phonology, it is possible that the observed morphological effect is indeed a kind of phonological effect. To exclude this possibility, it is necessary to differentiate the role of morphological awareness and phonological awareness in reading research.

Both phonological awareness and morphological awareness are considered to be aspects of metalinguistic awareness. Metalinguistic awareness refers to the ability to identify, reflect on, and manipulate linguistic units (Anderson & Li, 2006). Metalinguistic awareness is important in the process of learning to read (Nagy & Anderson, 1998). Successful reading entails accurate mapping between one's print and speech systems. Without metalinguistic awareness, children have no insights into the units of speech; consequently, they do not understand which units of speech are represented by encountered print.

Phonological awareness is important for reading because print represents the speech system. In an alphabetic writing system, such as English, the graphemes represent the phonemes. Children will have no clue that the letter *m* in *mum* represents /m/; if they do not know /mum/ can be divided into /m/, /ʌ/ and /m/. In a nonalphabetic system, such as Chinese, the graphemes do not represent the phonemes; instead, the graphemes represent a larger sound unit—the syllable. In Chinese, grapheme is the character; each character represents a syllable, as well as a morpheme. For example, the word 书店 (*shu1dian4, book store*) consists of two characters. If children are not aware that in speech *shu1dian 4* can be divided into two syllables *shu1* and *dian4*, they will probably remember 书店 as a whole unit instead of mapping the grapheme 书 onto the syllable *shu1*. Therefore, children's ability to distinguish and manipulate sound units is essential when they learn to decode the print and map it to the speech system.

What is the role of morphological awareness in reading? Although the relationship between morphemes and the writing system is not as straightforward as that between phonemes and the writing system, the writing system represents not only phonemes, but also morphemes, the smallest unit of meaning, For example, the word *classroom* is composed of the two morphemes *class* and *room*. If the writing system only represented phonemes, the form of the word might be / klʌsrum/, which represents the phonemes in a more efficient way. A child who understands that *class* is a unit of meaning can decode such words as *classes*, *classroom*, and *classmates* faster than those who do not.

In the Chinese writing system, morphemes are more salient than those in English. The Chinese writing system is "morphographic," that is, the graphemes represent morphemes, which are also syllables. A child who does not understand that a character maps onto a morpheme will not be able to distinguish among the great number of homophones that share the same pronunciations. In Chinese, one syllable usually maps to several characters, while one morpheme maps onto only one character. For example, the syllable *shu1* corresponds to about 20 characters, such as 书 (book), 蔬 (vegetable), 叔 (uncle), but each character represents only one morpheme. Therefore, one-to-one morpheme-grapheme correspondences are more reliable than one-to-several syllable-grapheme correspondences in Chinese. Given the prominence of morpheme-grapheme correspondences in Chinese, some researchers have hypothesized that the role of morphological awareness in Chinese is somewhat analogous to the role of phonemic awareness in English (e.g., Nagy et al., 2002). That hypothesis may have underestimated the role of phonological awareness in Chinese. Since, in Chinese graphemes also represent syllables, morphological awareness cannot replace the function of phonological awareness in reading. However, the effect of morphological awareness on Chinese reading is analogous to the effect of phonological awareness on English reading. To examine the relative effect of morphological awareness on reading in different writing systems, I reviewed previous studies that investigated morphological awareness in alphabetic orthographies and in the nonalphabetic system—Chinese—respectively. .

Morphological Awareness and Reading in the Alphabetic Systems

In the past few decades, there have been an increasing number of studies investigating the relationship between morphological awareness and literacy in English (e.g., Carlisle, 1995, 2000; Carlisle & Fleming, 2003; Nagy et al., 2006; Singson, Mahony, & Mann, 2000) and other alphabetic orthographies such as French (e.g., Casalis & Louis-Alexandre, 2000; Plaza & Cohen, 2003, 2004). Those studies provided converging evidence that morphological awareness affects reading in different alphabetic orthographies.

In a longitudinal study, Carlisle and Fleming (2003) assessed the role of morphological awareness in reading development. First- and third- graders were assessed, using two tasks in which their comprehension and productive ability of morphemes were tested separately. Two years later, they were given one test assessing their ability to process derived words in sentences and another one, their reading comprehension. The results showed an association between the lexical analysis of complex words in early elementary years and reading comprehension in the third and fifth grades.

Studies assessed phonological awareness, along with the morphological awareness. The contribution of morphological awareness is still found to be significant, even after taking into account the phonological effect. Carlisle and Nomanbhoy (1993) investigated in first graders the relationship among phonological awareness (syllable and phoneme deletion), morphological awareness (judgment of word relations and production of word forms), and reading ability (real word reading). They found that both phonological and morphological awareness contributed significantly to variance in word reading, but that phonological awareness was the greater contributor.

The importance of morphological awareness was also supported in studies that used structural equation modeling. In a more recent study, Nagy, Berninger, and Abbott (2006) used structural equation modeling to evaluate the roles of morphological awareness and phonological skill in English reading ability. They found that morphological awareness made a unique contribution to reading outcomes over and above the contribution made by phonological awareness.

Morphological Awareness and Reading in Chinese

The importance of morphological awareness in reading Chinese has been demonstrated in a number of studies (Ku & Anderson, 2003; McBride-Chang, Shu, Zhou, Wat, & Wagner, 2003; Shu, McBride-Chang, Wu, & Liu, 2006). McBride-Chang et al. (2003) designed two special tasks to test the morphological awareness of kindergarten and second, grade students in Hong Kong. The tasks were based on two special features of Chinese—the relatively large number of homophones and the large proportion of compound words. The study also involved the measurements of phonological awareness and reading ability. The results of the regression analyses showed that the measures of morphological awareness predicted a statistically significant amount of variance in character recognition in the kindergarten sample (9%) and the combined sample (3%).

In a more recent study, Shu, McBride-Chang, Wu, and Liu (2006) investigated the role of morphological awareness in reading ability of Chinese dyslexic and normal children. Morphological awareness was one of the factors that distinguished the dyslexic group and age-matched group. The results from path analyses suggested that morphological awareness was the strongest predictor of reading outcomes in both dyslexic and normal children.

Ku and Anderson (2003) used the parallel tasks of morphological awareness to assess both Chinese-speaking children and English-speaking children in primary school. They also found that morphological awareness was strongly related to reading ability. However, since they did not measure phonological awareness, they cannot rule out the possibility that the effect is partly due to the involvement of phonological awareness.

In summary, the results of past studies provide evidence to support the importance of morphological awareness in reading. The tasks used were varied among studies. Inflectional and derivational morphology were tested in English and compounding structures were tested in Chinese. The tasks of inflectional morphology, derivational morphology, and compound morphology were all considered to be morphological awareness tasks. Therefore, the different results for English and Chinese might have been a result of the differences between the tasks that were used. In order to eliminate a task-specific effect, comparable tasks should be adopted to make cross-language comparisons. Furthermore, clear definitions of morphological tasks would also facilitate understanding the specific relationship between morphological awareness and reading achievement. In the study by Wang et al. (2006), separate tasks for compound awareness and derivational awareness were used to investigate the cross-language transfer of morphological awareness in bilingual acquisition. That study is reviewed in the following section.

Bilingual Children's Compound Awareness and Reading Ability

Wang et al. (2006) investigated the contribution of phonological processing and morphological processing in Chinese-English bilingual students' reading acquisition. It was the first empirical study to explore the contribution of compound awareness to reading development in bilingual children.

Comparable tasks in Chinese and English were conducted to test students' morphological awareness, phonological awareness, oral vocabulary, real-word reading, and reading comprehension. Two aspects of morphological awareness were tested in both Chinese and English: compound awareness and derivational awareness. Given that homophones are abundant in Chinese, a task was designed to test students' ability to distinguish between different morphemes among homophones. Seventy-four students recruited from two levels of a Chinese-language school were tested in groups. The results of hierarchical regression analyses revealed that English compound awareness predicted a unique amount of variance in both Chinese character reading and reading comprehension, even after the impact of the potential within-Chinese-related predictors has been accounted for. Although the measurement of compound awareness, as well as other tasks, may reflect individual differences on other general factors, such as attention and memory expenditure, cross-language morphological transfer in acquiring two different writing systems is indeed the most plausible explanation for those results. Cross-language morphological transfer stems from the shared morphological structure of the Chinese and English writing systems; that is, the compound structure instead of the derivational structure. Furthermore, the results indicate that reading Chinese heavily involves compounding processes and any transfer across languages would be beneficial.

Although compound awareness in English makes a unique contribution to Chinese reading comprehension, the contribution of compound awareness in Chinese was not significant. The differential levels of difficulty between the English and Chinese tasks may be the reason. In the English test, there were three subgroups in the compound-awareness task. In one subgroup, the child was presented with a riddle followed by two choices. The child's task was to choose the better answer to the riddle. For example, "Which is a better name for a bee that lives in the grass: grass bee, or bee grass?" In the second subgroup, the items were the same as those in the first subgroup but presented in a contrasting way. For example, "Which is a better name for grass where lots of bees like to hide: bee grass, or grass bee? In the final group, the questions were more complex than the previous two groups. The child was asked to choose the best compound name from among four choices based on a short description. For example, "If you found a lid for a dish to keep candy in, what would it be called: dish lid candy, candy dish lid, dish candy lid, or candy lid dish? The Chinese test of compound words included only two-morpheme compound words. Therefore, the English test of compound awareness may reflect children's ability to combine several semantic units and may influence the processing of Chinese phrases.

The Present Dissertation

In the preceding sections, the literature on compound processing and bilingualism were reviewed as two independent fields. The literature on compound processing suggests that whether and how compound words are decomposed during processing is affected by semantic transparency, morphological family size, position-in-string, headedness, and conceptual combination. The literature on bilingualism proposes models on how the two languages are organized in the bilingual lexicon—either by an integrated lexicon or by shared semantic representations but separate lexical representations. Although studies have provided evidence of bilingual children's cross-language transfer in compound structures, no research, to my knowledge, has directly examined cross-language activation when children encountered compounds in one language at a time. The first part of this section discusses how this issue can be addressed. As the first investigation on this issue, this dissertation could not address all the relevant factors (e.g., morphological family, position-in-string, headedness, and conceptual combination) and different bilingual lexicon models (e.g., BIA model). Only the effect of semantic transparency is examined. Instead of manipulating the other factors, such as frequency, I controlled some of these factors to minimize the potential confounds in Experiments 1 and 2.

On a macro-level, the literature on reading development has shown the importance of morphological awareness. However, it is not clear how reading development is affected by compound awareness as a specific aspect of morphological awareness. The second part of this section, based on the study of Wang et al. (2006), identifies direction of further investigation of the relationship between compound awareness and bilingual reading development.

How Are Compounds Represented and Processed in the Bilingual Lexicon?

Whether compounds are decomposed into their constituent morphemes or processed as whole words is the central issue of compound-processing research. Previous studies of monolingual populations have provided evidence that the constituents of a compound are activated during compound processing (e.g., Libben, 1998). The compound processing includes not only decomposition but also composition. Once compounds are decomposed into their constituent morphemes, they are combined on-line to access the meanings of the compounds. In bilingual populations, an important question becomes whether the translation equivalents of the constituent morphemes in the other language can be activated. A follow-up question then, is: once the translation equivalents of the constituent morphemes in the other language are activated, whether they are combined on-line.

Levy, Goral, and Obler (2006) suggested that these questions could be addressed by manipulating the properties of compounds in one language and those of the translation equivalents in the other language. The combination of the translated constituents will form a new translated compound word/nonword in the other language. For example, the Chinese compound *火山 (volcano)* contains two free morphemes *火 (fire)* and *山 (mountain)*. The combination of the translated constituents, *fire* and *mountain*, will form a compound nonword in English, *fire mountain*. As a comparison, the Chinese compound *牙刷 (toothbrush)* contains two free morphemes *牙 (tooth)* and *刷 (brush)*. The combination of the translated constituents, *tooth* and *brush*, will form a translated compound real word in English, *toothbrush*. If the translation equivalents of the constituent morphemes cannot be activated or if they are not combined on-line in the other language, there will be no difference in lexical judgment between *火山 (volcano)* and *牙刷 (toothbrush)* in a Chinese lexical-decision task. By comparing the influence from L1 to L2 and the influence from L2 to L1, the hypothesis of the revised hierarchical model (Kroll & Stewart, 1994) can also be tested. Based on that model there is a strong lexical link from L1 to L2 and a weak link from L2 to L1. If the influence from L1 to L2 is stronger than the influence from L2 to L1, the model will be supported.

Previous studies of compounds have shown that compound processing was affected by semantic transparency (e.g., Libben, 1998). Empirical studies on this issue produced contradictory results about whether semantically opaque compounds are processed through a morphological decomposition procedure; in other words, whether the constituents are activated during the processing of opaque compounds. Some previous studies have suggested that both transparent and opaque compounds are processed through a morphological decomposition procedure, but they might be decomposed through a different mechanism (e.g., Libben, 1998; Libben et al., 2003; Sandra, 1990; Zwitserlood, 1994). According to Libben (1994, 1998), both transparent and opaque compounds are decomposed at the lexical level, where the phonological and orthographical representations are stored. However, the meanings of the opaque morphemes will not be activated at the conceptual level.

Concerning the bilingual lexicon, one question of debate is: how lexical forms, especially in L2, are mapped to their respective meanings. According to the word association model, there are no direct links between L2 words and semantic representations. Concepts and the words in L2 are mediated by their translation equivalents in L1. According to the concept mediation model, L2 words can access their meanings directly, without the activation of their translation equivalents in L1. However, according to the revised hierarchical model proposed by Kroll and Stewart (1994), the way of mapping was altered by L2 proficiency. Initially, the meaning of L2 words is accessed via the link from L2 words to their L1 translation equivalents. Direct associations between L2 words and their meanings develop gradually with increasing L2 proficiency. There is a strong lexical link from L1 to L2 and a weak link from L2 to L1. The link strength becomes more balanced when L2 proficiency improves.

Those models can be tested by comparing the lexical influence of translated compounds on transparent compounds and opaque compounds. If the word association model proves to be tenable, the lexicality of translated compounds would have the same effect on transparent and opaque compounds, because transparent compounds and opaque compounds differ only at the conceptual level. If the concept association model proves tenable, the lexicality of translated compounds would have a greater effect on transparent compounds than on opaque compounds, because the conceptual representation of the constituents of opaque compounds and their translated equivalents would not be activated. A different performance between groups of varied L2 proficiency would support the revised hierarchical model.

What is the Role of Compound Awareness in Bilingual Reading Acquisition?

Although Wang et al. (2006) suggested that measurement, using compound words, can predict bilingual children's reading skill, no definitive conclusion can be drawn from a single study. Furthermore, the underlying mechanism of the relation between compound awareness and reading has not yet been discovered. Future research should systematically investigate different aspects of compound awareness, such as children's awareness of compounding structure, their sensitivity to meanings of constituent morphemes in compound words, and their ability to produce compound words.

The task used by Wang et al. (2006) concentrated on one aspect of compound awareness—the structure of the compounds. In order to perform the task correctly, children need to understand the relative positions of modifiers and heads in compound words. Besides an awareness of compound structure, other skills are necessary for children to understand and produce compound words; for example, the ability to identify the constituent morphemes of a compound word. It is not clear whether these skills are transferred between the two languages of bilingual children and whether those aspects also contribute to reading skills.

To test other aspects of compound awareness, future research could modify the tasks used in monolingual studies and apply them to bilingual children. One aspect of compound awareness is: children's sensitivity to the meanings of constituent morphemes. That aspect can be measured by a word identification test used by McBride-Chang et al. (2003). The test was designed to tap children's ability to distinguish homophones among several compound words. In the test, children were orally presented with three words containing different morphemes that have identical sounds in Cantonese (e.g., *籃球* [laam4kou1, basketball], *男孩* [laam4hai4, boy], *藍色* [laam4cik1, color blue]). Then a word containing the target morpheme was read to the participants (e.g., *男女* [laam4lui3, boy and girl]). The children were asked to point out the word containing the target morpheme. The task required the children to isolate the constituent morphemes in compound words and to retrieve their meanings.

Another aspect of compound awareness is children's ability to produce compound words, which can be measured by a morpheme-production task used by Shu et al. (2006). In that task, children were orally presented with a two-morpheme compound word (e.g., *草地* [cao3di4, law]). The children were asked to use one of the morphemes (e.g., *草* [cao3, grass]) in the presented word to produce two new compound words. In one of the words produced, the morpheme should have the same meaning as the original word (e.g., *小草* [xiao3cao3, small grass]). In the other compound word, the morpheme should have a different meaning from that of the original compound word (e.g., *草率* [cao3shuai4, cursory]). The task tapped children's understanding of the meanings of constituent morphemes in compounds and children's ability to produce new compounds.

In summary, this dissertation followed the directions described above, and focused on the following questions: (a) When children process compounds in one language, is their performance affected by their knowledge of compounds in the other language? (b) how do properties of compound words, such as semantic transparency, affect this cross-language activation? (c) does this cross-language activation differ between bilingual children who are more proficient in their second language (L2) and those who are less proficient? and (d) to what extent does compound awareness in one language contribute to reading skills in the other language?

Chapter III: Experiment 1

One way of conceptualizing the bilingual decomposition of compound words is to determine whether the translation equivalents of their constituent morphemes are activated. If a compound is decomposed in the target language (the language being tested), the translation equivalents of its constituents should be activated in the nontarget language (the language not being tested). The combination of the translation equivalents forms a new compound in the nontarget language (hereinafter, the “translated compound”). If a compound is decomposed and recomposed on-line in the nontarget language, it is reasonable to assume that the lexicality of the translated compound affects the lexical judgment in the target language.

Furthermore, according to the Revised Hierarchical Model (RHM, Kroll & Stewart, 1994) there is a strong link from L2 to L1 and a weak link from L1 to L2. When the target language is L2 (English), the translation equivalents of the constituents are easily activated in L1 (Chinese). However, when the target language is L1, the translation equivalents of constituents are not easily activated in L2. As a result, when the target language is L2, the effect on the lexicality of the translated compound in the nontarget language is stronger than when the target language is L1. In other words, the influence from L1 to L2 is stronger than the influence from L2 to L1. Those predications were tested in Experiment 1.

Hypotheses

Given the evidence of compound decomposition in the literature (e.g., Libben, 1998), the lexical decision on a compound word in the target language will be influenced by the lexicality of the compound formed by its translated constituents in the nontarget language. According to the Revised Hierarchical Model (Kroll &

Stewart, 1994), the influence from L1 (Chinese) to L2 (English) will be greater than the influence from L2 to L1 for the beginning bilingual speakers.

Method

Participants

The participants in this experiment were 30 six-year-old Chinese immigrant children from the Washington, DC metropolitan area. Their mean age was 6.95 years (SD=.65 years). They simultaneously attended English classes in public schools during the week and a Heritage Chinese weekend school. According to a demographic survey on the same population (Wang et al., 2005), the majority of the children learned Chinese as their first language and spoke both Chinese and English at home. Most of the parents were native speakers of Chinese; about half of the parents spoke both Chinese and English at home, and half spoke only Chinese at home.

Design and Materials

This experiment employed a 2 (lexicality in the target language: real words/nonwords) × 2 (lexicality of the translated compounds in the nontarget language: real words/nonwords) factorial design. Parallel materials in English and Chinese were used in the lexical-decision task. Sixteen compound words and sixteen compound nonwords were used in both languages. All the compound words/nonwords contained two free morphemes as constituents that mapped to the desired translations in the other language. Ten Chinese-English bilingual graduate students translated the constituents from Chinese to English. Another 10 Chinese-English bilingual graduate students back translated the constituents from English to Chinese. All the constituents were preferred translations from one language to the other by the translators (e.g., if more than 50% of the translators translated *brush* to *刷* and translated the *刷* to *brush*, then *brush* was the preferred translation of *刷* and *刷*

was the preferred translation of *brush*.). The combination of the translated constituents formed a new compound word/nonword in the other language–the translated compound.

The combination of the translated constituents, *fire* and *mountain*, forms a translated compound nonword in English, *fire mountain*. Therefore, the materials were divided into four conditions according to the lexicality of the compound in the target language and the lexicality of the translated compound in the nontarget language—either Chinese or English (see Table 1 for sample items; see Appendix A for a complete list of items.) The four conditions were: (a) the real-word/real-word (RR) condition, which contained real compounds whose translated compounds were real words in either Chinese or English; (b) the real-word/ nonword (RN) condition, which contained real compounds in the target language, whose translated compounds were not real words in the nontarget language; (c) the nonword/real-word (NR) condition, which contained compound nonwords in the target language and translated compounds were real words in the nontarget language; and (d) the nonword/ nonword (NN) condition, which contained compound nonwords whose translated compounds were not real words in either Chinese or English.

Table 1

Sample Items of Experiment 1

	Target language			
	English		Chinese	
Nontarget language	Real words	Nonwords	Real words	Nonwords
Real-words	***tooth brush*** *(牙 刷)* *[tooth brush]*	***fire mountain*** *(火 山)* *[volcano]*	***牙 刷*** *(tooth brush)* *[tooth brush]*	***校 书*** *(school book)* *[school book]*
Nonwords	***school book*** *(校 书)* *[school book]*	***bird hair*** *(鸟 发)* *[Feather]*	***火 山*** *(fire mountain)* *[volcano]*	***鸟 发*** *(bird hair)* *[Feather]*

Note. Text in bold denotes test items in the target language. Each Chinese character/English word in parentheses is the translation equivalent of the corresponding constituent at the same position (e.g., 牙 is the translation equivalent of *tooth*. Both are the first constituents in the compounds.). The meanings of Chinese compound words and the interpretations of English and Chinese nonwords are in brackets.

A novel, compound nonword can be interpreted as a real concept. For example, *bird hair* can be interpreted as *feather*. One may argue that the difference observed between the NR and NN conditions is because of the different degree to which they could be interpreted as real concepts. To control for that, the compound nonwords were mapped onto real concepts to the same degree. The semantic similarity between the compound nonwords and the real concepts (e.g., the similarity between "*fire mountain*" and "*volcano*") was rated by adults and matched across the two conditions involving compound nonwords (i.e., NR and NN). Sixteen undergraduate native English speakers and 13 international graduate students who were native Chinese speakers rated the English and Chinese items, respectively, in terms of the similarity between the compound nonwords and the real concepts. A seven-point rating scale was employed, in which the choices ranged from "completely different" to "exactly the same." The results of the rating are listed in Table 2.

One might argue that children's familiarity with the concepts underlying the compound nonwords would also affect their responses. To eliminate that possibility, children's familiarity with those concepts was rated by twenty parents of the Chinese-English bilingual children. Half the parents rated the English stimuli; the other half rated the Chinese stimuli. The familiarity levels were matched across NR and NN condition within each language. The children's familiarity with the real compound words was also rated by the parents and matched across the RR condition and RN condition within each language. A seven-point rating scale was employed, in which the choices ranged from "very unfamiliar" to "very familiar." Table 2 shows the results of the familiarity rating.

An initial list of 72 items was found in each language, based on their lexicality in the language of testing and the lexicality of the translated compounds—a combination of the translated constituents. Adults rated the items on the relevant factors mentioned above. Based on the result of the rating study, 32 of the 72 items were selected.

Table 2

Average Level of Similarity and Familiarity for Four Conditions

Condition	English		Chinese	
	Similarity	Familiarity	Similarity	Familiarity
RR		5.83		4.59
RN		5.35		4.10
NR	3.99	4.81	3.99	4.66
NN	4.32	5.16	3.80	3.78

Procedure

Each student decided whether or not a word heard from a CD player was real and indicated his/her decision by circling a happy face for a real word or a sad face for a nonword (see Appendix C for test instructions). Whole classes were tested in small groups. Every 3 to 6 children were assigned a tester, who monitored the children's responses to ensure that all the instructions were followed.

Results

Results of the test are displayed in Table 3. The overall pattern of results is illustrated in Figure 5. A two (lexicality in the target language: real words/nonwords) × two (lexicality of the translated compounds in the nontarget language: real words/nonwords) ANOVA was performed on accuracy for each language. In the subject analysis (F_1), both variables were within-subject factors. In the item analysis

(F_2), summing over participants, both variables were between-subject factors. One item, which was 2 *SD*s away from the cell mean, was deleted from the item analysis.

When tested in English, the ANOVA showed a significant effect of interaction in both subject analysis, $F1$ (1, 29) = 32.411, p<.001, and item analysis, $F2$ (1, 27) = 5.343, p=.029. A post-hoc test of the interaction was conducted. Accuracy of the RR condition was higher than that of the RN condition, $t1$ (1, 29) = 6.963, p<.001. The accuracy of the NR condition was lower than that of the NN condition, $t1$ (1, 29) = 2.590, p= .015. The effect of the lexicality of the translated compounds in the nontarget language (Chinese) was marginally significant in subject analysis, $F1$ (1, 29) = 4.456, p=.044, but not in item analysis, $F2$ (1, 27) = 1.318, p=.261. There was no effect of lexicality in the target language (English) either in subject analysis or in item analysis, both *F*s <1.

When tested in Chinese, the ANOVA showed a significant effect of lexicality in the target language (Chinese) in subject analysis, $F1$ (1, 29) = 9.348, p=.005, but not in item analysis, $F2$ (1, 27) = 3.311, p=.08. There was no interaction effect either in subject analysis, $F1$ (1, 29) = 1.946, p=.174, or in item analysis, $F2$ (1, 27) <1, p=.484. The effect of the lexicality of the translated compounds in the nontarget language (English) was not significant either in subject analysis or in item analysis, both *Fs* <1.

Table 3

Mean Accuracies and Standard Deviations (*SD*s) of Lexical Responses

	Target language *M (SD)*			
Nontarget language	English		Chinese	
	Real words	Nonwords	Real words	Nonwords
Real words	.80 (.09)	.68 (.19)	.53 (.19)	.65 (.18)
Nonwords	.61 (.14)	.77 (.21)	.52 (.19)	.70 (.22)

Discussion

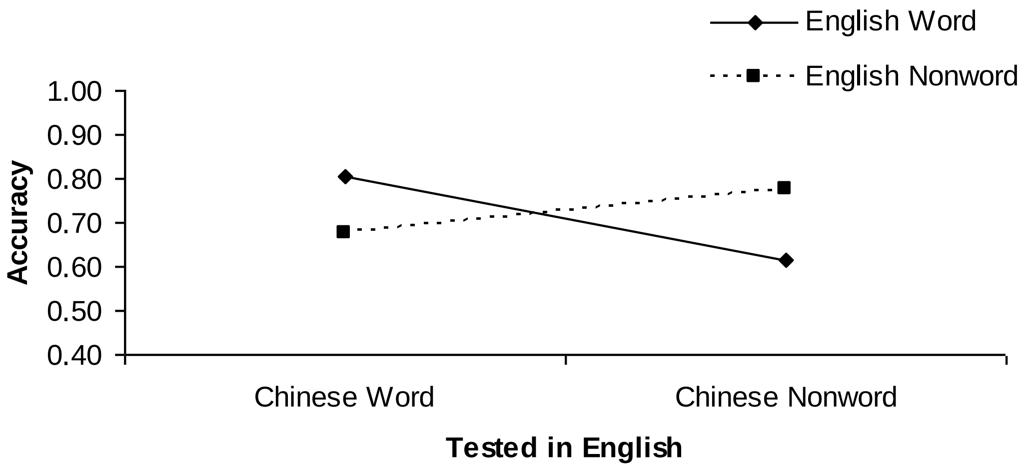
When the test was in English, there was an interaction effect between the lexicality of the compound words in English and the lexicality of the translated compounds in Chinese. That result suggests that the lexicality of the translated compound in L1 (Chinese) affected the lexical decisions in L2 (English). When the lexical status in L1 (Chinese) and L2 (English) were the same, there was a facilitative effect. Accuracy was greater for the RR and NN conditions than for the RN and NR conditions. That result provides evidence of compound decomposition.

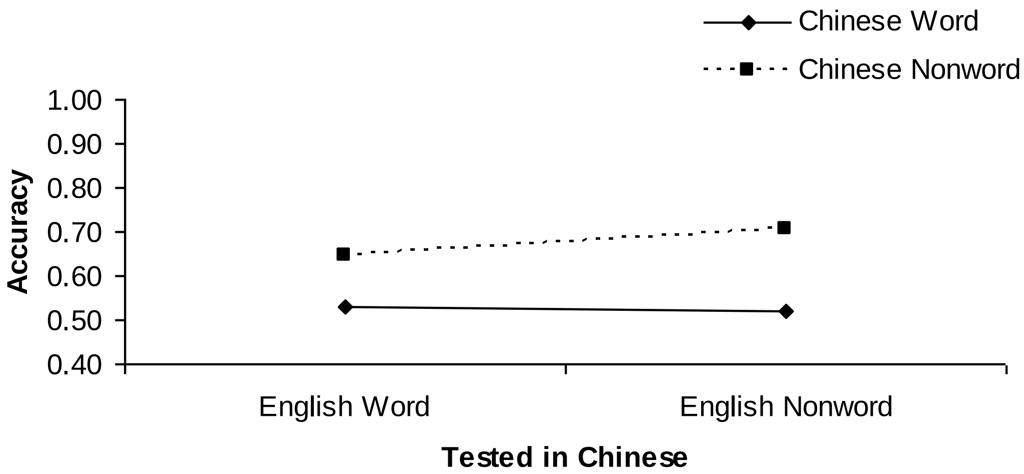
The effect of interaction between lexicality in two languages suggests that when processing a compound in English, the constituents of the compound in English and their translation equivalents in Chinese were activated. Furthermore, the compound of the translated constituents was activated as well. For example, when a child heard the real English compound word, *toothbrush*, he/she decomposed the word into *tooth* and *brush*. Then the Chinese translation equivalents of the two constituents—*牙 (tooth)* and *刷 (brush)* — were activated and recomposed into *牙刷.* Since *牙刷* is a real Chinese word, it helped the child identify *toothbrush* as a real word in English. However, when a child heard the real English compound word, *schoolbook*, the translated compound of which is not a real Chinese word (校书), the contradiction of the lexical status in the two languages confused the child and resulted in a false judgment.

When testing was conducted in Chinese, there was no interaction effect between the lexiality in Chinese and the lexicality of the translated compound in English. That result suggests that the lexicality of the translated compound in L2 (English) has no effect on the lexical decision in L1 (Chinese). Compared to the significant effect from L1 (Chinese) to L2 (English), the lack of effect from L2 (English) to L1 (Chinese)

Figure 5

Mean response accuracies in the lexical-decision task





indicates that there was a stronger effect from L1 to L2 than from L2 to L1. The asymmetry between L1 and L2 supports the revised hierarchical model (RHM; Kroll & Stewart, 1994) and is in line with findings reported in previous studies (e.g., Kroll et al., 2002; Sholl et al., 1995). According to the RHM, there is a strong lexical link from L2 to L1 and a weak lexical link from L1 to L2; therefore, the translated compound in the nontarget language is more likely to be activated when bilingual children hear a compound in L2 (English) than when they hear it in L1 (Chinese).

An alternative explanation of the results could be the differences in the language properties between Chinese and English. As mentioned in the previous sections, Chinese is extremely rich in compound words. Since there are abundant compounds in Chinese, the difference between real word and pseudo word is not always clear. When tested in Chinese, it is extremely difficult for children to make lexical judgments therefore no interaction or main effects were found.

In summary, the findings of this study provided evidence of compound decomposition and cross-language activation in the bilingual compound processing. The difference between L1 and L2 could be explained by the RHM model. There are also several limitations of this study. In this study, I only included semantically transparent words and interpretable pseudo compound words; so I did not address the question of whether semantically opaque words were also decomposed into their translation equivalents during the process. Furthermore, it is not certain whether the cross-language activation occurred at the lexical level or at the semantic level. In the future, these questions will be addressed by adding semantic transparency as an experimental factor.

Chapter IV: Experiment 2

Experiment 1 addressed the question of whether the lexicality of translated compounds in the nontarget language will influence compound processing in the target language. However, as discussed in the literature review, compound processing is affected by some important factors, such as semantic transparency and headedness, which were not manipulated in Experiment 1. Experiment 2 further investigated how bilingual children process compound words in two languages by examining the effects of semantic transparency, which has been shown to be an important factor in compound processing (e.g., Libben, 1998, 2003; Sandra, 1990; Zwitserlood, 1994). Whether the constituents of opaque compounds are activated during compound processing is the central research question of this issue. Given the contradictory results in the literature (e.g., Libben, 1998, 2003; Sandra, 1990; Zwitserlood, 1994), Libben (1994, 1998) suggested that both transparent and opaque compounds were decomposed at the lexical level; however, opaque compounds are not decomposed at the conceptual level. The difference between transparent and opaque compounds can also be used to test models in the bilingual lexicon, which also emphasizes the difference between lexical representations and semantic representations (e.g., Kroll & Stewart, 1994).

Studying the effect of semantic transparency in the bilingual processing of compound words is another approach in examining the predictions of the models of both compound processing and the bilingual lexicon. In Experiment 2, the influences of the nontarget language on the target language were compared between transparent and opaque compounds. According to the decomposition model proposed by Libben (1994, 1998), transparent compounds and opaque compounds are processed differently on the semantic level, compared to the lexical level. Therefore a main effect of transparency is expected. According to the Word Association Model (e.g., Potter et al., 1984), L2 words and L1 words are linked by the translation equivalent at the lexical level. The model predicts no difference between transparent and opaque compounds in terms of cross-language activation. According to the Concept Association Model (e.g., Potter et al., 1984), L2 words and L1 words are linked through a shared conceptual representation at the semantic level. The model predicts that the lexical status of translated compounds has a greater effect on transparent compounds than on opaque compounds, because the constituents of opaque compounds are not activated at the conceptual level. According to RHM (Kroll & Stewart, 1994), the strength of the links between L1 and L2 is altered with the increasing level of L2 proficiency. The model predicts that the asymmetry of links between L1 and L2 lexical representations is more profound for less proficient L2 learners than for proficient bilinguals. In Experiment 2, the differential effect of language proficiency is also investigated.

Hypotheses

Given the effect of semantic transparency in compound processing (e.g., Libben, 1998, 2003; Sandra, 1990; Zwitserlood, 1994), the lexicality of translated compounds will have a greater effect on transparent compounds than on opaque compounds. According to the Revised Hierarchical Model (Kroll & Stewart, 1994), the lexicality of translated compounds will have a greater effect on semantic transparent words than on opaque words for participants with low L2 proficiency. The interaction between the lexicality of translated compounds and semantic transparency would be greater for participants with low L2 proficiency than for participants with balanced language proficiency between L1 and L2.

Method

Participants

The participants were Grade 2 and Grade 3 Chinese immigrant children from the Washington, DC metropolitan area. One hundred and forty-five children completed the experiment. The data for five subjects were deleted because of low response accuracy for fillers. The cut off point was .5, which was the chance level.

The children were divided into four groups, based on their level of language proficiency. A modified version of the Peabody Picture Vocabulary Test-III (PPVT-III; Dunn & Dunn, 1997), which has been used as the index of English proficiency in previous research (e.g., Nicoladis, 2003, 2006), was used as a measure of oral vocabulary. A translated version of the PPVT-III was used to test Chinese language proficiency. Children were divided into four groups, based on their oral vocabulary scores: both low (ELCL), English low, Chinese high (ELCH), English high, Chinese low (EHCL), and both high (EHCH). To sharpen language-proficiency differences among the groups, the participants whose oral vocabulary scores fell into the mid-range of either language were not included in the analyses.

In order to divide the participants into four groups of approximately equal sample size, the cut-off points were based on the distribution of the scores. A child was classified as having low proficiency in one language if his/her oral vocabulary score for that language was lower than .60 and classified as having high proficiency if the oral vocabulary score was higher than .73. As a result, the data for 81 of the 140 children were included for subsequent analyses of variance (ANOVA). Table 4 summarizes the means of English and Chinese oral vocabulary tests for each group. The high-proficiency groups and the low-proficiency groups were statistically different from each other on their scores of the oral vocabulary tests of the corresponding languages. For example, the mean English oral vocabulary scores of the EHCH and EHLH groups were significantly higher than those of the ELCH and ELCL groups (all *p*s < .01).

To further examine whether language proficiency affects children's performance on lexical judgment tasks, in addition to the ANOVA in which language proficiency is a categorical variable, regression analysis was conducted in which the language proficiency was a continuous independent variable. In the regression analysis, the data from 140 children were included.

Table 4

Sample Sizes, Means, and Standard Deviations of English and Chinese Oral Vocabulary Tests for Each Group

		English		Chinese	
Groups	N	Mean	SD	Mean	SD
ELCL	21	0.48	0.11	0.45	0.07
ELCH	20	0.45	0.11	0.79	0.06
EHCL	19	0.82	0.06	0.53	0.07
EHCH	21	0.81	0.06	0.79	0.05

Note. ELCL = English Low and Chinese Low; ELCH = English Low and Chinese High; EHCL = English High and Chinese Low; EHCH = English High and Chinese High.

Design and Materials

A 2 (semantic transparency in the target language: transparent/opaque) × 2 (lexicality of the translated compounds in the nontarget language: real word/nonword) × 4 (language proficiency in L1 and L2: both high; English low, Chinese high; English high, Chinese low; both low) design was employed. Sixteen transparent and 16 opaque compound words in English and Chinese were used as test items. All the compound words contained two free morphemes as constituents, which mapped to the desired translations in the other language.

The combination of the translated constituents formed a translated compound in the nontarget language—either a real word or nonword. The transparent and opaque compounds were divided into two equal-size groups, depending on the lexicality of their translated compounds in the nontarget language (see Table 5 for sample items; see Appendix B for a complete list of the items). Thirty-two compound nonwords in each language were used as fillers. The purpose of the fillers was to make the number of positive responses equal to the number of negative responses.

Table 5

Sample Items of Experiment 2

	Target language			
Nontarget language	English		Chinese	
	Transparent	Opaque	Transparent	Opaque
Real words	***tooth brush*** *(牙 刷)*	***white flag*** *(白 旗)*	***牙 刷*** *(tooth brush)*	***白 旗*** *(white flag)*
Nonwords	***school book*** *(校 书)*	***dead line*** *(死 线)*	***火 山*** *(fire mountain)* [volcano]	***花 生*** *(flower birth)* [peanut]

Note. Boldface denotes test items in the target language. Each Chinese character/English word in parentheses is the translation equivalent of a corresponding constituent at the same position (e.g., *牙* is the translation equivalent of *tooth*. Both words are the first constituents in the compounds.). The meanings of used Chinese compound words are listed in brackets.

Based on the lexical status of the translated compounds, an initial list of items was selected (60 for English and 58 for Chinese). To determine whether bilingual children consider the items as semantically transparent compounds or semantically opaque compounds, two groups of Chinese-English bilingual children rated the items for transparency in Chinese and English. Those children were enrolled in two fourth-grade classes at the same weekend Chinese heritage language school as the participants of this experiment. Sixteen children from one class rated the English items and 12 children from the other class rated the Chinese items. The rating task was performed in groups. The children heard the words from a CD player and rated each compound in terms of the extent to which its meaning was predictable from the meanings of its parts. A four-point rating scale was employed, in which the choices ranged from “very unpredictable” to “very predictable.” To determine the semantic transparency of the two constituents in each compound word, after completing the rating task of the whole compound words, the children were asked to rate each constituent in each compound in terms of the extent to which the underlined constituent morpheme retained its meaning in the compound word. A four-point rating scale was employed, in which the choices ranged from “loses all of its meaning” to “retains all of its meaning.” (See Appendix B for the instructions of the transparency rating.)

Table 6 shows the results of the transparency-rating task. On average, both the constituents had the same transparency status as the whole words. Two or three items in each cell had one constituent whose transparency was slightly different from the whole word. The ratings of those constituents were more than one standard deviation, but less than three standard deviations away from the cell mean. Because of children’s limited vocabulary, it was difficult to find very many compound words whose constituents had the same transparency as the whole word; so, to maintain the sample size, items with uneven transparency were not eliminated from the analyses. To reduce any potential confounding effect, such items were evenly distributed across the different conditions.

One may argue that children’s familiarity with the compound words affects their lexical judgment. Therefore, children’s familiarity with those items was rated by two fourth-grade classes of Chinese-English bilingual children from the same Chinese language school. These children did not participate in the aforementioned transparency rating task. Ten children from one class rated the English items and twenty-one children from the other class rated the Chinese items. Both entire compound words and their constituents were rated in terms of how common or rare the children considered them (see Appendix B for the instructions for familiarity rating). Table 6 shows the results of the familiarity-rating task. Ideally, the familiarity levels would be the same across all four conditions. According to the rating results, familiarity with the four conditions was successfully matched only in English, not in Chinese. To compensate for the failure to control for familiarity, post hoc analyses, with familiarity as a control variable, were conducted.

Based on the rating results of the familiarity and transparency-rating tasks, 32 items were selected for each language. A post hoc survey was conducted to ascertain whether the constituents of the compound words in the target language could be translated into the desired translation in the nontarget language. A group of Chinese-English bilingual adults who reside in the United States translated the constituents of the items from the target language to the nontarget language. Fifteen participants translated from Chinese to English; twelve different participants translated from English to Chinese. Two items from each language were excluded from the analyses, since fewer than 30% of the participants translated the items into the desired translation. For example, the translation of *bottle neck* is *瓶颈*, which is a real word in Chinese. Therefore, *颈* is the desired translation of *neck*. However, *neck* can also be translated as *脖*, which is a synonym of *颈*. Since *颈* is more infrequently used than *脖* in spoken Chinese, most of the participants translated *neck* as *脖* and only 17% of them translated it as *颈*; therefore, *颈* is not the preferred translation of *neck*. Since the

瓶 and 脖 cannot form a real compound word in Chinese, *bottle neck* was excluded from the analyses.

Procedure

Following the same procedure as in Experiment 1, the children judged whether or not the word they heard from a CD player was real. The test of language proficiency was modified for group testing. After hearing a word from the CD player, the children circled a picture that best corresponded to the word (see Appendix C for test instructions).

Table 6

Average Level of Transparency and Familiarity for Four Conditions

Condition	Transparency			Familiarity		
	Whole Word	Constituents 1st	Constituents 2nd	Whole Word	Constituents 1st	Constituents 2nd
English						
Transparent						
Real	3.58	3.30	3.25	1.90	1.10	1.21
Nonword	3.40	3.07	3.33	1.91	1.16	1.15
Opaque						
Real	2.27	2.34	2.21	2.10	1.19	1.21
Nonword	2.44	1.96	2.39	2.13	1.26	1.47
Chinese						
Transparent						
Real	2.98	2.90	2.90	2.69	1.31	1.62
Nonword	3.33	2.85	2.94	2.13	1.28	1.48
Opaque						
Real	2.21	2.64	2.41	3.38	1.24	1.67
Nonword	2.13	2.40	2.48	3.14	1.46	1.48

Results

ANOVA

One item, which was two *SD*s away from the cell mean, was deleted from the analyses in each language. The accuracy of the children's responses is displayed in Table 7. A 2 (semantic transparency in the target language: transparent/opaque) × 2 (lexicality of the translated compounds in the nontarget language: real word/nonword) × 4 (language proficiency groups: both low; English low, Chinese high; English high, Chinese low; and both high) ANOVA was performed on accuracy for each language. In the subject analysis (F_1), semantic transparency and lexicality were within-participant factors, and language proficiency was a between-participant factor. In the item analysis (F_2), the semantic transparency and lexicality were the between-subject factors, and language proficiency was a within-subject factor.

The overall pattern of results is illustrated in Figure 6. When tested in English, the ANOVA showed a significant main effect of transparency F_1 (1, 77) = 224.85, p<.01; F_2 (1, 25) = 7.92, p<.01. On average, children judged transparent items more accurately than opaque items. There was a significant main effect of language proficiency F_1 (3, 77) = 9.54, p< .01; F_2 (3, 75) = 15.46, p < .01. The main effect of lexicality on translated compounds in the nontarget language (Chinese) was significant in the subject analysis F_1 (1, 77) = 27.76, p< .01, but not in the item analysis, F_2 (1, 25) = 1.10, p=.30.

The three-way interaction was not significant, Fs < 1. The two-way interaction between transparency and lexicality and the two-way interaction between lexicality and language proficiency were not significant, Fs <1. The two-way interaction between transparency and language proficiency was marginally significant in the subject analysis, F_1 (3, 77) = 2.63, p = .058, but not in the item analysis, F_2 (3, 75) = 1.45, p = .24.

To further control for the potential effect of familiarity, familiarity was entered as a covariant variable in item analysis. After controlling for familiarity, the main effect of transparency was still significant, F_2 (1, 24) = 20.07, as was the main effect of lexicality F_2 (1, 24) = 4.39, p = .047. The main effect of language proficiency and the interaction between transparency and language proficiency disappeared, *F*s < 1.

When tested in Chinese, the ANOVA showed a significant main effect of transparency F_1 (1, 77) = 138.27, p<.01; F_2 (1, 25) = 12.98, p<.01, and a significant main effect of language proficiency F_1 (3, 77) = 5.99, p < .01; F_2 (3, 75) = 10.80, p < .01. The main effect of lexicality of the translated compounds in the nontarget language (Chinese) was significant in the subject analysis, F_1 (1, 77) = 43.52, p < .01, and was marginally significant in the item analysis, F_2 (1, 25) = 3.94, p=.058.

The three-way interaction was not significant, *F*s < 1. The two-way interaction between transparency and lexicality was not significant, *F*s < 1, neither was the two-way interaction between lexicality and language proficiency, F_1 (3, 77) = 1.48, p = .23; F_2 < 1. The two-way interaction between transparency and language proficiency was significant in the subject analysis, F_1 (3, 77) = 5.23, p <.01, but not in the item analysis, F_2 <1. After controlling for familiarity in the item analysis, the main effects of transparency and lexicality, as well as the interaction between transparency and language proficiency, disappeared, *F*s < 1.

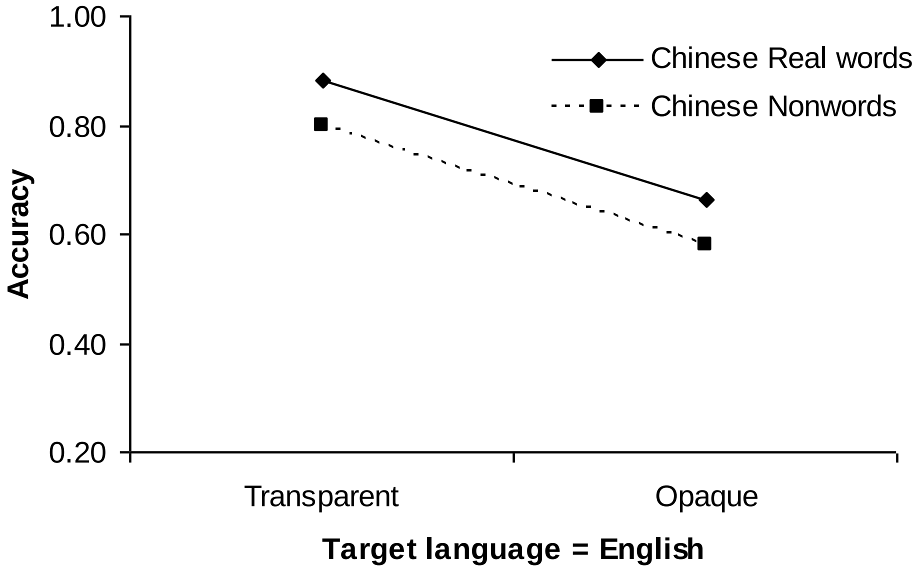
Table 7

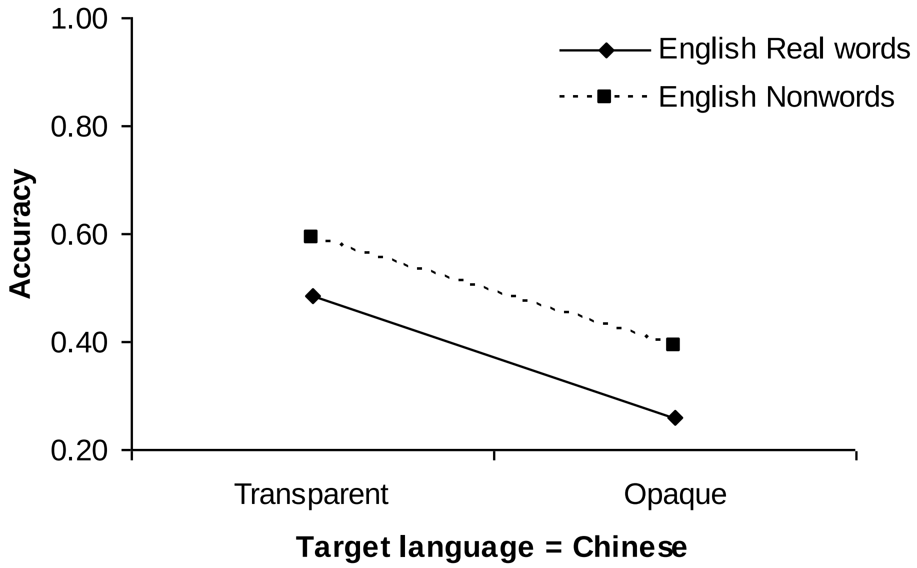
Mean Accuracies and Standard Deviations (*SD*s) of Lexical Response

		Transparent		Opaque	
Language	Group	Real words	Nonwords	Real words	Nonwords
English	ELCL	.82 (.17)	.73 (.20)	.62 (.19)	.51 (.15)
	ELCH	.86 (.13)	.75 (.19)	.55 (.24)	.49 (.14)
	EHCL	.93 (.09)	.88 (.13)	.76 (.18)	.70 (.24)
	EHCH	.91 (.13)	.85 (.10)	.72 (.13)	.63 (.17)
	Total	.88 (.14)	.80 (.17)	.66 (.20)	.58 (.19)
Chinese	ELCL	.38 (.20)	.49 (.20)	.21 (.14)	.35 (.27)
	ELCH	.61 (.17)	.75 (.15)	.30 (.16)	.42 (.16)
	EHCL	.43 (.22)	.49 (.17)	.29 (.22)	.35 (.22)
	EHCH	.52 (.21)	.64 (.21)	.24 (.17)	.44 (.22)
	Total	.49 (.22)	.59 (.21)	.26 (.17)	.39 (.22)

Figure 6

Mean response accuracies of all the subjects in the four language proficiency groups





Regression Analyses

To further examine whether children's performance was related to their language proficiency in the two languages, regression analyses were conducted in which both the test scores of Chinese and English oral vocabulary were independent variables. The accuracies of the lexical decision task in the four conditions were dependent variables in the four separate analyses. A stepwise variable selection procedure was used to identify the significant predictors.

The Chinese oral vocabulary score was not statistically significant in predicting accuracies of the four conditions in the English lexical decision task. The English oral vocabulary score explained a significant amount of variance in all of the conditions in the English lexical decision task (18%, $p < .001$, in transparent real condition; 6%, $p < .01$, in transparent nonword condition; 15%, $p < .001$, in opaque real condition; 18.3%, $p < .001$, in opaque nonword condition). The English oral vocabulary score was not statistically significant in predicting accuracies of the four conditions in the Chinese lexical decision task. The Chinese oral vocabulary score explained a significant amount of variance in making lexical judgments on transparent words (15%, $p < .001$, in transparent real condition; 13%, $p < .001$, in transparent nonword condition). Neither of the two independent variables (i.e., English and Chinese oral vocabulary) reached significance as predictors of accuracies on the Chinese opaque compounds. Since the accuracies of Chinese opaque words were below chance level, it is reasonable to suspect that there was a floor effect. Therefore, it was difficult to detect the potential relationship between oral proficiency and children's performance on Chinese opaque compounds.

Discussion

The purpose of Experiment 2 was twofold: (a) to examine whether semantically opaque words are decomposed, as semantically transparent words are; (b) to test the hypotheses of the RHM model (Kroll & Stewart, 1994) by investigating the influence of language proficiency on the response patterns in L1 and L2. Results from Experiment 2 demonstrated that the mean response accuracy for transparent compounds was higher than that for opaque compounds. Further, the lexicality of translated compounds in the non-target language affected response accuracy on both transparent words and opaque words in the target language. However, there was no interaction between semantic transparency and the lexicality of translated compounds. Response patterns were the same for groups with different levels of language proficiency. These results have implications for the models of both compound processing and bilingual lexicon.

Compound Decomposition

The results provided evidence to support compound decomposition. First, as expected, based on previous findings (e.g. Libben et al., 2003; Sandra 1994; Zwitserlood, 1994), children were more accurate when judging semantically transparent words in both languages. The main effect of semantic transparency remained significant after controlling for familiarity; that fact helped exclude the confounding effect of familiarity. The difference between transparent words and opaque words was whether the meanings of the constituent morphemes contributed to the meaning of the whole compound. When considered as whole compound words, transparent words and opaque words were the same in terms of familiarity. If both transparent words and opaque words were processed as whole words and were not decomposed into their constituent morphemes, response accuracy for the transparent words should be the same as that of opaque words.

The transparency effect also suggests that the semantic representations of the compounds are activated when children make lexical judgments. The lexical-decision task itself did not require the activation of semantic representations. The task required participants only to judge whether or not a word was real. Participants can base their decisions on the lexical form or the semantic form or both. Since transparent compounds and opaque compounds differ only in semantic level, the transparency effect found in this experiment suggests that the semantic information on the constituent morphemes is automatically activated in a lexical-decision task.

Although the transparency effect provided evidence of compound decomposition for semantically transparent words, it was uncertain whether semantically opaque words were also decomposed. There are two possible interpretations. The first is that opaque compound words were not decomposed into their constituents, but were, rather, processed as whole words (e.g., Sandra, 1990). The second interpretation is that both opaque compounds and transparent compounds were decomposed at the lexical level, but opinions differ on whether their constituents were activated at the semantic level (Libben, 1998).

According to the first interpretation, opaque compounds were processed as whole words, and their constituent morphemes were not activated at all. That interpretation could be excluded by the lexicality effect found in this study. Response accuracy for both transparent compounds and opaque compounds was affected by the lexicality of the translated compounds in the nontarget language. As discussed in Experiment 1, cross-language effects of the translated compounds indicated that both the constituent morphemes and their translation equivalents in the nontarget language were activated.

Therefore, the finding that both opaque compounds and transparent compounds were decomposed into their constituent morphemes is not consistent with the first interpretation.

According to the second interpretation, the constituent morphemes of transparent words were activated at both the semantic level and the lexical level, but the constituent morphemes of opaque words were activated at only the lexical level (Libben, 1998). That interpretation could explain both the lexicality effects and the transparency effects in Experiment 2. Since both transparent words and opaque words were decomposed at the lexical level, both were affected by the lexicality of the translated compounds. Since only the semantic representations of the transparent constituents were activated, the accuracy of lexical judgments for transparent compounds was higher than that for opaque compounds. However, there is another question that remains to be answered, that is how the semantic representations of the constituents were activated when L2 was the target language. That question is addressed in the following section.

Cross-language Activation

The surprising aspect of the results was the lack of interaction between semantic transparency and lexicality. There was no difference between transparent compounds and opaque compounds in terms of cross-language activation, although the processing of transparent compounds and opaque compounds is different. The interpretation of the results could be based on the models of both compound processing and the bilingual lexicon. As discussed in the prior section, the findings are in line with the compound-processing model proposed by Libben (1998). According to that model, both transparent compounds and opaque compounds are decomposed at the lexical level, but at the semantic level, only the constituents of transparent compounds are activated. In L1, the semantic representations could be activated directly. However, not all researchers yet agree about how semantic representations are activated when the target language is L2. The concept association model, the word association model (Potter et al., 1984), and the revised hierarchical model (Kroll & Stewart, 1994) have different implications concerning this question.

According to the concept association model, L1 words and L2 words are associated via the shared semantic representations. In other words, when a bilingual speaker hears a word in L2, he/she could access its meaning directly. Moreover, the translation equivalent of the word in L1 could not be accessed without activating the semantic representation. Since only the constituents of transparent compounds would be activated at the semantic level, the model would predict a greater cross-language effect for transparent compounds than for opaque compounds. For example, when a child hears the transparent compound *toothbrush* and the opaque compound *white flag*, both compounds are decomposed at the lexical level. At the semantic level, the meanings of *tooth* and *brush* will be activated, but the meanings of *white* and *flag* will not. The translation equivalents of *tooth (牙)* and *brush (刷)* in L1 are activated and recombined into a real Chinese word *牙刷*. On the contrary, the translation equivalents of *white (白)* and *flag (旗)* are not activated, since the meanings of *white* and *flag* are not activated. Therefore, the lexicality of translated compounds should have a greater effect on transparent compounds than on opaque compounds. However, results from the present experiment revealed a similar magnitude of cross-language activation for both transparent compounds and opaque compounds.

I argue that these results somewhat support the word association model and the revised hierarchical model. According to the former, L2 words and L1 words are linked at the lexical level, but not at the semantic level. Both the transparent compounds and opaque compounds are decomposed at the lexical level; therefore, in line with the present findings, the model would predict that transparent compounds and opaque compounds would not differ in terms of cross-language activation. For example, both the transparent compound *toothbrush* and the opaque compound *white flag* are decomposed at the lexical level. Not only the translation equivalents of *tooth (牙)* and *brush (刷)*, but also those of *white (白)* and *flag (旗)*, are activated in L1 and recombined into real Chinese words *牙刷* and *白旗*. Therefore, the lexicality of translated compounds would have similar effects on transparent compounds and opaque compounds. Once the translation equivalents of *tooth (牙)* and *brush (刷)* are activated, their meanings are activated at the semantic level. On the contrary, the meanings of *white (白)* and *flag (旗)* may not be activated, since their meanings do not help children understand the meaning of the compound *white flag*. Therefore, the accuracy of children's response to transparent compounds was higher than to opaque compounds. These results also support the RHM, which recognizes the linkage between L1 and L2 words at the lexical level for beginning learners of L2.

The RHM differs from the word association model in two respects. First, the RHM emphasizes the asymmetry between L1 and L2. In RHM, the link from L2 to L1 is stronger than the link from L1 to L2. Second, the RHM emphasizes the role of L2 proficiency in the bilingual lexicon. For learners with low L2 proficiency, the L1 words and L2 words are linked at the lexical level. For learners with a more-balanced language proficiency between L1 and L2, the L1 words and L2 words could be linked at both the lexical level and the semantic level. I addressed those hypotheses in this experiment.

In Experiment 2, children were tested in both English (L2) and Chinese (L1). Although the pattern of results was similar for the two languages, the results for

English were more robust than those for Chinese. In English, the main effects of transparency and lexicality were held to be significant after controlling for the effect of familiarity. However, in the Chinese tests, the main effects of transparency and lexicality disappeared after controlling for familiarity. These results suggest that the observed cross-language effect from English (L2) to Chinese (L1) might be because of the differences in familiarity with the items across the conditions. Therefore, the cross-language effect might be stronger from L1 to L2 than visa versa. Children are more likely to use their knowledge in L1 when judging the lexicality of a word in L2. If so, the results would support the RHM, which hypothesizes a strong link from L2 words to L1 words and a weak link from L1 words to L2 words. When a child hears a word in English (L2), the translation equivalent in Chinese (L1) is easily activated because of the strong link from L2 to L1. On the contrary, when he/she hears a word in Chinese (L1), the translation equivalent in English (L2) may not be activated because of the weak link from L1 to L2.

To test the other hypothesis of RHM, I also investigated the effect of language proficiency. Contrary to the prediction of RHM, language proficiency did not affect the way bilingual children process compound words in either L1 or L2. Neither the three-way interaction among the three factors nor the two-way interaction between language proficiency and lexicality was significant. Only a main effect of language proficiency and interaction between language proficiency and transparency in both languages were found. In addition, after controlling for the effect of familiarity, the interaction between transparency and language proficiency became insignificant, and the main effect of language proficiency disappeared in English. These results suggest that more-proficient children were better in making lexical judgments than less-proficient children in Chinese. However, the lexicality of ttranslated compounds in the non-target language did not differentially affect children with different levels of language proficiency in either Chinese or English.

Results of the regression analyses further supported those of the ANOVA. Only language proficiency in the target language contributed to children's performance in the target language. Language proficiency in the nontarget language did not make a significant cross-language contribution. Language proficiency in the target language has similar influences on children's performance in the four conditions, except Chinese opaque words (Given the low accuracies of the Chinese opaque compounds, the floor effect might be the reason why Chinese language proficiency was not a significant predictor of the lexical judgments of Chinese opaque compounds.) Therefore, I suggest that the predictive power of language proficiency was independent of the semantic transparency or lexical status of the translated compounds.

Previous studies have provided controversial results with respect to the role of language proficiency in bilingual lexical processing. Some studies have provided evidence for RHM by showing that sensitivity to the meaning of L2 words developed with increasing proficiency in the L2 (e.g., Kroll et al., 2002; Kroll & Stewart, 1994). Some studies have suggested that less- and more-proficient L2 learners are equally sensitive to the meaning of L2 words (e.g., Sunderman & Kroll, 2006). The results of the present study showed that all groups of different language-proficiency levels relied on the translation equivalents in L1 to access the meanings of L2 words. Moreover, response patterns were similar across proficiency groups. One possible explanation of the discrepancy between the results obtained by the present study and previous studies comes from the fact that the participants in the present study are different from those in the previous studies. The results of previous studies come form adult learners of L2 instead of bilingual children. Contrary to the adult L2 learners who had mastered their L1 when they began to learn L2, the bilingual children were learning L2 before they mastered their L1. Although Chinese could be considered their L1, as the language they learned at home before they were introduced to English, English became their dominant language once they entered elementary school. In addition, children might be less sensitive than adults to conceptual information, since their conceptual representations were still developing in both L1 and L2. In future research, adult bilingual learners could be examined to determine whether the results of the present study could be generalized to an adult bilingual population. Also, in the present study, the selection of items was limited because children have limited vocabularies. Using adults participants could help us overcome those limitations.

In summary, the results of Experiment 2 supported the compound-processing model (Libben, 1998) and partially supported the RHM (Kroll & Stewart, 1994). Both transparent compounds and opaque compounds were decomposed into their constituent morphemes at the lexical level. The translation equivalents of both transparent and opaque constituents were activated in L1 at the lexical level. The semantic representations of transparent constituents were activated via their translation equivalents in L1. As hypothesized by the RHM, there was a greater cross-language effect from L1 to L2 than from L2 to L1. However, contrary to the RHM hypothesis, the response patterns did not change as language proficiency increased in L2.

Chapter V: Experiment 3

It is well documented in the literature that phonological awareness is important in learning to read (e.g., Badian, 1998; de Jong & van der Leij, 2002; see also Ehri et al., 2001, for a review). Relatively less is known about the contribution of morphological awareness. To fill the gap in the literature, Wang et al. (2006) investigated the contribution of phonological awareness and morphological awareness in Chinese-English bilingual children's reading acquisition. Results of this study provided evidence to support the importance of morphological awareness in reading across languages. In Experiment 3, I further examined the role of compound awareness in Chinese-English bilingual children's reading acquisition with two improvements.

First, the task used by Wang et al. (2006) concentrated on one aspect of compound awareness—the structure of the compounds. However, children need other types of skills to understand and process compound words correctly. In Experiment 3, in addition to the awareness of the compound structure, a new task was employed to test another aspect of compound awareness — children's sensitivity to the meanings of constituent morphemes in compound word. This task is similar to the homophone identification tasks that have been shown to be good predictors of reading skills in Chinese monolingual children (e.g., McBride-Chang et al., 2003; Shu et al., 2006).

Secondly, Wang et al. (2006) found that compound awareness in English made a unique contribution to Chinese reading comprehension, but the contribution of compound awareness in Chinese was not significant. The English tasks included both two-morpheme and three-morpheme compounds, while the Chinese tasks included only two-morpheme compounds. The observed language effects were confounded by differences in the two tasks. In Experiment 3, the Chinese compound structure task was modified to make it more comparable to the English task.

Hypotheses

Wang et al. (2006) was the only study that investigated the role of compound awareness in Chinese-English bilingual children is learning. Based on the results of that study, I hypothesize that compound awareness in one language is correlated with compound awareness in the other language; that compound awareness, beyond phonological awareness, contributes to reading skills in both Chinese and English; and that compound awareness in one language contributes to reading skills in the other language, over and above within-language predictors.

Method

Participants

One hundred and forty-five children participated in this study. Five children were absent from more than three test sessions (i.e., more than 40% of the tests); data for those five cases were excluded from the analysis. In addition, ten participants missing fewer than 30% of the tests because they were absent from one or two testing sessions. Pairwise deletion was employed to keep as much of the data as possible. Ultimately, data from 140 participants were used. When computing the bi-variate correlations between two tests, if a child had no values for one or both tests, the child's data were not used. Therefore, the degree of the freedom for a particular correlation coefficient was based upon the actual number of participants included in the calculation.

The participants were Chinese immigrant children from the Washington, DC metropolitan area. They simultaneously attend English classes in public schools during the week and Chinese weekend schools, two of the Hope Chinese School campuses in the vicinity. The participants were recruited from Grade 2 (n=91, mean age: 7.97 years, SD=.74) and Grade 3 (n=49, mean age: 8.79 years, SD=.69) Chinese classes. They were also enrolled in Grade 1 to Grade 4 English classes (19 from

Grade 1; 61 from Grade 2; 44 from Grade 3; 16 from Grade 4), and the mean grade of their English classes was 2.41 (SD=.86). The mean age of the participants was 8.26 years (SD=.82 years).

The teacher in the Chinese school distributed to the parents a short questionnaire requesting basic demographic information and family language and literacy experiences. Approximately 61% of the parents returned the questionnaire. Almost 90% of the children were born in the United States, 7% in China, and the balance in other countries. Most of the children (78%) learned Chinese first; some (18%) learned English first; and others (4%) learned the two languages simultaneously. Most (89%) spoke both Chinese and English at home, 8% spoke only English at home, and 3% spoke only Chinese at home. On average, they spoke English 60% of the time and Chinese 40% of the time. About 77% of the parents spoke both Chinese and English at home, and 23% of the parents spoke only Chinese at home. On average, they spoke English 23% of the time and Chinese 77% of the time. About 72% of the families engaged in Chinese literacy activities at home, and 96% of the parents believed that learning Chinese was important for the children.

Measures

Most of the tasks listed below were adopted from Wang et al. (2006). A new task for compound awareness was added to both the Chinese and English measures. The scores from the lexical-decision task in Experiment 2 were converted to test scores and served as a measure of compound awareness, allowing the researcher to examine whether children's judgments on transparent and opaque compounds contributed to their reading achievement. The tasks for Chinese compound awareness, character naming, and oral vocabulary were modified (See Appendix D).

English Measures

Lexical-decision task for transparent and opaque compounds. The data for this task were borrowed from Experiment 2. The children judged whether or not the words they heard from a CD player were real. Although the task was not designed as a test of compound awareness, it could tap into children's ability to identify and reflect on compound words. The items contained both transparent and opaque compounds. When making a lexical judgment on an unfamiliar transparent word, a child had greater chance of judging the word as real if he/she understood that the meaning of the compound word was related to its constituents. When making a lexical judgment on opaque words, a child could judge them as a nonword if the child found that the meanings of the constituents were not related to the meaning of the whole word. Since a child's processing of transparent compounds and opaque compounds might be different, the accuracy of transparent compounds and opaque compounds was calculated separately.

Compound-structure task. This task assessed children's understanding that a compound word is made up of a modifier and a head, which is always the right-end constituent in English. The task had three parts. In the first two parts, the child was given a riddle and two choices. The child was to choose the better answer. For example, "Which is a better name for a bee that lives in the grass: grass bee, or bee grass?" In the third part, the child was to choose the best compound word from among four choices, each consisting of three to four morphemes. For example, "If you found a lid for a dish to keep candy in, what would it be called: dish lid candy, candy dish lid, dish candy lid, or candy lid dish?" To exclude the potential influence of memory load on children's performance, the children both heard the oral stimuli over a CD player and read the items which were printed on their test book.

Polyseme- identification task. A polyseme is a word with multiple meanings. For example, *ball* has different meanings in *baseball* and *ballroom*. Although *ball* in these two words originated from different words, their lexical forms are same nowadays. Since the likelihood that children would have the knowledge about the origins of these words is very slim, it is reasonable to assume that the origins of the words would have no effect on children's responses. This task assessed children's ability to differentiate the meanings of polysemous morphemes in compound words. The form of the task was similar to the morpheme-judgment task used by Shu et al. (2006), but the items were different. In the current task, a child was orally presented with two 2-morpheme compound words. Each word had a common morpheme. In half the items, the common morpheme had the same meaning in both words (e.g., *candy bar* and *chocolate bar*), and in the other half it had a different meaning (e.g., *candy bar* and *bar tender*). The child was to decide whether the common morpheme in each pair of words had the same or a different meaning. To control the potential effect of the position of the morpheme, in half of the 18 presented items, the common morpheme was at the same position in the two compounds (e.g., *candy bar and coffee bar*), and in the other half, it was at a different position in the two compounds (e.g., *bar tender and coffee bar*).

Phoneme-deletion task. The phoneme-deletion task has been shown to be a good predictor of reading skill in English (e.g., Stanovich, Cunningham, & Cramer, 1984). From a CD player, children heard a nonword, then they were asked how the word would be pronounced without a certain sound, and then given three choices. Each choice was numbered, either 1, 2 or 3, for their answer sheets. Each child's task was to circle the best answer. For example, "*mab*; how would *mab* sound without /b/: /ab/, /mab/ or /ma/?"

Oral vocabulary. The Peabody Picture Vocabulary Test-III (PPVT-III) was adapted as a measure of receptive vocabulary. The test was modified so that it could be administered to groups of children. Thirty items were selected that were appropriate for age groups in the current study. Children heard a word from a CD player, and then they circled the best picture for each word.

Real-word naming. In this task, children were instructed to read the word shown on a card. The words were adopted from the word recognition subtest of the Wide Range Achievement Test-Revised (WRAT-R; Jastak & Jastak, 1984). The children's responses were recorded by a digital voice recorder. Half the data were coded by the author the dissertation and the other half were coded by a native English speaker. There were 35 items in all. For each item, a totally accurate pronunciation received 1 point. To calculate inter-rater reliability, the data for 20 participants were randomly selected and coded by both raters. The inter-rater reliability was .98.

Reading comprehension. Four paragraphs from the reading subset of the Wide Range Achievement Test-Expanded Edition (WRAT-E; Robertson, 2001) were selected to test participants' reading comprehension. The children read the paragraphs and answer 18 multiple-choice questions about the passages.

Chinese Measures

Lexical-decision task for transparent compounds and opaque compounds. The data for this task were also borrowed from the lexical-decision task in Experiment 2. The accuracies of lexical judgments on transparent compounds and opaque compounds were calculated as indicators of children's ability to identify and reflect on transparent and opaque compounds.

Compound-structure task. This task was adopted from Wang et al. (2006) and modified to make it parallel to the English compound-structure task. There were two subgroups in this task. Nonwords were used in this task. The nonword compounds were made up of free morphemes that could stand alone as words. In the first subgroup, the child was asked to choose the better two-morpheme compound to answer a question. For example, "长得像马的羊叫什么更好呢？马羊还是羊马？" (Which is a better name for a sheep that looks like a horse: horse sheep, or sheep horse?) In the second subgroup, the child's task was to choose the best three-morpheme compound name for a short description among four choices. For example, "这里有一棵树，上面有一只会吃虫子的鸟，应该叫它什么呢？鸟虫树？虫鸟树？树鸟虫？还是虫树鸟？" (There is a tree with a bird that can eat bugs, what would it be called: bird bug tree, bug bird tree, tree bird bug, or bug tree bird?)

Polyseme-identification task. This task was comparable to the English polyseme-identification task. The child was presented with a pair of two-morpheme words, which shared a common polysemous morpheme. The child was asked to judge whether the common morpheme in each of 18 pairs of words had the same or a different meaning. For example, *草(cao3)* means *grass* in both *草地* (cao3di4, meadow) and *水草* (shui3cao3, float grass), but it has a different meanings in *草地* (cao3di4, meadow) and *草图* (cao3tu2, sketch), it means *grass* in the first word and *rough* in the second word. To control for the effect of the position of the common morpheme, it was at one position for half the items and at a different position for the other half.

Onset, rime, and tone oddity. Chinese syllables can be analyzed by onset, rime, and tone. Onset is the initial consonant in a syllable. Rime is composed of a vowel or a vowel plus a final consonant. Tone is a suprasegmental unit in a syllable and it is attached to the rime. Tone has a lexical function as well—syllables with the same segment but different tones have different meanings. For example, the only difference between the syllable *man3* and *man4* is the tone; the first one corresponds to 满 which means *full*, and the second one corresponds to 慢 which means *slow*. This task was to tap into children's ability to differentiate the phonological units—onset, rime and tone—in syllables. From a CD player, the children heard three syllables. The children's task was to choose the syllable that did not share any of the qualities—onset, rime or tone—with the other two syllables. There were 30 items, 10 in each condition. One practice item was given for each condition.

Oral vocabulary. Thirty items were selected and translated from the PPVT-III (Dunn & Dunn, 1997). There was no overlap of Chinese and English vocabulary test items. The children circled the best picture for the given word.

Character- and real-word naming. This task consisted of 25 characters and 15 two-character words. As in the English task, the children read the characters or words shown on cards. The two-character words were selected from the textbook used in the Chinese language school. Teachers had rated a list of two-character words in terms of how familiar they were to the children. A five-point rating scale was employed, in which the choices ranged from *very unfamiliar* to *very familiar*. To ensure that the children were familiar with the words, the ratings for all of the selected items were above 2 points. The average level of familiarity was 3.93 points. Children's responses were recoded via a digital voice recorder and were scored by a native Chinese speaker. Another native Chinese speaker coded the data of 20 subjects that were randomly selected. The inter-rater reliability was .99. A fully accurate pronunciation of a test item earned one point.

Reading comprehension. The task consisted of two parts: sentence comprehension and paragraph comprehension. Six sentences and three paragraphs were selected and translated from the reading comprehension subtest of the WRAT-E (Robertson, 2001).

In the sentence comprehension section, the children chose the most appropriate picture for a given sentence. In the paragraph comprehension part, the children read the paragraphs and answered multiple-choice questions about each paragraph. Some unfamiliar characters were included in the items. To ensure that the children's responses reflected comprehension rather than their recognition ability and to facilitate their recognition, the unfamiliar characters were marked with pinyin, an alphabetic, phonetic transcription system used to help children learn to read Chinese characters.

Procedure

English-word and Chinese-character reading tasks were administered individually. The other tasks were administered in groups when the children were attended the weekend Chinese schools. Testing was conducted over five 20-30 minute sessions. There was a one-week interval between sessions. Each session included two or three tasks. The order of sessions and the order of tasks within each session were counterbalanced among the groups.

Results

Table 8 shows the reliability, means, and standard deviations for each task. The reliability for most of the measures was greater than .40, except the English polyseme-identification task, which had a reliability of .38. After four unacceptable items were deleted, the reliability of the task increased to .52. Independent sample *t* tests revealed that the third graders were significantly better than second graders on four tasks: English lexical decision for transparent compounds ($p < .05$), English vocabulary ($p = .01$), English comprehension ($p < .01$), and Chinese rime ($p < .05$). Since the focus of the present study was cross-language transfer, the data from the two grades were pooled together to increase the sample size in analyses.

Correlations among All of the Variables

The simple correlations among all the Chinese and English tasks, including age, are shown in the lower triangle of Table 9. The partial correlations controlling for age are shown in the upper triangle of Table 9. The simple correlations and the partial correlations showed similar patterns of relations among the variables.

Among the English tasks, oral vocabulary was correlated with all the other English tasks (all *p*s $< .01$). English phoneme deletion was correlated with compound-structure awareness ($r = .43$, $p < .01$) and polyseme identification ($r = .20$, $p < .05$). All the compound-awareness tasks in English were correlated with each other (all *p*s $< .01$). Both the English phoneme-deletion and compound tasks were correlated with real-word naming and reading comprehension (all *p*s $< .01$; except for the correlation between lexical decision of opaque compounds and reading comprehension, $r = .17$, $p < .05$).

Among the Chinese tasks, oral vocabulary was correlated with the lexical decisions on transparent compounds ($r = .41$, $p < .01$), compound structure ($r = .24$, $p < .01$), and polyseme identification ($r = .42$, $p < .01$), as well as real word naming ($r = .37$, $p < .01$), and reading comprehension ($r = .17$, $p < .05$). Chinese phonological awareness tasks were correlated with compound structure awareness (all *p*s $< .01$). Lexical decisions on transparent compounds and opaque compounds were not correlated with any other variables. Compound-structure awareness and polyseme identification were correlated with each other ($r = .35$, $p < .01$). Chinese real-word naming was correlated with all other variables (all *p*s $< .01$) except the lexical-decision tasks on transparent compounds and opaque compounds. Chinese-reading comprehension was correlated with oral vocabulary ($r = .17$, $p < .05$), rime oddity (*r*

= .27, *p* <.01), tone oddity (*r* = .27, *p* <.01), and compound-structural awareness (*r* = .43, *p* <.01).

For cross-language correlations, English phoneme deletion was correlated with the three Chinese phonological awareness tasks—onset, rime and tone awareness (*r* = .35, .48 and .29 respectively, all *p*s <.01). English lexical decision on transparent compounds was correlated with Chinese lexical decision on transparent (*r* = .23, *p* <.01) and opaque compounds (*r* = .34, *p* <.01). English lexical decision on opaque compounds was correlated with Chinese lexical decision on opaque compounds (*r* = .20, *p* <.05). English compound-structure awareness, and polyseme identification were correlated with Chinese compound-structure awareness and polyseme identification (all *p*s <.01). English phoneme deletion, compound-structure awareness, and polyseme identification were correlated with both Chinese real-word naming (*r* = .42, .47 and .23 respectively, all *p*s <.01) and reading comprehension (*r* = .22, *p* <.05 for English phoneme deletion; *r* = .33, *p* <.01 for English compound structure and *r* = .28, *p* <.01 for English polyseme identification). Chinese phonological awareness tasks were correlated with both English real-word naming (*r* = .20, *p* < .05 for onset; *r* =.43, *p* < .01 fro rime and *r* =.34, *p* < .01 for tone) and reading comprehension (*r* = .25, *p* < .01 for onset; *r* = .44, *p* < .01 fro rime and *r* =.19, *p* < .05 for tone). Chinese compound structure awareness, and polyseme identification were correlated with both English real-word naming (*r* = .31, *p* < .01 for compound structure awareness and *r* = .18, *p* < .05 for polyseme identification) and reading comprehension (*r* = .25, *p* < .01 for compound structure awareness and *r* = .26, *p* < .01 for polyseme identification). Finally, Chinese real-word naming and reading comprehension were correlated with English-real word naming and reading comprehension (all *ps* < .01).

Table 8

Reliability, Means, and Standard Deviations of All the Measures for Children in Grade 2 and Grade 3

Tasks	Reliability (alpha)	Grade2 N	Grade2 Mean	Grade2 SD	Grade3 N	Grade3 Mean	Grade3 SD
English tasks							
Oral vocabulary	0.81	88	0.58	0.17	49	0.71	0.13
Phoneme deletion	0.71	88	0.80	0.18	49	0.82	0.14
Lexical decision transparent	0.54	88	0.82	0.13	49	0.87	0.09
Lexical decision opaque	0.56	88	0.59	0.15	49	0.71	0.13
Compound structure	0.81	87	0.71	0.17	49	0.75	0.18
Polyseme identification	0.52	88	0.66	0.17	49	0.76	0.14
Real-word naming	0.85	91	0.57	0.13	48	0.66	0.11
Reading comprehension	0.65	91	0.73	0.17	48	0.79	0.11
Chinese tasks							
Oral vocabulary	0.68	89	0.65	0.13	48	0.65	0.15
Onset oddity	0.69	91	0.77	0.19	49	0.79	0.16
Rime oddity	0.79	91	0.90	0.18	49	0.94	0.13
Tone oddity	0.68	90	0.60	0.23	49	0.71	0.24
Lexical decision transparent	0.63	90	0.55	0.18	48	0.53	0.20
Lexical decision opaque	0.45	90	0.31	0.15	48	0.34	0.16
Compound structure	0.62	90	0.57	0.16	49	0.63	0.16
Polyseme identification	0.53	89	0.62	0.17	48	0.63	0.13
Real-word naming	0.95	91	0.57	0.25	48	0.68	0.25
Reading comprehension	0.68	90	0.39	0.18	48	0.50	0.18

Table 9

Correlations among Age, Chinese tasks, and English Tasks

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
English tasks																		
1. Oral vocabulary	--	.29**	.24**	.38**	.59**	.48**	.47**	.46**	.06	.26**	.20*	.17*	-.19*	-.04	.17*	.18*	.08	.21*
2. Phoneme deletion	.27**	--	.15	.15	.43**	.20*	.44**	.40**	.15	.35**	.48**	.29**	-.11	.05	.25**	.29**	.42**	.21*
3. Transparent compounds	.39**	.15	--	.54**	.33**	.17	.16	.17*	.09	.19*	.07	-.05	.18*	.29**	.11	.09	.13	.04
4. Opaque compounds	.46**	.16	.58**	--	.28**	.25**	.30**	.11	-.09	.18*	.16	.13	.02	.15	.02	-.02	.11	-.01
5. Compound structure	.59**	.43**	.37**	.32**	--	.36**	.53**	.45**	.22*	.43**	.39**	.30**	-.03	.05	.44**	.28**	.48**	.31**
6. Polyseme identification	.56**	.20*	.27**	.33**	.39**	--	.42**	.32**	.07	.19*	.21*	.27**	-.12	.05	.21*	.35**	.25**	.25**
7. Real-word naming	.59**	.41**	.31**	.39**	.55**	.51**	--	.47**	.01	.18*	.40**	.27**	-.18*	.04	.27**	.24**	.35**	.25**
8. Reading comprehension	.51**	.39**	.25**	.17*	.48**	.38**	.52**	--	.07	.24**	.42**	.14	-.23**	-.05	.22**	.29**	.35**	.36**
Chinese tasks																		
9. Oral vocabulary	-.01	.14	.03	-.12	.19*	.02	-.05	.04	--	.10	.15	.17*	.44**	.07	.27**	.42**	.37**	.19*
10. Onset oddity	.27**	.35**	.20*	.20*	.44**	.21*	.20*	.25**	.09	--	.50**	.10	.08	.01	.24**	.15	.22**	.13
11. Rime oddity	.25**	.48**	.13	.20*	.41**	.25**	.43**	.44**	.12	.51**	--	.21*	-.05	.06	.26**	.14	.34**	.25**
12. Tone oddity	.26**	.29**	.05	.19*	.33**	.33**	.34**	.19*	.14	.12	.24**	--	.01	-.01	.35**	.20*	.36**	.25**
13. Transparent compounds	-.07	-.10	.23**	.07	.00	-.05	-.07	-.17*	.41**	.10	-.01	.06	--	.40**	.04	.11	.10	-.14
14. Opaque compounds	.07	.06	.34**	.20*	.08	.12	.13	.00	.04	.03	.09	.04	.43**	--	-.08	.00	-.05	-.18*
15. Compound structure	.23**	.26**	.16	.07	.45**	.25**	.31**	.25**	.24**	.25**	.28**	.38**	.06	-.05	--	.36**	.59**	.42**
16. Polyseme identification	.12	.28**	.06	-.03	.26**	.31**	.18*	.26**	.42**	.15	.13	.18*	.09	-.02	.35**	--	.31**	.17*
17. Real-word naming	.06	.42**	.11	.10	.47**	.23**	.30**	.34**	.37**	.22**	.34**	.35**	.10	-.05	.58**	.31**	--	.58**
18. Reading comprehension	.25**	.22*	.09	.03	.33**	.28**	.28**	.38**	.17*	.14	.27**	.27**	-.11	-.14	.43**	.16	.57**	--

* $p < .05$. ** $p < .01$.

Modeling Relations among Chinese and English Tasks

Prior to the modeling work, univariate and multivariate normality were assessed by examining the univariate skewness and univariate kurtosis. The distribution of several observed variables was moderately non-normal (English lexical decision on transparent compounds, skewness = -0.89, kurtosis = 1.01; English phoneme deletion, skewness = 1.20, kurtosis = 1.89; English compound structure, skewness = -0.96, kurtosis = 1.40; Chinese onset oddity, skewness = -1.82, kurtosis = 2.78). Only the distribution of the Chinese rime-oddity test was severely non-normal (skew>2, kurtosis>4). An inspection of the distribution indicated that 65% of the children correctly answered all the items and 15% of the children correctly answered 90% of the items. Given the ceiling effect of this task, it was excluded from the analysis. Since the distributions for the other tasks were only moderately non-normal, the maximum likelihood (ML) method was used. Although this method requires normally distributed data, it has been shown to be quiet robust to the violation of normality (e.g., Chou & Bentler, 1995; Curran, West, & Finch, 1996). To control for the potential influence of age, a partial correlation matrix controlling for age was used in the analysis.

Confirmatory Factor Analysis (CFA) on Measurements of Compound Awareness

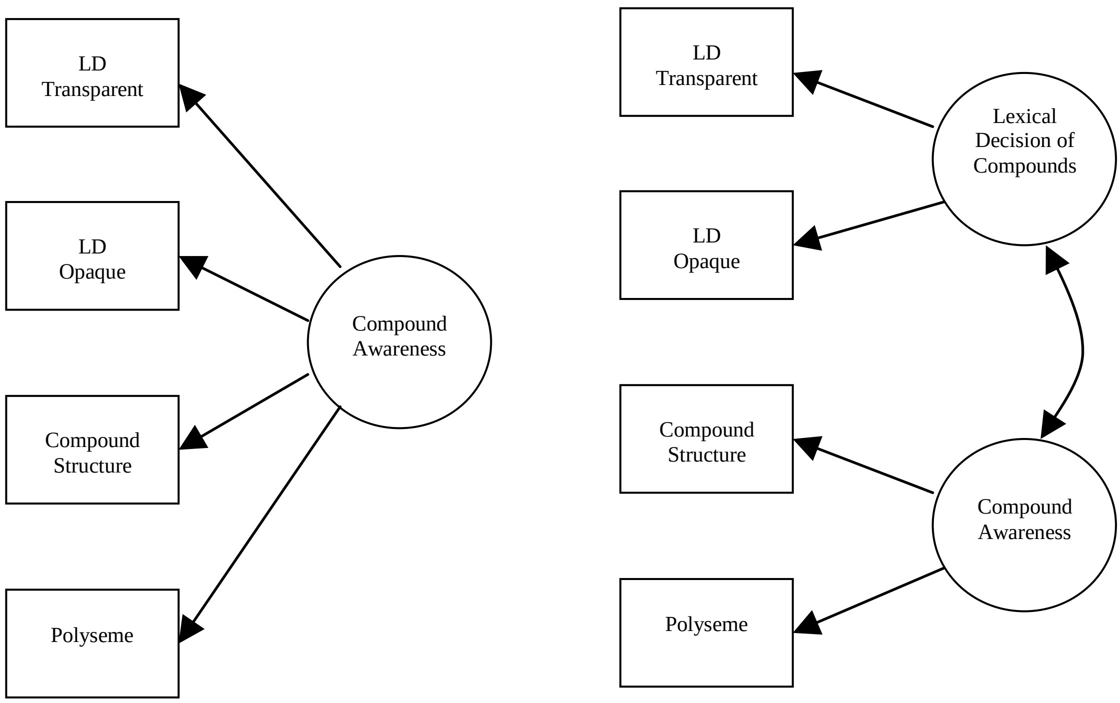
Since there are four indicators of compound awareness in each language and only one of them was used in previous studies (Wang, Cheng & Chen, 2006), two preliminary CFA models were tested to see whether the indicators were assessing the same underlying variable. The two models are shown in Figure 7. In the model with one factor, all four indicators loaded on one latent variable. In the model with two factors, the scores on the lexical-decision task on transparent and opaque compounds loaded on one factor (lexical decisions on compounds) while the compound structure task and the polyseme identification task loaded on the other factor (compound awareness). Covariance was allowed between those two factors. Since the one factor model was nested in the two-factor model, the change of χ^2 was calculated, based on one degree of freedom (See Table 10 for a summary of the goodness of model-fit indexes).

The results suggested that the two-factor model was significantly better than the one-factor model in both Chinese, $\Delta\chi^2$ (1, *N*=140) =24.15, *p*<.01, and English, $\Delta\chi^2$ (1, *N*=140) =9.54, *p*<.01. Since the two-factor model was statistically significantly better than the one-factor model, two factors were entered for further analysis. To distinguish the two factors, the one represented by the scores of the lexical-decision task was labeled "lexical decision on compounds," and the other factor, represented by the compound-structure task and the polyseme-identification task, was labeled "compound awareness."

Structure equation modeling

Structure equation modeling was conducted to test the relative importance of phonological awareness and compound awareness as predictors of the reading outcomes, including word reading and reading comprehension, within and across languages. Different from previous studies that tested path models using observed variables (e.g., Nagy, Berninger, Abbott, 2006; Shu et al., 2006), models using latent variables were tested in this study. Since a path analysis model, using observed variables, does not take measurement error into account, the results from such an approach are more biased than those from a latent-variable path analysis approach (Stephenson & Holbert, 2003).

Figure 7. CFA models on measurements of compound awareness



Model with one factor   Model with two factors

Table 10

Summary of the Model-Fit Statistics on CFA Models of Compound Awareness

Model	χ^2	*Df*	*p*	CFI	SRMR	RMSEA(CI)
Chinese						
One factor	26.44	2	.000	.42	.13	.30 (.20-.40)
Two factors	2.29	1	.130	.97	.05	.10 (.00-.26)
English						
One factor	11.78	2	.003	.88	.07	.19 (.09-.30)
Two factors	2.24	1	.135	.99	.02	.09 (.00-.27)

Note: CFI = comparative fit index; SRMR =standardized root mean residual; RMSEA=root mean-square error of approximation; CI= 90% confidence interval of RMSEA.

Confirmatory Factor Analysis

The first step in the analysis was to use CFA to assess whether the measurements reflect the latent variables in which I am interested. In addition, the CFA model provides correlations among the latent variables that may not be specified by the theories. Therefore, the CFA model served as a basis for the structural model. Some variables (e.g., English phonemic awareness) had only one measurement as an indicator. To create latent variables without increasing the number of estimated parameters, latent variables were defined by fixing the error term of the single indicator to $(1-r)s^2$ [1](Kline, 2005; Sass & Smith, 2006).

Originally, both the latent variables—lexical decision on compounds and compound awareness—were included in the CFA model. However, observation of the original CFA model showed that the latent variables of lexical decision on compounds in the two languages were not correlated with the reading outcomes in either language. Given the small sample size of the present study, the latent lexical-decision variable was not to be included in the formal analysis. Therefore, in the initial CFA model there were 8 latent variables and 11 observed variables: English vocabulary (measured by the English vocabulary test), English phonemic awareness (measured by English the phoneme-deletion test), English compound awareness (measured by the English compound-structure test and polyseme-identification test); English word reading or reading comprehension; Chinese vocabulary (measured by a Chinese vocabulary test), Chinese phonological awareness (measured by onset and tone oddity), Chinese compound awareness (measured by Chinese compound-structure test and polyseme-identification test); Chinese word reading or reading comprehension.

[1] Note: r =reliability of the measurement; s^2=Variance of the measurement.

Table 11

Summary of the Model-Fit Statistics on Structural Equation Models

Model	χ^2	*df*	*p*	CFI	SRMR	RMSEA(CI)
Word recognition						
Initial CFA	49.92	21	.000	.99	.05	.10 (.06-.14)
Initial structural	102.63	29	.000	.98	.15	.14 (.11-.16)
Final structural	124.36	39	.000	.98	.16	.13 (.10-.15)
Reading comprehension						
Initial CFA	45.16	21	.002	.98	.05	.09 (.05-.13)
Initial structural	96.55	29	.000	.95	.14	.13 (.10-.16)
Final structural	110.36	39	.000	.94	.15	.12 (.09-.14)

Note: CFI = Comparative fit index; SRMR =standardized root mean residual; RMSEA=Root mean-square error of approximation; CI= 90% Confidence interval of RMSEA.

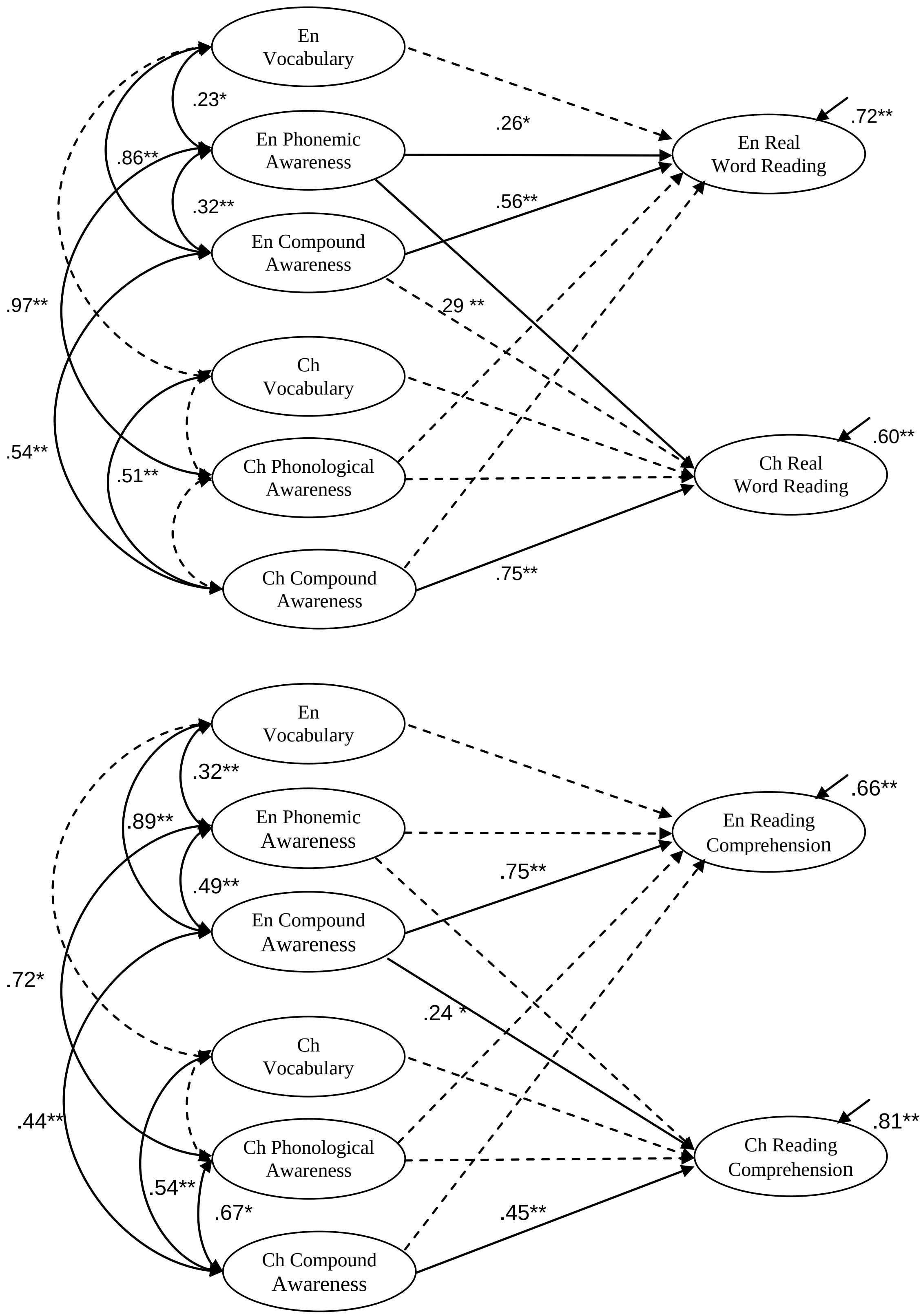
The initial CFA model fit the data well; therefore no re-specification of the model was conducted.

Structural modeling

The next step in the analyses was to create a theory-derived structural model based upon the final CFA model. Figure 11 illustrates the structural models. Based on the theoretical framework and previous literature (e.g., Shu, McBride-Chang, Wu & Liu, 2006), in the initial structural models there were paths from oral vocabulary, phonological awareness, and compound awareness to reading outcomes within each language. Moreover, to explore the cross-language transfer of phonological awareness and compound awareness, there were paths from phonological awareness and compound awareness to the reading outcomes in the other language. Oral vocabulary, phonological awareness, and compound awareness were allowed to correlate with each other within each language and correlate with their counterparts in the other language. The initial structural model was modified by deleting non-significant paths. In the final structural model, all the paths and correlations were significant. According to the joint criteria for examining model fit recommended by Hu and Bentler (1999), a model can be retained under one of the two conditions: a) CFI≥.96 and SRMR≤.09; or b) SRMR≤.09 and RMSEA SRMR≤.06. Although the CFI values in the present models were greater than .95, the SRMR values were greater than .09 and RMSEA values were greater than .06 (See table 10 for data model fit indexes). Therefore, neither the initial structural model nor the final structural model fit the data well.

In the final structural model, English phonemic awareness and compound awareness directly predicted English real-word naming (standard path coefficient β= .26, p<.05, and β=.56, p<.01, respectively). Chinese compound awareness and English phonemic awareness directly predicted Chinese real-word naming (β = .29, p<.01, and β = .75, p<.01, respectively). English compound awareness directly predicted English reading comprehension (β = .75, p<.01). Chinese and English compound awareness directly predicted Chinese reading comprehension (β = .24, p<.05, and β = .45, p<.01, respectively). Within English, the correlations among oral vocabulary, phonemic awareness, and compound awareness were significant. Within Chinese, Chinese oral vocabulary was significantly correlated with Chinese compound awareness for predicting both real word naming and reading comprehension. Chinese phonological awareness was significantly correlated with Chinese compound awareness for predicting reading comprehension. Across languages, English phonemic awareness and compound awareness were correlated with their counterparts in Chinese.

Figure 8. Final structural models of real-word reading and reading comprehension



Discussion

The goals of Experiment 3 were: (a) to establish valid measurements of compound awareness, which has been rarely studied; (b) to investigate the role of compound awareness in reading development in English and Chinese; and (c) to investigate the cross-language transfer of compound awareness to reading achievements.

To address the first question, multiple tasks involving compound words were conducted. The results of confirmatory-factor analysis showed that the tasks of compound structure and polyseme identification were loaded on one factor and the tasks of lexical decision on transparent words and opaque words were loaded on the other factor. That result indicated that these tasks reflected two different constructs. Since compound awareness should reflect children's ability to identify, reflect on, and manipulate morphemic structure (Anderson & Li, 2006; Carlisle, 1995), the tasks of compound structure and polyseme identification were more appropriate measurements of compound awareness than the lexical-decision tasks.

When performing the compound-structure task, the children had to identify the two constituents in compound words and understand that in noun-noun compound words, the first constituent was a modifier and the second was a head. When performing the polyseme-identification task, the children needed to identify the two constituents and reflect on their meanings. On the contrary, when performing the lexical-decision tasks, the children did not need to reflect on the constituent morphemes of the compound words. The task required the children to judge only whether or not the word they heard was a real word. They could rely on their memory of the compound words to make the judgment. Although the compound words could be automatically decomposed into their constituents, if the children knew a compound word well, they could easily tell whether or not it was real, based on their vocabularies, without explicitly analyzing the meanings of the constituents.

The second goal of Experiment 3 was to investigate the contribution of compound awareness to reading development within each language. The results of structural equation modeling showed that compound awareness in each language was a significant predictor for both real-word naming and reading comprehension. In Chinese, among the within-language predictors—oral vocabulary, phonological awareness, and compound awareness—compound awareness was the only significant predictor of Chinese real-word reading and reading comprehension. Those results were in line with previous findings in Chinese (e.g., Shu et al., 2006) and in bilingual populations (e.g., Wang et al., 2006) and confirmed the importance of compound awareness in reading Chinese. The unit of Chinese writing system is the character, and each character represents one morpheme. The ability to identify the constituent morphemes in compound words helps children identify the characters in reading materials. Their insights of the meanings of the constituent morphemes help them understand the meanings of the written characters that represent the constituent morphemes. Their insights of the structure of compound words not only help them understand the spoken language but also facilitate their reading comprehension.

In English, compound awareness was also a significant predictor of real-word naming and reading comprehension. Although previous research has investigated the role of morphological awareness in reading English (e.g., Carlisle & Fleming, 2003), derivational and inflectional morphology were the focus instead of compound morphology. The results of the present study suggest that compound awareness also contributes to reading development in English, at least among the Chinese-English bilingual children who participated in the present study. Morphological awareness has been shown to be an important predictor of reading outcome in English in previous literature. Although compound awareness in this study is not the same as the inflectional and derivational awareness investigated in previous studies (e.g., Carlisle & Fleming, 2003), it taps into some common abilities among these three aspects of morphological awareness, such as the ability to identify the morphemes in multi-morphemic words. Such abilities improve reading skills not only in Chinese but also in English.

The third goal of Experiment 3 was to investigate the cross-language transfer of compound awareness to reading outcomes. The results of structural equation modeling showed that compound awareness in English was a significant predictor for reading comprehension in Chinese. That suggests that compound awareness could transfer from one language to the other, partially confirming the findings of Wang et al. (2006), who investigated the role of morphological awareness in the reading development of Chinese-English bilingual children. Their study showed that English compound awareness explained a unique variance in Chinese real-character reading and reading comprehension. In the present study, English compound awareness was not a significant predictor of Chinese real-word reading. The method of data analysis of the present study was different from that of Wang et al. (2006), in which hierarchical regression was conducted. Although the results of hierarchical regression analyses showed the relative contribution of compound awareness and phonological awareness, they do not differentiate between direct effects and indirect effects. In the present study, structural equation modeling provided a more comprehensive analysis of the data. It incorporated the correlations among the predictors within and across languages. Therefore, the model reflects not only the direct effect of compound awareness but also the indirect effects of compound awareness. In the model, the direct path from English compound awareness to Chinese real-word reading was not significant, but the correlation between English and Chinese compound awareness was significant—that is, English compound awareness had indirect effects on Chinese real word reading through the connection via Chinese compound awareness.

In the present study, phonological awareness and compound awareness were included in the same model to predict reading outcomes in both languages. It provided an opportunity to understand the underlying mechanism of cross-language transfer. The results suggested that both phonological awareness and compound awareness correlated with their counterparts in the other language. In predicting real-word reading, English phonemic awareness and compound awareness directly contributed to English real-word reading, and English phonemic awareness and Chinese compound awareness directly contributed to Chinese real-word reading. In predicting reading comprehension, English compound awareness directly contributed to English reading comprehension; and compound awareness in both English and Chinese directly contributed to Chinese reading comprehension. Those results revealed that linguistic awareness acquired in one language could be transferred to another language via both direct effects and indirect effects. For example, English compound awareness could be transferred to Chinese by a direct path from English compound awareness to Chinese reading comprehension. English compound awareness could also be transferred to Chinese word reading indirectly via Chinese compound awareness.

One interesting discovery of the present study was the reverse transfer from English (L2) to Chinese (L1). Although this finding was similar to that of Wang et al. (2006), in most bilingual literature, the transfer found was from L1 to L2. One possible explanation might be that the children who participated in the present study were more proficient in L2 than in L1. Although they learned Chinese as their first language at home, they were exposed to English in the school environment. Their metalinguistic awareness of Chinese (L1) was not fully developed, so they easily became more fluent in English. Possibly, the development of metalinguistic awareness in English is faster than in Chinese.

The present study has several limitations. First, its sample size was relatively small for the tested models. Consequently, the present study has limited power to confirm the hypotheses. Although the model kept only the significant paths, it did not indicate that the deleted paths were not important. For example, although the path from Chinese phonological awareness to Chinese real-word naming was not significant, it did not indicate that phonological awareness made no contribution to real-word naming. The purpose of deleting insignificant paths was to search for the most important predictors of reading outcomes. Second, the data did not fit the model very well. That might be related to the small sample size. Third, given the difficulty of recruiting participants, children were recruited from a wide age-range (from 6 to 10 years old). Although I controlled for the effect of age in the analysis, the heterogeneity of the sample increased the errors of the tests. The diversity of the sample increased the variance of the test scores and decreased the power of the analysis. Finally, the reliability of some tests was relatively low, as in the Chinese polyseme-identification task. The low reliability of the tests also decreased the power of the structural equation modeling (Hancock, 2006).

In summary, the present study supported the role of compound awareness in reading outcomes of Chinese-English bilingual children. Compound awareness not only predicted reading outcomes within each language but also transferred across the two languages. The results of structure equation modeling provided a potential framework for explaining cross-language transfer by incorporating direct effects (e.g., direct effects from English compound awareness to Chinese reading comprehension) and indirect effects (e.g., indirect effects of English compound awareness on Chinese real word reading via Chinese compound awareness) in the same model. In addition, the compound-structure task and polyseme identification were shown to be valid measurements of compound awareness in both Chinese and English.

Chapter VI: General Discussion

The aim of the present study was to investigate the cross-language activation of compound words in bilingual processing as well as the transfer of knowledge of compound words in one language to reading in the other language. Experiments 1 and 2 investigated how bilingual children process compound words in their two languages at the micro-level. Experiment 3 examined the role of compound awareness in biliteracy acquisition at the macro-level. In this section, the results of the three experiments are summarized and discussed from three perspectives: compound decomposition, semantic effects in compound processing, and cross-language activation and transfer.

Compound Decomposition

Whether compound words are decomposed into their constituent morphemes is one of the most controversial issues in research on compound processing (e.g., Libben, 1998; Sandra, 1990; Zwitserlood, 1994). Experiments 1 and 2 provided direct evidence of compound decomposition. The results of both experiments showed that the properties of the constituent morphemes affected the accuracies of lexical decisions. Although compound decomposition has been evidenced in previous studies, those studies were focused on adult monolingual populations. The present study addressed that subject from a bilingual perspective. Our results suggested that the translation equivalents of the constituent morphemes in the nontarget language were activated when bilingual children made lexical judgments on the compounds of the target language.

There is a general concern among most of the previous studies about whether semantically transparent words are decomposed during compound processing (e.g., Libben, 1998; Sandra, 1990; Zwitserlood, 1994). Controversial results, however, were found in some studies regarding whether semantically opaque compounds were decomposed as well. Sandra (1990) found that only transparent compound was primed by the semantic prime that has a semantic relation with one of the constituent morphemes (e.g., using *house* as the prime of *classroom*). Libben et al. (2003) found priming effects for both transparent and opaque compounds using the lexical prime (one of the constituent morphemes; e.g., using *room* as the prime of *classroom*). The presence of one of the constituents or semantic prime increases the chance for participants to decompose compound words. The design of Experiment 2 provided a new perspective to address the issue of compound decomposition. The lexical-decision task did not involve any semantic or lexical primes. The absence of primes precluded participants from using decomposition as a testing strategy. Therefore, Experiment 2 provided robust evidence of decomposition for both transparent compounds and opaque compounds.

In contrast to studies of compound processing in adults, those centered on children are rare. Nicoladis (2003, 2006) investigated the cross-language transfer of compound structures in French-English bilingual children. However, her studies involved only semantically transparent compounds and did not examine the decomposition issue directly. The findings of Experiments 1 and 2 provided direct evidence of compound decomposition by Chinese-English bilingual children. Moreover, the findings of the present study revealed the importance of decomposition in morphological processing.

Although Experiment 3 was not designed to address the issue of compound decomposition, it provided indirect evidence of the process. Compound decomposition serves as the foundation for compound tasks. For example, in order to decide whether *bar* has the same meaning in *candy bar* and *bar tender*, the children needed to decompose the two words into their constituents to access the meaning of *bar*.

Semantic Effects in Compound Processing

Whether the semantic information of the constituent morphemes is activated during compound processing is another key question in the field. Consistent with previous research using adult monolingual populations (e.g., Libben et al., 2003; Sandra, 1990; Zwitserlood, 1994), the results of Experiment 2 showed a significant effect of semantic transparency in bilingual children. Specifically, they performed better with transparent words than with opaque words. Using semantic priming of constituent morphemes, Sandra (1990) found priming effects in semantically transparent compounds but not in opaque compounds. Using lexical priming, Libben et al. (2003) found priming effects for both transparent and opaque compounds, but the priming effect was greater for transparent compounds than for opaque compounds. According to Libben (1998), on the semantic level, the processing of semantically transparent compounds differs from that of opaque compounds. Only the semantic representations of transparent constituents are activated. Semantic transparency effects found in the present study suggest that the activation of semantic information was involved in the processing of transparent words. Furthermore, the results of Experiment 2 suggest that the semantic representations of transparent morphemes were activated via the translation equivalents in L1.

The results of Experiment 3 showed that the polyseme-identification task was a valid measurement of compound awareness and a predictor of reading skills. The polyseme-identification task was designed to assess children’s ability to differentiate the meanings of polyseme morphemes in compound words. These results suggest that sensitivity to semantic information of the constituent morphemes of a compound word is vital for the acquisition of compound awareness and reading skills. Although the compound-structure task was not designed to assess children's sensitivity to meanings of constituent morphemes, knowing the meanings may have facilitated their judgments.

Cross-language Activation and Transfer

The two languages of bilingual children are not independent of each other. The interaction between the two languages is the focus of the present study. Although Nicoladis (2002, 2003) investigated the cross-language transfer of compound structure by French-English bilingual children, those studies did not address the issue of cross-language activation and could not directly test the hypotheses of bilingual-lexicon models. On the contrary, Experiments 1 and 2 directly investigated the cross-language activation of constituent morphemes. Results suggest that the translation equivalents of the constituent morphemes in L1 (Chinese) were activated when making lexical decisions in L2 (English). Moreover, the cross-language effect was independent of semantic transparency and language proficiency. Those results provided evidence of cross-language activation during compound processing.

The findings also suggest that cross-language activation occurred at the lexical level instead of at the semantic level. Those results can be best accommodated in the RHM model (Kroll & Stewart, 1994). The RHM model differentiates lexical links from semantic links and emphasizes the asymmetry between L1 and L2. Although the effect of language proficiency proposed by the RHM model was not found in the present study, most of the results supported the other hypotheses of the RHM model.

On a macro level, Experiment 3 examined the cross-language transfer of compound awareness in biliteracy acquisition. Results showed that the compound-awareness tasks in the two languages correlated with each other, indicating that the processing of compound words in the two languages required similar abilities, such as the ability to decompose compound words into their constituents, sensitivity to the meanings of the constituent morphemes, and the knowledge of the structure of compounds. The results of the present study were not only consistent with the findings of Wang et al. (2006), but also extended those findings by providing a latent path model for bilingual transfers.

Perhaps the most interesting finding of Experiment 3 was that the compound awareness in English (L2) directly predicted reading comprehension in Chinese (L1). On one hand, that finding provided evidence of cross-language transfer of compound awareness. On the other hand, a reverse transfer from L2 to L1 was not expected, especially when the results of Experiments 1 and 2 showed that the lexicality in L1 affected children's response in L2. The possible explanation lies in the differences among the experiments. Firstly, the three experiments were conducted on different levels. In Experiments 1 and 2, the cross-language activation was found on a micro-level. The results indicated that when processing compounds in L2 (English) the translation equivalents of the constituent morphemes in L1 (Chinese) was activated. In Experiment 3, the cross-language transfer of compound awareness was investigated on a macro-level. The subject of linguistic transfer was linguistic structures, such as order of constituent morphemes (e.g., Nicoladis, 2006), instead of individual words. Secondly, auditory stimuli were used in Experiments 1 and 2, but reading was investigated in Experiment 3. The cross-language transfer found in Experiment 3 was from English compound awareness to Chinese reading. Since no reading was involved in Experiments 1 and 2, this could be one of the potential reasons that the English compound awareness in these two experiments did not affect children's responses to auditory stimuli of Chinese compounds.

In summary, the contribution of the present study was twofold. On one hand, in Experiments 1 and 2, the compound processing of Chinese-English bilingual children was examined directly at a micro-level. The results of these two experiments provided evidence of compound decomposition, semantic activation, and cross-language activation. On the other hand, in Experiment 3, cross-language transfer of compound awareness was investigated at a macro-level. The findings of Experiment 3 reflected the important aspects in compound processing, such as compound decomposition and semantic activation of transparent constituents. The findings of Experiment 3 also revealed the important role of morphological awareness in biliteracy acquisition.

Limitations

The participants of the present study were a group of Chinese-English bilingual immigrant children. The nature of the population posed several limitations. First, although the children who participated in the study learned Chinese as their first language at home; they became more proficient in English than in Chinese after they began learning in American public schools, where they only spoke English. Therefore, the findings of the present study cannot be generalized to other bilingual populations whose Chinese (L1) is more proficient than their English (L2). Second, since the children could be accessed only when they attended weekend Chinese language schools, the data had to be collected over brief period of time. Group testing was conducted to improve the efficiency of data collection. Because of group testing, the reliability of some tasks was relatively low. Last, the limited number of immigration children enrolled in the weekend language schools virtually precluded increasing the sample size for Experiment 3. Also, the age range of the sample was relatively large, from 6 to 10 years old, since the participants were recruited from two Chinese grades to increase the sample size. The diversity of the participants increased the variation of data and lowered the power of the analysis.

In addition to the limitations related to the participants, other limitations are also noteworthy. In Experiments 1 and 2, there were a limited number of items under each condition, only eight items in each cell. Given the limited vocabulary of the children, it was difficult to find appropriate items that could meet all the criteria of item selection. Although a concerted efforts were made to control for potentially confounding variables, in Experiment 2 the familiarity with Chinese items was not matched across the conditions. In Experiment 3 the reliabilities of some measurements were relatively low.

Future Directions for Research

Findings from Experiments 1 and 2 served beginning steps toward our better understanding of bilingual compound processing. Clearly, more research is needed. In the present study, only the semantic transparency effect was investigated. Previous studies have suggested that other properties of the constituents are also important in compound processing, such as family size, position in string and headedness. The effects of those properties could be examined. For example, in the present study, the semantic transparency of the head and modifier were fixed. In future research, the transparency of the modifier and head could be manipulated to investigate the role of the head and modifier separately in compound processing, such as in Libben et al. (2003). For another example, the family size of some morphemes and their translation equivalents may be different in the two languages of bilinguals. The family size of morphemes could be controlled in the target language and manipulated in the nontarget language to test whether family size in the nontarget language affects the processing of compounds in the target language.

Again, compound words can be divided into several types, based on the structure of the words (e.g., noun-noun and adjective-noun compounds). Compound structures can also vary across languages. For example, in English, the head of a compound is always the second constituent, but in French, the head can be either the first or the second constituent. Such a contrasting feature could be utilized to investigate the issue of cross-language transfer (e.g., Nicoladis, 2002, 2003). Chinese is rich in compound words and has some unique compounding structures, such as adjective-adverb compounds. Pseudo-compounds in English could be constructed, based on the structure of Chinese compounds to examine cross-language transfer.

In the present study, the special nature of the Chinese-English bilingual immigrant children limited the generalization of results. Future research should investigate adult ESL learners, using a paradigm similar to that of the present study. In contrast to bilingual children, adult learners of English are very proficient in their L1 and less so in their L2. A clear differentiation of L1 and L2 would make it easier to examine the models of the bilingual lexicon. Furthermore, given the abundant vocabulary of adults in their L1, there would be more flexibility in item selection and in using other research paradigms, such as priming.

The findings of Experiment 3 revealed the importance of compound awareness in Chinese-English biliteracy acquisition. However, compound awareness is only one aspect of morphological awareness. Future research should include other aspects of morphological awareness, such as children's awareness of derivational morphology and inflectional morphology. Moreover, the relative contributions of those aspects to reading skills are also worth investigation. Furthermore, previous studies have suggested that the relative contributions of phonological awareness and morphological awareness change with age (e.g., Carlisle, 2000; Deacon, 2007). In the present study, age was treated as a control variable. Longitudinal studies need to be conducted to investigate the changing roles of morphological awareness and phonological awareness across time.

Educational implications

The findings of this study have implications for bilingual education in general. The results of Experiments 1 and 2 suggest that, when bilingual children process compounds in one language, the translated equivalents in the other language are activated. Therefore, teachers need to pay attention to both languages that are spoken by the bilingual children. Given the importance of compound decomposition and semantic transparency, future research could yield instructional methods to help children understand both the meanings of whole words and the meanings of constituent morphemes. For example, when teaching the word *classroom*, teachers teach how the meanings of *class* and *room* are related and how they contribute to the meaning of the whole word. Furthermore, the translation equivalents of *class* and *room* in their L1 could be utilized to facilitate their learning of new words in L2.

Findings from Experiment 3 showed that compound awareness is composed of two important aspects: awareness of compound structure and sensitivity to the meaning of the constituent morphemes. Instruction in both aspects of compound awareness could facilitate the development of reading skills by bilingual children. Future research should find instructional methods to improve the morphological awareness of Children.

Conclusion

The results of this study fill a gap in the literature by providing knowledge on how Chinese-English bilingual children process compound words in their two languages. Only a handful of studies have explored compound processing of bilingual children (e.g., Nicoladis, 2002, 2003; Nicoladis & Krott, 2007), and all the studies focused on French-English bilingual children. The results of this dissertation revealed the importance of compound decomposition and semantic transparency in compound processing. Experiment 3 further demonstrated that compound awareness made a unique contribution to reading skills in both languages of Chinese-English children. Furthermore, compound awareness of English directly predicted reading comprehension of Chinese.

Appendix A. Experimental Items in Experiment 1

Table A1

English Experimental Items and Rating Results of Items in Experiment 1

Lexicality in English	Lexicality in Chinese	English items	Similarity	familiarity
Real words	Real words	bookstore		6.90
		tablecloth		6.70
		Eyeball		6.50
		cow skin		3.80
		birdcage		5.44
		ink fish		3.70
		toothbrush		6.90
		wheelchair		6.70
	Nonwords	cupcake		6.70
		horseshoe		5.30
		moon face		4.80
		nightclothes		5.60
		roadbed		3.20
		sunflower		7.00
		windshield		3.33
		schoolbook		6.90
Nonwords	Real words	book table	3.94	7.00
		ice river	3.13	2.80
		face color	3.13	2.10
		fire mountain	5.19	4.90
		milk oil	3.00	7.00
		pig meat	5.88	6.70
		bug tooth	2.56	4.40
		song drama	5.13	3.60
	Nonwords	wheel shoes	5.19	6.60
		bird hair	4.81	5.50
		clothes arm	3.94	5.60
		word bird	3.88	4.70
		wind boat	5.13	6.50
		water leopard	2.63	3.70
		star sea	4.81	2.70
		horse seat	4.19	6.00

Table A2

Chinese Experimental Items and Rating Results of Items in Experiment 1

Lexicality in Chinese	Lexicality in English	Chinese items	Similarity	Familiarity
Real words	Real words	书店		6.20
		桌布		5.40
		眼球		4.33
		牛皮		3.00
		鸟笼		3.00
		墨鱼		3.20
		牙刷		7.00
		轮椅		4.60
	Nonwords	书桌		5.80
		冰河		2.80
		脸色		5.00
		火山		6.10
		奶油		4.90
		猪肉		6.11
		虫牙		4.40
		歌剧		2.20
Nonwords	Real words	杯蛋糕	4.23	3.90
		马鞋	2.46	3.40
		月亮脸	3.69	5.33
		夜衣	3.92	6.20
		路床	5.92	1.70
		太阳花	4.92	4.89
		风盾	3.54	4.00
		校书	3.23	3.40
	Nonwords	轮鞋	4.58	4.60
		鸟发	3.85	5.10
		衣臂	4.23	5.20
		话鸟	3.54	3.50
		风船	4.23	4.70
		水豹	3.15	2.90
		星海	3.31	1.70
		马座	3.54	2.50

Appendix B. Experimental Items and Rating Forms in Experiment 2

Table B1

English Experimental Items and rating results of items in Experiment 2

Conditions	Items	Transparency			Familiarity		
		Whole Word	Constituents		Whole Word	Constituents	
			1st	2nd		1st	2nd
Transparent Real words	tablecloth	3.69	3.50	3.40	2.10	1.10	1.30
	wheelchair	3.50	3.31	3.44	1.90	1.10	1.30
	wallpaper	3.81	3.44	3.19	1.80	1.10	1.10
	starlight	3.63	3.19	3.38	2.60	1.10	1.10
	green tea	3.56	2.94	3.63	1.70	1.10	1.20
	blood pressure	3.25	3.31	3.13	1.80	1.10	1.30
	false teeth	3.81	3.38	3.38	2.10	1.20	1.10
	eyeball	3.63	3.40	2.63	1.40	1.10	1.20
Nonwords	password	3.19	2.88	3.56	1.10	1.40	1.10
	fireman	3.13	2.63	3.44	1.40	1.10	1.10
	desk top	3.31	3.38	3.19	1.80	1.10	1.20
	horseshoe	3.47	3.44	2.94	1.90	1.10	1.10
	schoolbook	3.75	3.50	3.56	1.90	1.10	1.10
	nightclothes	3.69	3.38	3.56	2.70	1.10	1.20
	fairy story	3.20	2.88	3.50	3.10	1.30	1.10
	starfish	3.50	2.50	2.88	1.40	1.10	1.30
Opaque Real words	hotdog	1.88	2.19	1.31	1.00	1.10	1.10
	secondhand	2.25	2.56	2.25	2.50	1.10	1.10
	honeymoon	1.73	1.44	1.69	2.40	1.40	1.50
	white collar	2.69	2.81	2.94	2.60	1.00	1.50
	ponytail	2.50	1.75	2.00	1.40	1.40	1.10
	eye-shadow	2.31	2.81	2.13	2.00	1.10	1.10
	four eyes	2.50	2.88	3.13	2.80	1.20	1.10
	bottleneck	2.69	2.13	2.44	3.90	1.20	1.10
Nonwords	butterfly	1.73	1.00	2.53	1.10	1.30	1.40
	first aid	2.56	1.88	3.13	1.20	1.10	1.40
	deadline	2.81	1.63	1.81	1.60	1.50	1.40
	windshield	2.69	2.50	2.81	1.60	1.30	1.60
	potluck	2.07	2.13	2.75	3.90	1.20	1.30
	blackjack	1.94	1.63	1.94	2.60	1.10	2.20
	seedbed	2.75	2.81	2.06	3.10	1.20	1.10
	draw back	2.63	2.31	2.44	3.70	1.30	1.20

Table B2

Chinese Experimental items and rating results of items in Experiment 2

Conditions	Items	Transparency			Familiarity		
		Whole Word	Constituents		Whole Word	Constituents	
			1st	2nd		1st	2nd
Transparent	书店	3.80	3.40	3.20	1.81	1.05	2.14
Real words	星光	2.78	2.70	3.00	3.10	1.24	1.24
	鸟笼	2.70	3.20	2.40	2.86	1.19	2.38
	墙纸	2.78	2.80	2.80	2.76	1.43	1.24
	眼球	2.90	2.70	2.70	2.67	1.33	1.24
	绿茶	3.20	2.60	3.80	2.33	1.57	1.67
	冷汗	2.70	2.90	2.40	3.29	1.38	1.43
	假牙	3.70	3.10	3.60	1.86	1.43	1.24
Nonwords	冰河	3.60	3.30	3.20	2.14	1.45	1.29
	火山	3.60	2.80	3.30	2.00	1.14	1.10
	信纸	3.20	2.50	2.10	2.67	1.43	1.24
	奶油	3.20	2.70	3.30	2.29	1.19	1.76
	书桌	3.20	3.20	2.60	2.29	1.05	1.10
	脸色	3.30	2.70	2.70	2.19	1.33	1.85
	晚餐	2.90	3.20	3.10	1.86	1.30	2.43
	毛笔	3.60	2.40	3.20	1.57	1.33	1.05
Opaque Real words	热狗	2.60	2.80	2.80	1.86	1.38	1.14
	蜜月	2.00	2.10	2.80	3.62	1.52	1.29
	眼影	2.00	2.70	2.10	3.43	1.33	1.48
	风铃	2.00	3.00	2.50	3.48	1.10	2.25
	雪盲	2.00	2.70	2.30	3.71	1.10	2.10
	四眼	2.30	2.60	2.20	3.86	1.14	1.33
	白领	2.60	2.60	2.20	3.71	1.10	2.10
	面值	1.67	2.80	1.70	3.90	1.14	2.38
Nonwords	龙眼	2.00	2.80	3.00	3.33	1.81	1.33
	血汗	2.00	2.20	2.40	3.67	2.19	1.43
	虫牙	2.40	2.40	3.00	3.14	1.14	1.24
	半岛	2.10	2.00	2.50	3.76	1.67	2.48
	点心	2.22	1.80	1.67	1.76	1.19	1.05
	花心	2.60	3.20	2.30	3.00	1.14	1.05
	二胡	1.60	2.40	2.50	3.29	1.05	1.76
	东西	2.33	1.60	1.60	1.48	1.29	1.48

Transparency Rating of English Items: Whole Word

Now you will hear some big words that are formed by two small words. For example, the word '**blackboard**' is formed by the word '**black**' and the word '**board**'. Sometimes you can predict the meaning of the big word from the meanings of the two small words. For example, you can predict the meaning of **"blackboard**" from "**black**" and "**board**". Sometimes you can not predict the meaning of the big word from the meanings of the two small words. For example, you can not predict the meaning of "**breakfast**" from the meanings of "**break**" and "**fast**".

A list of big words is given below. I will read each of them once. I would like to find out the extent to which you think these big words are predictable from the meanings of the two small words. There are no right or wrong answers --I just want to know what you think about the words. Your job is to tell me how predictable each big word is from its parts. Please rate each words according to the scale explained below. Circle the appropriate number following each word:

1. = **Very unpredictable**.
2. = **Unpredictable**.
3. = **Predictable**.
4. = **Very predictable**.

Now let's do some practice:

	Word	Very unpredictable	unpredictable	predictable	Very predictable
1	classroom	1	2	3	4
2	cranberry	1	2	3	4
3	breakfast	1	2	3	4

Please answer all of the questions. Try to work quickly but carefully.

Transparency Rating of English Items: Constituents of Whole Word

This time, a small word in each big word is underlined. Now I would like you to find out the extent to which the underlined small word retains its meaning in the big word. For example, the word **blue** retains all of its meaning in **blueberry**, but the word **straw** loses all of its meaning in **strawberry**.

I will read the big word first then I will read the underlined small word. Your job is to tell me how much meaning of the small word is retained in the big word. Please rate each word according to the scale explained below. Circle the appropriate number following each word:

1. = the small word **loses all of its meaning** in the big word.
2. = the small word **loses some of its meaning** in the big word.
3. = the small word **retains some of its meaning** in the big word.
4. = the small word **retains all of its meaning** in the big word.

Now let's do some practice:

	Word		Loses all of its meaning	Loses some of its meaning	retains some of its meaning	retains all of its meaning
1	class<u>room</u>	room	1	2	3	4
2	<u>straw</u>berry	straw	1	2	3	4

Please answer all of the questions. Try to work quickly but carefully.

Transparency Rating of Chinese Items: Whole Word

Now you will hear some big words that are formed by two small words. For example, the word 黑板 is formed by the word 黑 and the word 板. Sometimes you can predict the meaning of the big word from the meanings of the two small words. For example, you can predict the meaning of **"黑板"** from "黑" and "板". Sometimes you can not predict the meaning of the big word from the meanings of the two small words. For example, you can not predict the meaning of "秋千" from the meanings of "秋" and "千".

A list of big words is given below. I will read each of them once. I would like to find out the extent to which you think these big words are predictable from the meanings of the two small words. There are no right or wrong answers --I just want to know what you think about the words. Your job is to tell me how predictable each big word is from its parts. Please rate each words according to the scale explained below. Circle the appropriate number following each word:

1. = **Very unpredictable**.
2. = **Unpredictable**.
3. = **Predictable**.
4. = **Very predictable**.

Now let's do some practice:

	Word	Very unpredictable	unpredictabl e	predictable	Very predictable
1	书包	1	2	3	4
2	樱花	1	2	3	4
3	秋千	1	2	3	4

Please answer all of the questions. Try to work quickly but carefully.

Transparency Rating of Chinese Items: Constituents of Whole Word

This time, a small word in each big word is underlined. Now I would like you to find out the extent to which the underlined small word retains its meaning in the big word. For example, the **蓝** retains all of its meaning in **蓝莓**, but the **草** loses all of its meaning in **草莓**.

I will read the big word first then I will read the underlined small word. Your job is to tell me how much meaning of the small word is retained in the big word. Please rate each word according to the scale explained below. Circle the appropriate number following each word:

1. = the small word **loses all of its meaning** in the big word.
2. = the small word **loses some of its meaning** in the big word.
3. = the small word **retains some of its meaning** in the big word.
4. = the small word **retains all of its meaning** in the big word.

Now let’s do some practice:

	Word		Loses all of its meaning	Loses some of its meaning	retains some of its meaning	retains all of its meaning
1	书<u>包</u>	包	1	2	3	4
2	<u>樱</u>花	樱	1	2	3	4

Please answer all of the questions. Try to work quickly but carefully.

Familiarity Rating of English Items

Now I am going to read some words to you. Some words are common while others are rare. Common words are ones that we often hear people say. For example, "***blackboard***" is a common word that you have heard many times before. Rare words are ones that we seldom, if ever, hear. For example, "***catwalk***" is a rare word that means a narrow walkway. Some words are neither common nor rare; these are expressions that we sometimes hear but not too often. For example, "***brown-bag***", which means the practice of carrying one's lunch, is neither common nor rare.

A list of words is given below. I will read each of them once. I would like to find out how common or rare you think these words are. There are no right or wrong answers --I just want to know what you think about the words. Your job is to tell me how often you have heard each word. Please rate each word according to the scale explained below. Circle the appropriate number following each word:

5. = I have heard it **many times** before.
6. = I have heard it **several times** before.
7. = I have heard it **a few times** before.
8. = I have heard it **once** before.
9. = I have **never** heard it before.

Please answer all of the questions. Try to work quickly but carefully.

Now let's do some practice:

	Word	many times	several times	a few times	once	never
1	windfall	1	2	3	4	5
2	classroom	1	2	3	4	5
3	catfish	1	2	3	4	5

Familiarity Rating of Chinese Items

Now I am going to read some words to you. Some words are common while others are rare. Common words are ones that we often hear people say. For example, "*黑板*" is a common word that you have heard many times before. Rare words are ones that we seldom, if ever, hear. For example, "*憧憬*" is a rare word that means a strong desire. Some words are neither common nor rare; these are expressions that we sometimes hear but not too often. For example, "*信任*", which means *trust*, is neither common nor rare.

A list of words is given below. I will read each of them once. I would like to find out how common or rare you think these words are. There are no right or wrong answers --I just want to know what you think about the words. Your job is to tell me how often you have heard each word. Please rate each word according to the scale explained below. Circle the appropriate number following each word:

1. = I have heard it **many times** before.
2. = I have heard it **several times** before.
3. = I have heard it **a few times** before.
4. = I have heard it **once** before.
5. = I have **never** heard it before.

Please answer all of the questions. Try to work quickly but carefully.

Now let's do some practice:

	Word	many times	several times	a few times	once	never
1	盲目	1	2	3	4	5
2	教室	1	2	3	4	5
3	墨鱼	1	2	3	4	5

Appendix C. Test Instructions for Experiments 1 and 2

English Instruction

You are going to hear some words. Some of the words are real word; some of the words are not real words. I need you to tell whether the word you hear is real or not. There is a smiling face and a sad face (show the pictures to the children). If you think the word is real please circle the smiling face (point to the smiling face). If you think the word is not real please circle the sad face (point to the sad face). Now let's do some practice:

BLACKBOARD-------is BLACKBOARD a real word? Yes, it is a real word. Then you should circle the smiling face. Let's try another one.

STAR CHAIR--------is STAR CHAIR a real word? No, it's not a real word. Then you should circle the sad face. Let's try another one.

DOG BIRD-------is DOG BIRD a real word? No, it's not a real word. Then you should circle the sad face.

Do you have any questions? Once we start, please do not ask any questions until you finish all the words.
Turn to the next page. Now you are going to hear more words, please try your best to make your choice even if you are not sure whether it is real or not. If you miss one word, please do not stop there; just continue with the following words. Now let's begin.

Chinese Instruction

下面你会听到一些词。里面有一些词不是真的词。我要你来决定你听到的词是不是真的。每个词会跟着一对脸(Show the pictures to the children)。如果你认为一个词是真的，你就在笑脸上画个圈(point to the smiling face)。如果你觉得一个词不是真的，你就在哭脸上画个圈(point to the sad face)。先来做几个练习：

黑板-----黑板是真词吗？对，是真的词。那你就在笑脸上画个圈。再来练一个。
星椅-----星椅是真词吗？不，它不是真词。那你就在哭脸上画个圈。再来练一个。
狗鸟-----狗鸟是真词吗？不，它不是真词。那你就在哭脸上画个圈。
有问题吗？开始以后，就不要再问问题了。
翻到下一页。现在你会听到更多的词。就算你不是很清楚这个词是不是真的，你也要作出选择。如果错过了一个词，不要停下来，请接着做下面的题。下面就正式开始了。

Appendix D. Measures in Experiment 3

Polyseme-identification Task

English Instruction

Now you will hear some big words that are formed by two small words. For example, the word '***blackboard***' is formed by the word '***black***' and the word '***board***'. You will hear a list of pairs of big words. In each pair of big words there will be a shared small word. Sometimes, the meaning of the shared small word is the same in the two big words. Sometimes, the meaning of the shared small word is different in the two big words. For example, the meaning of '***right'*** is the same in '***right hand***' and '***right side***', but the meaning of ***'right'*** is different in '***right hand***' and '***copy right***'.

Now, your job is to tell whether the shared small word has the same or different meanings in the pairs of big words. If you think the meanings of the small words are the same please circle the SAME sign. If you think the meanings of the small words are different please circle the DIFFERENT sign. Now let's do some practice.

Practice

No1. Textbook, Bookstore--------is the meaning of ***book*** same or different in the two words? Yes, the meaning of ***book*** is the same in '***textbook***' and '***bookstore***'. Then you should circle the SAME sign. Let's try another one.

No.2 Ballroom, Baseball----- is the meaning of ***ball*** same or different in the two words? Yes, the meaning of ***ball*** is different in '***ballroom***' and '***baseball***'. Then you should circle the DIFFERENT sign.

Each time you will hear two words. Listen carefully and make a judgment as soon as you can. All right, let's do some more.

English items

1	side road	roadblock	10	first class	classroom
2	homeland	take home	11	sweetheart	heartbreak
3	matchbox	match point	12	armchair	firearm
4	waterfall	rainfall	13	railway	highway
5	feedback	horseback	14	yardstick	backyard
6	lighthouse	lightweight	15	offspring	springtime
7	weekday	workday	16	airplane	airline
8	eyeglass	wineglass	17	playwright	playground
9	bedroom	bedside	18	footstep	barefoot

Chinese Instruction

下面你会听到一些大词，每个大词都是由两个小词组成的。比如，“***黑板***”这个词就是由“***黑***”和“***板***”组成的。每次我会读两个大词。这两个大词中会有一个相同的小词。有时这个小词在两个大词中的意思一样。有时这个小词在两个大词中的意思不一样。比如***中***这个词，***中***在***中国***和***中文***里的意思是一样的，但***中***在***中文***和***中间***里的意思就是不一样的。

下面我要给你读两个词。请你判断小词在两个大词里的意思是不是一样的。如果你觉得是一样的，就在一样的标志上画圈。如果你觉得是不一样的，就在不一样的标志上画圈。

Practice

练习一：

茶杯，绿茶-----茶在这两个词里的意思一样吗？对，茶在茶杯和绿茶里的意思是一样的。那你就在一样的标志上画圈。再来练一个。

练习二

书本，本领----本在这两个词里的意思相同吗？对，本在书本和本领里的意思是不一样的。那你就在不一样的标志上画圈。

好了，下面我们正式开始。还是一样，每次我读两个词，你仔细听，然后做出选择。

Chinese Items

1	电池	静电	10	斑点	点头
2	安装	假装	11	冰山	冰箱
3	耳根	墙根	12	月球	年月
4	足球	满足	13	周末	周围
5	台灯	灯泡	14	白糖	白色
6	车站	马车	15	灯光	光头
7	方块	方向	16	书包	钱包
8	大海	海马	17	草稿	草帽
9	学生	出生	18	外国	祖国

Compound Structure Task

English Tasks (Adopted from Wang et al., 2006)

Parts 1&2: Two Morpheme Words
Instruction

I am going to read you some questions as you follow along. After each question there are two choices. I would like you to judge which choice is the better name for something that is described in my question, and then circle it. You may not have heard these names before. It doesn't matter. Listen to my question carefully.

Practice items:

1. Which is the better name for a bee who lives in the grass?
   1. Bee grass   2. Grass bee
2. Which is the better name for grass where lots of bees like to hide?
   1. Bee grass   2. Grass bee

Test items:
Part 1

1. Which is the better name for a box you keep your pet lizard in?
   1. Box lizard   2. Lizard box
2. Which is the better name for a swamp with lots of flowers in it?
   1. Flower swamp   2. Swamp flower
3. Which is the better name for a kind of paper you use to make flowers?
   1. Paper flower   2. Flower paper
4. Which is the better name for a rock that always has ants crawling on it?
   1. Ant rock   2. Rock ant
5. Which is the better name for bread you feed to the birds?
   1. Bird bread   2. Bread bird
6. Which is the better name for a stick that people use to catch snakes?
   1. Stick snake   2. Snake stick
7. Which is the better name for a spider that only eats ants?
   1. Spider ant   2. Ant spider

Part 2

8. Which is the better name for ants that like to crawl around on rocks?

1. Ant rock 2. Rock ant

9. Which is the better name for an ant that only eats spiders?

1. Spider ant 2. Ant spider

10. Which is the better name for a flower that grows in a swamp?

1. Flower swamp 2. Swamp flower

11. Which is the better name for a flower made out of paper?

1. Paper flower 2. Flower paper

12. Which is the better name for a lizard who lives in a box?

1. Box lizard 2. Lizard box

13. Which is the better name for birds that like to eat bread?

1. Bird bread 2. Bread bird

14. Which is the better name for a snake that hides by trying to look like a stick?

1. Stick snake 2. Snake stick

Part 3 : Multimorphemic words

Instruction

In this test, your job is to decide which of four phrases is the best name for something that is described in a sentence.

Look at the practice items, and circle the phrase that best answers each question.

Practice items:

a) If you found a lid for a dish to keep candy in, what would it be called?

dish lid candy
candy dish lid
dish candy lid
candy lid dish

Test items:

1. There was a drawer in my dresser where we kept the books, and I had a key that would lock it. What would you call this key?

drawer book key
book drawer key
book key drawer
key book drawer

2. What do you think would be a good name for a special kind of salt you use to put in fish tanks to make the water salty?

salt fish water
fish salt water
fish water salt
water fish salt

3. Someone discovered that the juice from a certain kind of plant tastes just like root beer. What would be the best name for the plant?

plant juice root beer
juice plant root beer
root beer juice plant
juice root beer plant

4. An artist created a new color of red paint that is exactly the color of the rocks on Mars. What would be the best name for that color?

red Mars rock
red rock Mars

Mars red rock
Mars rock red

5. An inventor built a vacuum cleaner so strong it could take the old chewing gum off the bottom of chairs. What should it be called?

chair bottom gum vacuum
bottom chair gum vacuum
vacuum chair bottom gum
vacuum bottom chair gum

6. You want to buy wood that is especially good for building a table to put a television on. What kind of wood would you ask for?

wood table television
table television wood
table wood television
television table wood

7. There's a shelf in your house where you keep the paper you use to wrap bread in. What would you call it?

bread paper shelf
paper bread shelf
shelf bread paper
shelf paper bread

8. My mother was annoyed because there was always dust on the window where we kept the plants. She would complain about:

window dust plant
dust window plant
window plant dust
plant window dust

Chinese Tasks

Part 1&2: Two Morpheme Words (Adopted from Wang et al., 2006)

Instruction
现在我要读一些问题给你听,每个问题后面都有两个选项, 请你把正确的答案圈出来，我们先来做个练习。

Practice items
练习：长在树上的花叫什么更好呢?
1. 树花　　2. 花树
只长花的树叫什么更好呢？
1. 树花　　2. 花树

Test items:
Part 1

1、给鸟吃的鱼叫什么更好呢?
1. 鱼鸟　　2. 鸟鱼

2、长在草上的刺叫什么更好呢?
1. 草刺　　2. 刺草

3、车上的人叫什么更好呢?
1. 人车　　2. 车人

4、被狗抓的猫叫什么更好呢?
1. 猫狗　　2. 狗猫

5、装饭的船叫什么更好呢?
1. 饭船　　2. 船饭

6、长得像马的羊叫什么更好呢?
1. 羊马　　2. 马羊

7、在山上的湖叫什么更好呢?
1. 山湖　　2. 湖山

Part 2

8、被刀杀死的猪叫什么更好呢?

1. 猪刀　　2. 刀猪

9、有湖的山叫什么更好呢?

1. 湖山　　2. 山湖

10、杀猪用的刀叫什么更好呢?

1. 刀猪　　2. 猪刀

11、装在船上的饭叫什么更好呢?

1. 饭船　　2. 船饭

12、长刺的草叫什么更好呢?

1. 草刺　　2. 刺草

13、做人的车叫什么更好呢?

1. 人车　　2. 车人

14、吃鱼的鸟叫什么更好呢?

1. 鸟鱼　　2. 鱼鸟

15、抓猫的狗叫什么更好呢?

1. 猫狗　　2. 狗猫

16、长的像羊的马叫什么更好呢?

1. 羊马　　2. 马羊

Part 3：Multimorphemic Words

Instruction

下面我们做一点点变化。这一次每个问题会有四个选项。还是一样，仔细听我的问题，选出一个能够最好的表示我所描述的那样东西的选项。我们先来做个练习。

Practice items

练习：有一辆车用来运装茶的瓶子，这辆车应该叫什么呢？

A 车瓶茶
B 瓶车茶
C 茶瓶车
D 瓶茶车

Test items:

1. 有人发现一种牛身上会发出桃子的香味，这种牛该叫什么呢？

A 香桃牛
B 桃香牛
C 香牛桃
D 牛桃香

2. 有一种水专门用来洗放肉的盘子，这种水该叫什么呢？

A 盘肉水
B 水肉盘
C 盘水肉
D 肉盘水

3. 一张桌子上面摆了一个放本的盒子，这张桌子该叫什么呢？

A 盒桌本
B 本盒桌
C 盒本桌
D 桌本盒

4. 一棵树上盖了一个给猫住的窝，这棵树该叫什么呢？

A 窝猫树
B 树猫窝
C 猫树窝
D 猫窝树

5. 有一种笔可以用来在玻璃做的椅子上写字，这种笔该叫什么呢？

A 玻璃椅笔

B 椅玻璃笔
C 玻璃笔椅
D 笔玻璃椅

6. 有一种马只吃山里面长的草，这种马该叫什么呢？

A 草马山
B 山草马
C 草山马
D 马山草

7. 有一个夹子用来夹放盐的袋子，这个夹子该叫什么呢？

A 袋夹盐
B 盐袋夹
C 袋盐夹
D 盐夹袋

8. 小明有一些钱用来买冬天穿的鞋，这些钱该叫什么呢？

A 钱冬鞋
B 鞋冬钱
C 冬鞋钱
D 鞋钱冬

9. 有一种花的花瓣长得很像兔子的耳朵，这种花该叫什么呢？

A 兔耳花
B 耳兔花
C 花兔耳
D 兔花耳

Phonological Awareness Task (Adopted from Wang et al., 2006)

English Phoneme Deletion Task

Instruction

I am going to read you some questions as you follow along. After each question there are three choices. The first choice corresponds to the 1 sign on your answer sheet. The second choice will correspond to the 2 sign. The third choice will correspond to the 3 sign. I would like you to circle the best answer for each question. Let's do the sample together.

Practice items

How would *(item)* sound without *(without), x, y,* or *z?* The answer is *(shaded red one).*

	Item	Without	1	2	3
1	**mab**	/b/	**ma**	mab	ab
2	**keff**	/k/	ke	**eff**	keff
3	**stet**	/s/	**tet**	ste	set
4	**nuft**	/t/	**nuf**	nut	aft

Test items

How would *(item)* sound without *(without), x, y,* or *z?*

	Item	Without	1	2	3
1	**zipe**	/z/	zipe	**ipe**	zi
2	**neep**	/n/	neep	**eep**	nee
3	**toof**	/f/	oof	toof	**too**
4	**sen**	/n/	**se**	sen	en
5	**skaff**	/k/	kaff	ska	**saff**
6	**sisp**	/p/	**sis**	sip	isp
7	**bift**	/t/	bit	**biff**	ift
8	**smool**	/m/	**sool**	mool	smoo
9	**skeak**	/s/	seak	**keak**	skea
10	**kesk**	/s/	kes	**keck**	esk
11	**fask**	/k/	**fass**	ask	fak
12	**sneck**	/n/	neck	**seck**	eck
13	**basp**	/p/	bap	**bas**	asp
14	**yift**	/f/	ift	yif	**yit**
15	**stoam**	/t/	**soam**	stoa	toam
16	**snize**	/s/	**nize**	size	ize

Chinese Onset, Rime and Tone oddity

Onset oddity.

Instruction:

下面你会听到三个字, 其中第一个字与答题纸上的数字 **1** 对应，第二个字与答题纸上的数字 **2** 对应，第三个字与答题纸上的数字 **3** 对应。在这三个字中有两个字开始的发音相同, 还有一个与他们不同。我想请你仔细听这三个字的发音，然后找出开始的发音与其他两个不同的那个字，并在相应的数字上画圈。记住，是开始的发音不同的那个字。

Practice items:

练习 1：bei 3 ba 1 **dao 4**

哪个字开始的发音和其他两个不同呢？ 正确答案是 3。

练习 2：bi 1 **zhu 4** ban 4

哪个字开始的发音和其他两个不同呢？ 正确答案是 2

好了，下面我们正式开始。每一组字我只读一遍，你要仔细听。

Test items:

(1)	de 1	da 4	xie 3
(2)	dong 3	duo 1	nian4
(3)	you 3	fen 1	fa 3
(4)	gang 1	ge 2	ma 1
(5)	guo 4	qian 2	gong 1
(6)	yao 4	jian 4	jin 1
(7)	li 3	ba 1	lao 3
(8)	mu 3	men 2	jian1
(9)	na 3	ni 3	xiang 3
(10)	na 3	ta 1	tai 4

Rime oddity.

Instruction:

请翻到下一页。

好了，现在我们来做一点点变化。在下面每组的三个字中有两个字后面部分的发音相同, 还有另外一个字后面部分的发音和他们不同。这一次，我想请你找出后面的发音与其他两个不同的那个字，并在相应的数字上画圈。记住，是找出后面的发音不同的那个字。

Practice items:

练习 1：wan 1 **gong 1** ban 1

哪个字后面的发音和其他两个不同呢？正确答案是 2。

练习 2： di 4 bi 4 **zhu 4**

哪个字后面的发音和其他两个不同呢？ 正确答案是 3

好了，下面我们正式开始。

Test items:

(1)	sui 4	bu 4	fu 4
(2)	wen 2	mang 2	ren 2
(3)	dong 1	si 1	gong 1
(4)	qu 4	xian 4	nian 4
(5)	ben 3	hen 3	jin 3
(6)	ting 1	jia 1	jing 1
(7)	li 3	liang 3	qi 3
(8)	ban 4	han 4	wai 4
(9)	dao 1	yao 1	jian 1
(10)	da 3	fa 3	you 3

Tone oddity.

Instruction:

请翻到下一页。

在下面每组的三个字中，有两个声调相同，还有另外一个与他们不同。请你把声调不同的那个字找出来，并在相应的数字上划圈。记住，是找出声调不同的那个字。

Practice items:

练习 1：ba 1 **de 2** chi 1

哪个字的声调与其它两个不同呢？正确答案是 2

练习 2：**cha 4** bai 2 guo 2

哪个字的声调与其它两个不同呢？正确答案是 1

好了，下面我们正式开始。

Test items:

(1)	wen 2	he 2	dui 4
(2)	shi 2	gui 4	mei 2
(3)	cong 2	yi 3	xie 3
(4)	xiao 3	cai 2	nan 2
(5)	hen 3	si 1	liang 3
(6)	ying 2	han 4	jia 2
(7)	lei 4	xian 4	lao 3
(8)	san 1	shi 1	da 4
(9)	mang 2	shu 1	hua 2
(10)	bu 4	jian 1	di 4

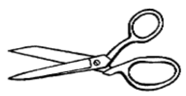
Oral Vocabulary Test (PPVT-III)

English Instruction

This test is to measure whether you know the English names of some pictures. Let's take a look at these pictures. See, there are four pictures in a row. Each of them is numbered 1, 2, 3, and 4. I am going to say a word, and then I want you to circle the number of the picture that best tells the meaning of the word.

All right, let's try one.
Look at these four pictures. What number is the picture that best tells the meaning of **"parrot"**?
Very good! The answer is 2.

Practice

 (1)	 (2)	 (3)	 (4)

Now, please turn to the next page. Like what we just did, every time I say a word, I want you to circle the number of the picture that best tells the meaning of the word. You may not be sure if you know the meaning of some of the words. Still, you need to look carefully at all of the pictures and guess the one you think is the correct answer. Please turn to the next page. Ready? No.1…

Chinese Instruction

下面你会看到一些图片，我想看看你知不知道它们代表的意思。你看，在这里每一行有四张图，每幅图下面标着 1，2，3，4。首先我会读一个词给你听，你要从这里面选出一张符合我刚刚读的那个词的意思的图片，也就是说那张图能够表示那个词的意思呢？然后在图片下面的数字上划圈就可以了。

Practice 好，现在先来跟我做一个练习。
请看这四张图，哪张图是“哭”呢？
答案是 4，你选对了吗？

现在你明白了吧！下面我们就正式开始了，每个词我只读一遍，所以你一定要仔细听，然后以最快的速度把图片挑出来，并在下面的数字上划圈。遇到不知道的题目时，你要大胆地猜一猜。好了，下面我们正式开始。请翻到下一页。

Test items

Item number	English Items	Chinese Items
1	nostril	农场
2	vase	地球仪
3	island	城堡
4	flaming	宇航员
5	palm	吃惊
6	deflated	仙人掌
7	clarinet	椭圆
8	exhausted	独木舟
9	pitcher	竖琴
10	vine	骑士
11	inhaling	信封
12	applauding	海岸
13	demolishing	争吵
14	snarling	计算
15	compass	牙医
16	astonished	长方形
17	microscope	下巴
18	archery	跳水
19	assisting	摄像机
20	salutation	降落伞
21	coast	挑选
22	banister	钩子
23	irregular	大脑
24	consuming	蜘蛛网
25	easel	孔雀
26	ladle	制服
27	liberated	液体
28	aviation	蔬菜
29	cultivating	红绿灯
30	currency	车辆

Real Word/Character Naming (Adopted from Wang et al., 2006)

English Instruction

"You're going to see some words on cards and I want you to say these words aloud as best as you can. You may not know all the words, but look at each of them carefully and try your best. Let's practice… "

Practice Items

good happy car
polynomial frequency

Test Items

1	in	19	contagious
2	cat	20	triumph
3	book	21	alcove
4	tree	22	bibliography
5	how	23	horizon
6	animal	24	municipal
7	even	25	unanimous
8	spell	26	benign
9	finger	27	discretionary
10	size	28	stratagem
11	felt	29	seismograph
12	split	30	heresy
13	lame	31	itinerary
14	stretch	32	usurp
15	bulk	33	irascible
16	abuse	34	pseudonym
17	contemporary	35	oligarchy
18	collapse		

Chinese Instruction

现在我要让你看一些字，我要你把这些字大声地读出来。你可能不知道所有这些字，但是请你仔细看每一个字，尽量读出来。我们先来练一练。

Practice Items

人　　上　　三

Test Items

1	天	21	老师
2	明	22	左面
3	儿	23	同学
4	坐	24	你们
5	风	25	花园
6	笔	26	大家
7	生	27	雪花
8	说	28	身体
9	她	29	秋天
10	也	30	四季
11	游	31	再见
12	习	32	喜欢
13	再	33	教室
14	快	34	高兴
15	爷	35	唱歌
16	是		
17	虫		
18	热		
19	外		
20	想		

Reading Comprehension Task (Adopted from Robertson, 2001)

English Instruction

Now you will read some stories and answer questions about what the stories say. On the next 4 pages, there are 4 stories. Read each story and then answer the questions about what the story says. All of your answers should come from what the story says. Keep working until you have finished the last story. There is only one correct answer for each question. Don't spend too much time on any one question. If you can't answer a question, skip it and come back to it later. Try to answer as many questions as you can. Are there any questions?

(After 15 minutes) Stop working. Time is up. Turn to the next page.

Chinese Instruciton

这里有一些中文的句子，在每句话下面都有四幅图，请你找出最能表示句子意思的那幅图。并把这幅图圈出来。

看第二句话，并把最能表示句子意思的图圈出来。（等所有学生做完）
现在翻到下一页， 看第三提，并把答案圈出来。（以此类推，直到做完 6 句话）

现在你要读一些中文的小故事，读完故事后，你要回答一些与故事有关的问题。下两页中，一共有 3 个故事，你要把他们都做完。所有的答案都与故事有关，每个问题只有一个正确答案。有一些字的后面标了汉语拼音，还有一些字你可能不认识，请你尽量根据你认识的字来猜故事的意思。请你尽量回答所有的问题。
(开始计时)
(After 15 minutes) 时间到。

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