English compound word processing:

Evidence from Mandarin Chinese-English bilinguals

by

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English compound word processing: Evidence from Mandarin Chinese-English bilinguals

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Abstract

Much research has focused on the how monolinguals process morphologically complex words. However, there has been less research that focuses on how bilinguals process morphologically complex words in their L2. This study investigated how bilinguals process English noun-noun compound words. Processing was investigated using a masked priming word recognition task in high-proficiency Mandarin Chinese-English bilinguals (Chinese is their native language and English is their second language). Participants made visual lexical decisions to compound word targets preceded by masked primes which were second constituents of the compounds, sharing either 1) a semantically transparent morphological relationship with the target (e.g. *bone-cheekbone*), which is called the transparent condition; 2) an apparent morphological relationship, but no semantic relationship with the target (e.g., *moon-honeymoon*), which is called the opaque condition; 3) an orthographic relationship with the target (e.g., *plate-birthplace*) , which is called the orthographic condition; 4) a direct translation in Chinese of the second constituent of the target (e.g., *纸(paper)-newspaper*), which is called the Chinese condition. The results showed that the transparent and Chinese conditions produced significant priming effects, but the opaque condition and orthographic condition did not. Regarding the processing of morphologically complex words, this study provides some evidence that Mandarin Chinese-English bilinguals used a decompositional route for transparent compound words, but whole word processing for opaque compound words. The priming effects found in the Chinese condition suggest that when Mandarin Chinese-English bilinguals process their second language, their first language is also activated.

Key words: compound words, Mandarin Chinese-English bilinguals, decomposition, masked priming

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Introduction

The processing of morphologically complex words has been focused in both in linguistic and psycholinguistic research over thirty years. These complex words have orthographic or phonological information, as well as morphological and semantic information. Researchers want to know how each piece of information is involved in whole word processing. How these features are stored and how the meanings of words are computed in the mental lexicon are critical questions in natural language processing. Moreover, the research on morphologically complex words focuses on the monolingual speakers. A few studies such as Lehtonen et al., (2003, 2006) and Silva & Clahsen (2008) are related to the processing of morphologically complex words in second language learners. However, these studies and focused on the inflectional or derivational words in L2.

In this study I will focus on the processing English compound words in Mandarin Chinese-English bilinguals. Not only do compound words provide the unique opportunity for examining the nature of morphologically complex words, but also compound words are productive in both languages.

In this thesis, I will provide a linguistic description of morphologically complex words in Chapter 1 and introduce recent research on morphologically complex words in psycholinguistics in Chapter 2. My goal is to explain how bilinguals process the target language in their mental lexicon; therefore, I will investigate the bilinguals' lexicon in Chapter 3. Based on the previous literature review, I will propose my hypothesis, design and methods in Chapter 4 and Chapter 5 respectively. In Chapter 6, I will provide the results and in Chapter 7, I will discuss how the bilinguals process the different compound words in different ways. (They used morpheme-based processing for transparent compound words and whole-word processing for opaque compound words.)

Chapter 1

The Linguistic description of morphologically complex words

1.1 Overview

In order to understand morphologically complex words, first the differences between monomorphemic words and morphologically complex words must be explained. In monomorphemic words, orthographic/phonological and semantic information can be found, but not much morphological information (there is a zero morpheme relationship); for example, *cup* includes the phonemes and the semantic meaning, which is a kind of container that looks like a bowl. In morphologically complex words, there are orthographic and phonological, semantic and morphological representations. For example, in *cups,* there are four types of representation: 1) the orthographic representation, 2) the morphological representation, *cup* with the plural form */s/* ; 3) the semantic representation, which is means a kind of container that looks like bowls; and 4) the phonological representation, according to the characters (voiced vs. unvoiced, or special consonants) of the last consonants, /s/ will be changed into a different allophone----- *[z], [əz], [s]* based on the phonological rule. The difference between monomorphemic words and morphologically complex words is the existence of multiple morphemes, which are combined by a morphological rule for complex words, e.g. *cups* (*cup* plus a plural suffix /s/). In morphologically complex words, one morpheme provides the central meaning of the words and the others will serve to modify this meaning (Spencer 1991: 5).

Traditionally, there are three main categories in morphologically complex words: inflectional-affixed, derivational-affixed, and compound words. Inflectional words do not change word forms from one syntactic category to another. The inflectional words are the different variants of the same syntactic categories; for example, *work* has several inflectional forms: *worked* (past tense), *worked* (past tense participle), *working* (continuous participle), but the category of each form is still a verb. Derivational words sometimes change the syntactic category of words, for example, *govern*+ *ment*---*government*. When the suffix -*ment* is added to the stem verb, the meaning is changed and the word category changes from a verb to a noun. The focus of this research is compound words; therefore, derivational and inflectional words will not be discussed in detail.

1.2 Compound Words

One category of morphologically complex words is compound words: two words combined and yield a new meaning. A compound word has the function of that a single word has in sentences. Compound words are different from inflectional and derivational words because in compound words, two constituents are words that exist now or existed historically and the constituents of the compound words are mostly from open-class word sets in a language. However, in derivational or inflectional words, the stems or roots exist independently in the mental lexicon and affixes are the close-class word sets in the language.

1.2.1 Compound words in English

Compound words in English have many variants, including noun compound words, verb compound words and adjective compound words. Nouns combine with adjectives, nouns, verbs, or prepositions to make noun compound words where the rightmost words are nouns. Therefore, noun compound words include several types: noun-noun compound words (*cheekbone*), adjective-noun compound words (*blackboard*), preposition-noun compound words (*upside*) and verb-noun compound words (*washroom*). In the CELEX database (Baayen, Piepenbrock, & van Rijn, 1993), there are 1,437 noun-noun compound words (Libben, 2005). This research focuses on noun-noun compound words because they are one of the most productive classes that form compound words in English. The noun-noun compound word in this study consist of two free morphemes, which have two elements where each element is a monomorpheme, because it can be easily found cross linguistically and it gives a direct test for the relationship between the storage and computation in the mental lexicon.

When compound words are taken into consideration, the headedness, which is one of the constituents that determine semantic meaning and word category of the whole compound words and the transparency of compound words, which explains the relationship between constituents and compound words, will influence the processing of compound words. In this project, the transparency of English compound words will be manipulated in order to narrow down the research scope, because transparency and headedness will influence the lexical processing.

1.2.1.1 Headedness of compound words

The head determines the basic properties of compound words. The word-class category of the head can be the same category as the whole compound. Mathews (1974: 82) used the following formula to explain compound words.

$[X]_{\alpha}+[Y]_{ß} \rightarrow [X+Y]_{ß}$

If compound words have heads, according to the formula $[X]_{\alpha}+[Y]_{ß} \rightarrow [X+Y]_{ß}$, the word class of ß is the same as the word class of compound words. ß is equal to the head of the compound words. In most cases, English compound words abide by the Right Hand Head Rule (RHHR). Therefore, the category of ß determines the category of compound words, but there are some compound words without definite heads or equal heads. Neither of the constituents can determine the basic properties of compound words or both constituents have the same contribution to compound words (*honeymoon* is neither *honey* nor a *moon*). A compound that has one element as the head of the whole compound is called an endocentric compound word. Most English compound words belong to the category of endocentric compound words (Spencer 1991: 310).

1.2.1.2. Transparency

In terms of the semantic criteria of compound words, compound words can be divided into two categories when transparency is considered. One is transparent compound words (compositional compound words), in which the whole meaning of compound words can be derived from their elements; for example, *cheekbone* is a *bone* at the top of the *cheek*. Another is opaque compound words (non-compositional compound words), in which the semantic meaning is outside of elements or they have to be inferred from the elements; for example, *honeymoon* is neither *honey* nor *a moon*.

According to Libben et al., (2003), English compound words exhibit a range of transparency from fully transparent compound words to fully opaque compound words.

a. Both elements of compound words are transparent (TT); for example, ‘cheekbone’ is a kind of bone.
b. The head element of compound words is transparent, but the non-head element is not transparent (OT); for example, ‘strawberry’ is a kind of berry but not directly related to the meaning of straw.
c. The head element in compound words is not transparent, but the other one is transparent (TO); for example, ‘jailbird’ is related to jail but not bird.
d. Neither of the elements is transparent (OO), and it is called opaque; for example, with ‘honeymoon,’ neither of the constituents contributes to the whole meaning of ‘honeymoon.’

Especially in psychological research, the different transparency of the morphological complex words has an influence on the processing and representing of the words in mental lexicon (Marslen-Wilson et al., 1994).

1.2.2 Compound words in Mandarin

Compound words are common phenomena in all languages and very productive (Jarema, 2006). Unlike English, which is an inflectional language, Mandarin Chinese is an isolating language, in which each character represents one morpheme. The language has more than 6000 different characters (morphemes) for high-level, scholarly literacy and 400 syllables with four distinct tones (Taylor & Taylor 1995: 89). Therefore, the majority of morphemes can be words or morphemes at the same time. Some morphemes are words in one situation and, in another situation; they are morphemes (Taylor & Taylor 1995: 35). Chinese has few inflectional and derivational words but more compound words (Li & Thompson 1981: 10-11). Even though the distributions of morphologically complex words are different in different languages, they also share similarities; for example, noun-noun compound words are common in both English and Chinese, and syntactic properties are similar to each other.

There are a massive number of compound words in Mandarin Chinese. Disyllabic compound words constitute 73.6% (by token) and 34.3% (by type) of a corpus (by the Institute of Language Teaching and Research, 1986, see Zhou 1994). In other words, 73.6% (by token) disyllabic words among the corpus of 1.3 billion words are compound words. Nowadays, most morphemes and characters are reused again to make new compound words (Zhou, 1994).

Chinese compound words consist of two or more free or bound roots (Packard, 2000:80). In Mandarin, some morphemes are free in some usages, but bound in other usages. Bound roots combine with other bound morphemes or free morphemes to create new compound words, which is the largest class of Chinese compound words. Free morphemes can also be constituents of Chinese compound words; in this case, Chinese compound words are similar to English compound words. My focus is noun-noun compound words that consist of two free morphemes in Chinese. Noun-noun compound words comprise 54 % of the many types of two-syllable nouns (Huang 1998). Chinese noun-noun compound words have a similarity with the compound words in English, regardless of language categories.

1.2.2.1 Headedness of the Chinese compound words

According to Huang (1998), noun compound words in Chinese abide by the RHHS (Right Hand Head Rule) rules, but there are some exceptions, in which the heads of the noun compound words are in the left position, or neither. For example, in *guotie* ('pot-sticker, fried dumpling'), the head is in the left position of the compound and in *dongzuo* (move-do 'movement, activity'), the head is in neither the right nor the left position, because the semantic meaning of *dongzuo* is outside of the compound word; in other words, neither of the constituents can provide direct meaning of the compound. In order to examine the headedness of Chinese compound words, Huang (1998) used the 1001-page *Guoyu Ribao Cidian* [A Dictionary of the *Mandarin Daily*], selecting 24,000 disyllabic compound word entries, analyzing the possible role of the head of Chinese compound words. Chinese compound words have a different type of headedness when the right-headedness or left-headedness is considered. However, noun compound words are significantly right headed (Packard 2000:194; Huang 1998). This is similar to noun-noun compound words in English.

1.2.2.2 Transparency of Chinese compound words

Few studies have investigated the transparency of Chinese compound words. Liu and Peng (1997) investigated the Chinese compound word processing, in which compound words are fully transparent and fully opaque. They used a semantic priming paradigm with SOA (Stimulus Onset Asynchrony) with 43 ms. They found that the fully opaque compound words did not produce the priming effects; for example, the fully opaque compound, 马上 ([horse, up] 'immediately'), did not produce priming effects when the target word, 绵羊 ([silky soft, sheep] 'sheep'), even though horse and sheep are semantically related to each other. However, the fully transparent compound words can prime the target compound words; for example, 背叛 ([hide something from; betray] 'betray') facilitated processing of the target compound words 覆盖 ([cover; cover] 'cover') because the first constituents are semantically related. In addition, Myers et al. (2006) categorized the Chinese compound words as TT, OT, TO, and OO. Chinese compound words have similarity with English compound word in terms of transparency.

1.3 Summary

English and Chinese both abide by RHHR, even though there are small exceptions in Chinese noun-noun compound words. Both languages have transparent compound words and opaque compound words. The similarities between the two languages give us information about how the Mandarin Chinese-English bilinguals process English compound words and what the role of morphology is in L2 learners. Especially, Mandarin Chinese-English bilinguals share the same lexicon for both languages or have a different lexicon for each language. I will discuss this in Chapter 3.

1.4 Compound words: why are compound words selected?

Compound words might have two representations in the mental lexicon: as whole words that look like mono-morphemic words or as combined words with two or more monomorphemes (Libben, 2006). Libben (1998) mentioned that an aphasia participant can explain compound words with combined style: as whole words and by constituents; for example, for *butterfly,* the aphasia RS explained it as *a kind of pretty fly*, in which the whole meaning is activated and also explained it as *yellow*, in which the *yellow* is related to constituent *butter*. From the aphasia's evidence, compound words can be stored in the mental lexicon as whole words (*a kind of fly*) or by their constituents (*yellow*). Again, compound words consist of two or more constituents, which are almost open class words; however, the stems of the inflectional and derivational words are open class words and affixes are closed class words. In the consideration of the representation of the morphologically complex words, both constituents of the compound words are almost at the same baseline in representation or processing. Therefore, I think that compound words will give a direct test representation of morphologically complex words in the mental lexicon.

Chapter 2

Psychological research on morphologically complex words

Psychologists have studied morphologically complex words to determine how complex words are represented and stored in the mental lexicon. As discussed earlier, morphologically complex words provide evidence for the basic issue of the processing in the mental lexicon. When researchers explain the processing of words in the mental lexicon, they cannot avoid morphologically complex words, because morphologically complex words are essential for connecting lexicon and incoming signal, which is speech or visual information (Zwitserlood, 1994). For researchers, there is no debate that the role of the semantic features of the words is represented in the mental lexicon; however, the problem is whether morphological properties of words are represented in the mental lexicon.

This has been debated for more than 30 years, since Taft and Forster (1975) proposed the first experiment and claimed the role of morphology in mental representation. Since Taft and Forster (1975), there has been extensive research about the role of morphology in word recognition. The majority of experimental research (Marslen-Wilson et al., 1994; Fiorentino, 2006; Libben, 1998; and Zwitserlood, 1994, among others) accepts the independent role of morphology in lexical processing. Some researchers (Plaut & Gonnerman et al., 2000; Butterworth, 1983, among others) do not accept the independent role of morphology, or they think that 'morphological effects' are the results of processing of semantic and orthographic information. Some researchers (Carammaza et al., 1988) take a moderate approach to explaining the existence of morphology in lexical processing. They accept both explanations about the role of morphology in lexical processing. Until now, the experimental research in the processing and representation of morphologically complex words has not been conclusive (Zwitserlood, 1994). The basic question for morphologically complex words in the mental lexicon focuses on the existence of morphological level representations in the mental lexicon. On the other hand, the main issue is that morphological representation is separated from semantic and phonological representations in the lexical representation.

2.1 Theoretical background

A number of theories have been proposed to address the issue of lexical representation of morphologically complex words. Here, I will focus on three theories and how they explain the role of morphology in the lexical representation.

2.1.1 Decompositional theory

The basic idea of decomposition theory is that it assigns a morphological role in lexical processing. In other words, a morphologically complex word is represented in the mental lexicon by its stem or constituent. Taft and Forster raised this issue in 1975, and they proposed the 'full parsing theory.' They suggested that morphologically complex words are decomposed before lexical access occurs.

Taft & Forster (1975) investigated morphologically complex words. Their focus was on derivational-affix words. In order to test their hypothesis, they manipulated the stems of derived words. In experiment 1, they used non-words such as non-real stems (*depertoire*) with prefixes and non-words with the real stems (*dejuvenate*) and in experiment 3 they also used non-words consisting of the real stem with a prefix (*uncorn*), in which the real stems and real prefixes were mismatched in the mental lexicon and non-words that consist of not real stems with prefixes (*depertoire*) .They thought that if words were decomposed before lexical access, the non-words with non-stems would be much harder than the non-words with real stems. They found that non-words with non-real stems and mismatched non-words were much more difficult for participants to recognize because the both non-words are decomposed and the non-words that have real stems will facilitate the lexical decisions. Overall, the results that participants have a hard time processing the non-words with non-real stems compared to non-words with real stems supported the hypothesis that the morphological decomposition happens in the mental lexicon and that the locus of the decomposition was prior to the lexical access. Now, this phenomenon is called the early-decomposition theory, in which the morphological decomposition happens before the lexical access, as opposed to a late-decomposition theory, in which morphological decomposition happens after the lexical access.

Taft and Forster (1976) extended their research to non-word compound words using the same paradigm. In their experiments, non-word compound words are of four types: word-word compounds (WW, e.g. *brieftax*), word-non-word compounds (WN, *cleanmip*), non-word-word compounds (NW, *thernlow*) and non-word-non-word compounds (NN, *spilkwut*). In the lexical decision task data, they found that non-word compound words were decomposed before lexical access. From the result of the four types of non-word compound words, the first constituents are very critical and the second constituents are irrelevant for the processing. This is because the reaction time (RT) for non-word compound words, in which the first constituents are words and the second are non-words (WN, *cleanmip*), or where both of them are words, but mismatched (WW, *brieftax*), is longer than for the ones, in which the position is reversed (NW *thernlow* and NN *spilwut*). They concluded that first constituents of compound words are a critical point for lexical access. Their results supported the early-decomposition theory of lexical access. Later (1986, cited from Taft 1991), they modified their explanation. They compared lexical decision responses between the reversed compound words (*berryblack*) and word-word compound words (*brieftax*). They found that the former had longer reaction times and more errors than the latter. If the second constituents of compound words had no role in processing, the reversed compound words should have short latency for lexical access, but they do not. Therefore, second constituents are also activated in the lexical processing. All these experiments support the idea that there is decomposition of morphologically complex words in online processing. However, the theory did not escape challenges by other theories.

2.1.2 Non-decompositional theories

Some theorists suggest non-decomposition theories. The main idea of these theories is that there is no independent role of morphology in the mental lexicon. Butterworth (1983) proposed his ‘full-listing theory’ in which there is no morphological decomposition level and all words are processed in the lexicon the same as monomorphomic words (one variant, among others including the connectionist model). He argued the *full parsing theory* is unable to explain the representation and storage of idiosyncratic words. For example, in *honeymoon*, the semantic meaning cannot be derived from the subparts of the compounds. According to this theory, morphologically complex words are treated as whole words, not as constituents or subparts in the mental lexicon. He supported the theory using evidence from speech production, perception and reading. The most consistent and extensive research came from reading. He used the example *kick the bucket*, in which participants judge the idioms (*kick the bucket*) more quickly than matched phrases (*kick the person*). It means that idioms are stored and represented as whole items or lexical items rather than as phrase structures.

Starting in the 1990s, there was a new explanation for processing morphologically complex words. Plaut and Gonnerman (2000) used the distributed connectionist model. This model said that morphological effects are the cumulative results of the semantic and orthographic effects. Therefore, according to this idea, there is no explicit morphological representation. The 'morphological effect' is the result of meaning-form mapping. There are only semantic and orthographic/phonological representations in the mental lexicon. The model can explain transparency differences in representations. Some morphologically complex words are neither fully transparent nor fully opaque. If the semantic relationship will change according to transparent to opaque words, then the gradient changes of priming effects from transparent to opaque to orthographic explain the semantic role in the processing. In other words, if morphological effects are cumulative effects of semantic and orthographic effects, the 'cumulative effects' will change according to semantic and orthographic similarity between targets and primes. The cumulative effects will be bigger when the relationship between target and prime are fully semantically related and orthographically similar to each other. In that case, morphologically, semantically and orthographically related primes and targets will produce very strong accumulative effects. The *full-parsing theory* is unable to explain the differences between the transparent and opaque words. The connectionist model, one implementation of a *full-listing theory*, showed that morphological effects can be predicted from the semantic and orthographic, or phonological, representations. Both the *full-listing theory* and connectionist theory suggest that morphology has no independent role in the mental lexicon.

2.1.3 Hybrid theories

A final group of theorists developed the *hybrid theories*. The basic idea is that morphologically complex words can be processed either as morphemes or as whole words. One robust model of the hybrid theories is the *AAM* (Augmented Addressed Morphology) model, proposed by Caramazza et al. (1988). An independent role of morphology in the mental lexicon depends on the places of the affixes, inflectional, derived or compound words and the transparency of the words. For example, *walked* is activated via root by *walk* and *-ed* separately and *went* will be activated by whole word processing (whole word route). Caramazza et al. also assumed that whole-word representation proceeds more quickly than morpheme-based activation. They compared the *full-parsing* and *full-listing theories* with the *AAM theory*. In three experiments, they manipulated verbal inflectional forms of Italian in lexical decisions. They used four types of non-words: 1) morphologically legal (ML) non-words, in which the verb stem plus decomposable affix (e.g. *cant+evi*, in which *evi* is a 2^{nd} person singular past tense); 2) morphologically illegal non-words (MI), in which the non-words are not decomposable, (e.g. *conzavi*, in which neither root nor affix is real root or affix in Italian); 3) stem only (SO), in which the stem is a legal root but affix illegal one (e.g. *canovi*); 4) affix only

(AO), in which the affix is a legal one, but the root is not (e.g. *canzevi*). They assumed three predictions that related to the effects of morphological structure for non-words. The *full-parsing theory* predicts differences between the non-words in the lexical decision in the first two types of non-words but not the SO and AO type non-words. The *full-listing theory* predicts that there is no difference between words and non-words, because there is no stripping the affix from the stem, whatever stem and suffix combination is legal or illegal in that language. All of them are non-words; therefore, the morphological structure of non-words does not influence participants' response time. However, the *AAM theory* predicts the morphological effects only for non-words. In order to test their hypotheses, they extended and replicated Taft and Forster's (1975) experiments and found (experiment 1 and 2) that the presence of morphological structure in non-words influenced the lexical decision. In other words, if the non-word includes the real stem (presence of morphological structure), participants will respond faster than to the non-words with non-real stems. In experiment 3, they manipulated the irregular inflectional verbs in Italian, because in the previous experiments (experiment 1 and 2), the morphological structures were explicit and decomposable. In experiment 3, the morphological structure of Italian irregular inflectional morphology is implicit and non-decomposable. The three experiments showed the morphological structure of the non-words affected the lexical decision task. Therefore, this model is good for predicting the representation of the regular and irregular verbs in the mental lexicon.

Overall, most research on morphologically complex word processing can be ascribed to one of two extreme theories. One is decomposition, which is supported by the decomposition (*full-parsing theory*), or dual-route model, in which there is an independent morphological level of representation or storage in the mental lexicon. The other is non-decomposition (atomism), which is supported by the *connectionist* or *full-listing theory*, in which there is no morphological representation or storage in the mental lexicon. The basic issue focuses on the role of morphology.

2.2 Previous research on compound words

Since Taft and Forster (1975) first used lexical decision in morphologically complex words, lots of research has been focused on the morphologically complex words. I will introduce the research on compound words with lexical decisions.

2.2.1 Lexical decisions

Lexical decision tasks are used in word recognition research. Researchers use reaction times and errors to deduce the structure of the mental lexicon. In a lexical decision, participants decide if sets of letter strings are words or non-words. Target words or non-words are morphologically complex words, which are inflectional, derivational or compound words. In lexical decisions, two major effects focused on in this literature are: priming effects and frequency effects.

2.2.1.1 Priming effects

In current research, a very commonly used technique in lexical decision tasks is a priming paradigm. The typical priming paradigm includes two stimuli that are presented, one after another (Forster & Davis, 1984). The first one is counted as a prime and the second as a target. Participants make a decision whether a target is a word or non-word.

The priming paradigm includes two subtypes in terms of the time-course: long-lag priming, where there are several (unrelated) items or an interval time between a prime and a target, and an immediate priming, where there is no item between a prime and a target. The latter is more frequently used than the former. Immediate priming also has two subtypes: masked priming and unmasked priming (Forster et al., 2003). Researchers record the RTs (response times) or errors of the participants for the targets that are immediately after the prime. Researchers manipulate the relationships between the prime and target to get different priming effects, in which a prime might or might not facilitate the identification of the target. In monolingual language research, the prime and target have several relationships: 1) a phonological/orthographical relationship, in which the prime and target are orthographically similar to each other; 2) a semantic relationship, in which the prime and target have a semantic association; 3) a morphological relationship, in which the prime and target share morphemes; and 4) an identity relationship, in which the prime and target are the same. The logic is that if researchers obtain independent morphological priming effects, the result should be attributed to the morphological structure between a prime and a target. Morphological priming effects provide evidence for the inner structure of the mental lexicon.

A. Unmasked priming

The pattern of the unmasked priming paradigm is 'prime-target-response.' In a lexical decision with unmasked priming research, repetition-priming effects were reported by many researchers (Murrel & Morton, 1974; Marslen-Wilson et al., 1994). Murrel et al. (1974) found the morphological effects in repetition priming. In that research, there were two stages: one was study and the other was test stage. In a morphological priming condition, words are identified faster in morphologically related primes (*cars* at study list, *car* at test) than in orthographical related primes (*card* at study, *car* at test).

In lexical decision tasks, Zwitserlood (1994) used the immediate constituent-repetition priming and semantic priming paradigm to test compound words in Dutch. Zwitserlood (1994) used compound words as primes and the constituents of compound words as targets. For example, for *bird*, she had two kinds of compound words as primes: one is *kergorgel* (*church organ*), which are transparent compound words; another is *drankorgel (drunkard),* which are opaque compound words in Dutch. The results showed that all morphological related conditions had facilitated priming effects. She also used an orthographic word condition, in which the constituents of compound words were primed by orthographically similar words but the constituents did not have positive priming effects. Especially in opaque compounds (majority is partially opaque, a few are truly opaque), the facilitated effects showed that, even though there was no semantic relationship between the target and prime, all morphological relationships produced facilitated priming effects regardless of transparency. In the semantic priming paradigm task, based on the first experiment, he added the truly opaque compound words and pseudo-compound words in Dutch. However, in experiment 1, the targets were both constituents of the compound words, but in the semantic priming condition (experiment 2), the targets were semantically related words of both constituents. She found that both fully (TT) and partially (TO) transparent items caused significant priming effects for the target constituents. However, the truly opaque compound words (OO) and pseudo-compound (carpet) words did not produce the priming effects. This seems a contradiction between the first and second experiments, but in the first experiment, the opaque compounds are mostly partially opaque compound words. However, in experiment 2 the truly opaque and partially opaque compound words were separated. The results suggested that compound complex words that are transparent or partly opaque compound words are decomposed before they are activated.

B. Masked priming

Forster and Davis (1984) proposed the masked priming paradigm, which yields different results in morphologically complex words. In this paradigm, the prime is presented on the screen for about 60 ms; immediately after, there are target words that follow. Participants make lexical decisions for target words as words or non-words. In most cases, a prime and a target used different letter cases or different sizes. There are two different categories in masked priming: one is forward masked priming, in which some symbols or hash marks (#####) are presented before the prime; another is backward masked priming, in which some symbols or hash markers are also presented before the target. Both kinds of masked priming reduce the possible influences of the prime on the target. For example, with masked primes, participants will respond to targets less frequently based on their visual effects or short-term memory.

Shoolman and Andrews (2003) used masked partial repetition priming (forward mask) for English compound and non-compound words. In the compound word set, they used four types of compound words: transparent compound words (*bookshop*); partially opaque compound words (*jaywalk*); pseudocompound words (*hammock*), in which two constituents serve as free morphemes, but do not serve as constituents in the compound words; and mono-morphemic words (*fracture*). All compound words were targets and their first or second constituents were primes. For non-words, there are two sets of non-words such as W-W non-word (*toadwife*) and NW-NW non-word (*skensile*). In order to test the strategic influence on morphological decomposition, they used two conditions in non-word items. First is an unbiased context condition, in which the non-word compound words consisted of NW-W or W-NW; beside these common non-words, they also used the W-NW non-word (*budroce*) and NW-W non-words (*stelstop*) to test the first and second constituents' role in the processing. Second is a biased context condition with reserved compound words and an associated one (*startstop*), in which they changed one of the constituents of the compound word to its associated part or changed the position of the original compound word (*budrose*). Moreover, they also control the proportion of W-W non-words in unbiased and biased contexts. In the unbiased context, they did not encourage the participants to use the combination of words; because there were only 25% non-words with real morphemes. In the biased context, because 75% non-words have real morphemes, such as combinations of W-W non-words, they encouraged participants to use the word combination. They found that in unbiased conditions, compound words were faster than the non-compound words, regardless of their first and second constituent primes. On the other hand, in the biased condition, the response times for all word types were equal to each other. However, there were accuracy-priming effects for compound words compared to non-compound words which are just the opposite of the unbiased context condition. Participants might use the strategies of word combination in a biased condition. Overall, they found that priming effects were greater for compound words than non-compound words in both conditions (biased and unbiased).The results suggested that there was some form of morphological representation in lexical processing.

Recent research supports the decomposition theory in English compound words. Fiorentino & Fund-Reznicek (2009) investigated morphological decomposition in compound words using a masked priming paradigm. They manipulated the English compound words as transparent (*flagpole*), opaque compound (*hallmark*) words, and orthographic overlap words (*plankton*) controlling frequency, number of letters and neighborhood effects. In the masked priming paradigm, the compound words are primes and the first (experiment 1) or second (experiment2) constituents are targets. In both of the experiments, they found strong priming effects regardless of transparency of the compound words, but they did not find any priming effects in the orthographically overlapping conditions. The results suggested that decomposition occurs at the early stage of the processing, regardless of the position of the constituents. This result replicated the research of Fiorentino (2006), in which he manipulated compound words (transparent and opaque compound words). He also found the priming effects in both transparent and opaque compound words regardless of position of the constituents.

2.2.1.2 Frequency effects

High-frequency words are much easier to recognize than low-frequency words. Taft and Forster (1976 experiment 5) manipulated the frequency of compound words and their constituents. They controlled the surface frequency of compound words, and changed the first constituents of the compound words in lexical decision tasks. They found that the compound words with high-frequency-first constituents are recognized faster than those with low-frequency-first constituents. Zhou & Marslen-Wilson (1994) used the different frequency (syllable frequency, whole word frequency and constituent frequency) in Chinese compound words. They found that whole-compound-word frequency is dominant in lexical decisions regardless of the constituent frequency and syllable frequency. However, the high frequency syllable in real words slowed down the response times, and this suggested that there was one level for organizing the syllable or morpheme principle; the level was dissimilar from unanalyzed whole-word morpheme representations in the mental lexicon. Juhasz et al. (2003) used lexical decisions (experiment 1) to investigate English compound words. In English compound words, they controlled whole frequencies of the compound words and manipulated the constituent frequencies. They found that the second constituent frequency (the ending lexeme frequency) plays a critical role in lexical decisions. In other words, compound words with high-frequency-second constituents are identified faster than those with low frequency-second constituents. First constituent frequencies come into play when second constituents are low frequencies. Thus, the role of the beginning lexeme frequency is limited compared to the role of the ending lexeme. That result is different from Taft and Forster's (1976), in which the first constituents were significant. At the beginning, they concluded that the first constituents play the most important role; later they switched the explanation and also agreed on the role of second constituents.

To investigate the cross-linguistic similarity, Duñabeitia et al. (2007) used two languages, Spanish and Basque, which have different internal structures in terms of compound words. Spanish is right headed in compound words, whereas Basque is random in headedness. In lexical decisions, they found that frequencies of the second constituents play an important role in response times, both in Spanish and Basque. Therefore, these experiments support the decomposition theory and suggest that compound words are decomposed before lexical access.

Chapter 3

The bilingual mind and its paradigm

Research about the representation of morphologically complex words has been primarily focused on monolingual speakers, and there is less research about how bilinguals process morphologically complex words in their target languages. Before introducing this study's second goal, which is how bilinguals process morphologically complex words in L2 condition, bilingual research on lexical representation and processing will be introduced.

3.1 The Bilingual Lexicon

Over the last half century, researchers have been focusing on the bilingual mental lexicon. Much research on bilinguals is focused on how bilinguals organize different languages in their minds. The basic question about the bilingual mental lexicon is whether a single system of memory exists for two or more languages or whether different systems exist for each language. In other words, do bilinguals have shared or separated language representations in their mental lexicon? There are three types of theories that are related to bilingual mental lexicon (Weinreich 1953: 10). These are: (1) compound bilingualism, in which the two languages are directly related to the one-concept system; (2) coordinate bilingualism, in which two languages share different concept systems and the two different concept systems are related to each other; and (3) subordinate bilingualism, in which the L2 not only depends on the L1 but also is related to the concept system via the L1. The main point of these three theories is whether or not the two languages share the same concept.

Kroll et al. (1994) proposed the Revised Hierarchal Model of lexical and conceptual representation in bilingual memory (RHM). In their model, the bilingual mental lexicon consists of L1 and L2 lexicons and concept level. L1 and L2 share the concept. L1 has more representation than L2 in the bilingual memory. However, the link from L2 to L1 is stronger than the link between L1 to L2. On the other hand, the links from L1 and L2 to concept level are different. The connection from L1 to concept level is stronger than the one from L2 to concept level. The strength of the links is related to the proficiency of L2, relative dominance of L1 and L2.

In their model, development of L2 will influence representation of the L1 and L2 in the mental lexicon. As bilinguals begin acquiring L2, they depend on the lexical connection between L1 and L2. When bilinguals become more proficient in L2, they will develop the connection between L2 and the concept level, but they still keep the lexical level connection between L1 and L2. They suggested that bilinguals share concepts between L1 and L2, but lexicons for L1 and L2 are separated.

At the end of the twentieth century, the research focuses on the models of bilingual lexicon (Obler, 2007) which are selective or non-selective bilingual lexicons. The selective bilingual lexicon model posits each language is activated from its mental lexicon and there is no interactive activation between the different languages. However, the non-selective bilingual lexicon model says both languages are activated and there is an interaction in the concept level between languages.

One of the non-selective models is the *Bilingual Interactive Activation model* (BIA), which was proposed by Dijkstra & van Heuven (1998, cited from the same authors in 2002). In this model, there are four hierarchically organized levels: features, letters, words, and language tags. The activation begins from features through language tags. The first two levels are bottom-up processing; in the third level (the word level), word categories activate the language tags and feed back to the letter level at the same time. In addition to this, in word level activation, word candidates or letters can activate some of the word candidates and letters at the same time they inhibit the other word candidates and letters. The fourth level (language tags) has activation and inhibition processes, in which the related language nodes are activated and non-target language nodes are inhibited. In this model, the resting level activation is influenced by the most recent time the words were used and the subjective frequency of the words. This model is only an orthographic-based model about bilingual mental lexicon; however, it does not include all aspects of bilingual word recognition. Later, Dijkstra & van Heuven (2002) modified the BIA model and proposed the BIA+ model, in which there are phonological and semantic representations. The BIA+ model assumes that word recognition in bilinguals is basically language non-selective processing. When a letter string appears, participants will activate the candidate words from both languages. The letter strings activate all orthographic, phonological, and semantic codes in both languages to represent the words. This model is very good for explaining the interlingual homophones (letter strings are the same for both languages, but have different meanings: for example, *room* in English has the meaning of 'cream' in Dutch) or cognate words (letter strings are orthographically and semantically overlapped in both languages: for example, *rico* in

Spanish vs. *rich* in English in both languages). These issues will be discussed in the following paragraph. This model is based on Roman alphabets. It must also be noted that this model has a mixed L1 and L2 lexicon.

3.2 Priming paradigm

In bilingual research, priming paradigms with lexical decisions are used most frequently. The priming paradigm includes two different types: (1) within-language priming (intra-language priming), in which primes and targets come from the same language; and (2) cross-language priming (inter-language priming), in which one language is used as a prime language and another is used as a target. In other words, L1 primes L2 or vice-versa. Equivalent translations are most frequently used in cross-language priming. It means that the words that are on the primes and targets should be equally translated between the two languages. For example, if a target is L2, there are at least two kinds of prime words: one is a word from the L2 itself, which is within-language priming; another is an equal translation word from the L1, which is cross-language priming. If there is a cross-language priming effect, it gives a direct test about how the two different languages are stored in the memory. However, in bilingual research, there are two types of test items to consider in the bilingual mental lexicon, especially in the cross-language priming: cognates and interlingual homographs.

3.2.1 Cognates

The cognates are a critical factor in determining bilingual structures in the mental lexicon. There is a possibility that bilinguals treat cognate and non-cognate words differently because the cognate words have similar roots. Therefore, in both languages cognate words are similar or overlap orthographically and semantically; for example, *rico* in Spanish versus *rich* in English (Sánchez-Casas et al., 1992). It is easy to produce priming effects between the targets and primes when equal translation priming is used.

The results that non-cognate words produce priming effects are not conclusive. It depends on whether researchers use masked or unmasked priming in their research. DeGroot & Nas (1991) used Dutch-English bilinguals, and they used cognate words and non-cognate words. The priming direction is from L1 (Dutch) to L2 (English).There were two types of priming conditions: one was masked priming (shorter SOA), and the other was unmasked priming. They found the facilitated effects both in cognate and non-cognate words when they used repetition priming with unmasked paradigms. There were repetition priming effects both in cognate and non-cognate conditions in the masked priming condition. One thing is clear: the masked priming paradigm may help to reveal priming effects on non-cognate word pairs. When masked priming is used with the cross-language priming paradigm (L2-L1), the results are different. Sánchez-Cases et al. (1992) used Spanish-English bilinguals with the semantic categorization task. They used masked priming, but the priming direction is from L2 (English) to L1 (Spanish). Priming types were identical, equally translated, and unrelated words. They found that there were no priming effects on the translated condition on the non-cognate words. If the priming pattern from L1to L2 or L2 to L1 is different in the masked condition, the equal translation priming is inconsistent (Jiang 1999).

Not only the priming paradigm (masked vs. unmasked priming) and priming pattern can influence the results, but also different script systems produce different results.

Gollan et al. (1997) examined priming in Hebrew-English bilinguals. Unlike the language pairs discussed above, the Hebrew and English languages have different scripts. Gollan et al. (1997) observed the same priming effects in non-cognate priming as their cognate parts in Hebrew-English bilinguals when the target language is the dominant language. In experiment 1, they used Hebrew-English bilinguals who were dominant in Hebrew; in experiment 2, they used Hebrew-English bilinguals but English was their dominant language. The orthographic characters of both languages might play a role in the bilingual processing. Their results converge with Jiang's (1999) result in Chinese-English bilinguals. Jiang (1999) also observed strong non-cognate priming effects in Chinese-English bilinguals. In Jiang's experiment, he manipulated the Chinese-English translation pairs in five experiments. In experiments 1 and 2, in order to test the asymmetrical cross-language priming, he used Chinese-English (法律 (law)-law)), which is an L1-L2 priming paradigm) and English-Chinese (method-方法 (method)), which is an L2-L1 priming paradigm) repetition masked priming. He found that both Chinese-English and English-Chinese priming produced priming effects in experiment 1, but not in experiment 2, in which he used a new set of materials and participants. He used different SOA (100 ms, 250 ms, and 300 ms) for experiments 3 to 5, and only included the L2-L1 priming paradigm and added English-English pairs in the repetition masked priming. He found that there were no priming effects in the English-Chinese pairs, but strong priming effects in L2-L2 priming. The results were consisted of the generalization that languages with different scripts yield non-cognate priming effects that were not significant when both languages' scripts were overlapped or both languages shared the same scripts to some degree. However, both Hebrew-English and Chinese-English bilinguals had strong non-cognate priming effects when the priming was from their native, or dominant, language to their second, or non-dominant, language. If a prime was a non-native language or a non-dominant language, there were no priming effects between the L2 to the L1. The priming effects consistently exit only one direction, which is from the L1 to the L2.

3.2.2 Orthographic similarity

The orthographic similarity (i.e. interlingual homographs) is a critical factor in determining bilingual structure in the mental lexicon. Interlingual homographs means that the words are identical in both languages, but the meaning is different. Interlingual homographs look like *false friends*. For example, *room* in English means *cream* in Dutch (Dijkstra et al. 2002). Interlingual homographic items in cross-language priming can cause null results compared to the control items, but the cognate items can cause facilitated effects compared to control items. The latter explains that cross-language priming effects (orthographic) and both languages are activated in language processing. However, there is an issue that the interlingual homographic items cannot cause the priming effects. There is activation in both languages, but the meaning of the words is different in both languages; therefore, there are inhibition effects instead of facilitated effects, which cause null results in homographic items. In other words, if the prime and target use different scripts, the orthographies are not the same and do not interact with each other (inhibit or compete with each other). Therefore, there is less inhibition in the different scripts when their related mental lexicon is activated.

3.3 Proficiency of second language

In bilinguals, proficiency with languages is a very critical factor. If proficiency of second language learners is higher in L2, participants are near-native speakers in the L2. Therefore, the structure of the second language may be similar to that of native speakers who speak the L2 as their native language. If the proficiency level is lower, second language learners will have a different structured lexicon than their counterparts who have the target language as their native language.

Kroll et al. (1994) proposed that the proficiency level might influence links between L1 and L2 and links between L1 or L2 to concepts in the mental lexicon. Therefore, the connection between L1 and L2 depends on the proficiency. High-proficiency-level bilinguals do not rely on the L1 language and develop a connection from L2 directly to the concept system. However, low-proficiency-level bilinguals still rely on the L1. It means that, in the early period of acquiring L2, participants rely heavily on equal translation between the L1 and the L2. At the later stage, bilinguals develop a connection between L2 and the concept level. This model highlights the development of L2 in bilinguals.

The researchers found the neurolinguistic evidence for proficiency effects. Perani et al. (1998) used Italian-English late bilinguals with high proficiency (experiment 1) and Catalan-Spanish early bilinguals (experiment 2). Participants listened to an English or Italian story in experiment 1 and a Catalan or Spanish story in experiment 2. After listening to the story, the experimenter asked questions. Brain scanning was executed while participants were listening to the story. Researchers found that high-proficiency bilinguals in Italian-English had similar activation foci at the left anterior middle temporal lobe and the left superior temporal lobe. The results were the same when they used Spanish-Catalan early bilinguals. They argued that proficiency is a more important factor than the age of acquisition; because both high proficiency Italian-English late bilinguals and high proficiency Spanish-Catalan early bilinguals, regardless of age of acquisition, produced the same pattern, in which the left anterior middle temporal lobe and left superior temporal gyrus were activated when participants were processing L1 and L2. From this research, it can be concluded that high proficiency bilinguals have similar structures of their native or dominant language but they don't test lexical processing, they only test comprehension. Moreover, using one language frequently can change the dominance of the language in the mental lexicon. In this research high-proficiency Mandarin Chinese-English bilinguals were considered as participants.

3.4 Issues about the processing of morphologically complex words in bilinguals

Previous research has typically focused on the monomorphomic words, or equal translation between L1 and L2, without considering morphologically complex words. Recently, bilingual researchers have investigated the processing of morphologically complex words in L2 (Lehtonen et al., 2003, 2006; Portin et al., 2007; Silva & Clahsen 2008). How do L2 speakers process morphologically complex words in their L2? Do they rely on their L1 language or do they process it separately from their L1? There are three possibilities: (1) they still depend on their L1 language structure; (2) they transfer the L1 system to the L2 system when they are processing the L2 words; and (3) they process the L2 and the L1 separately, whether the L1 is similar to the L2 or not.

Some research supports different kinds of ideas, respectively. Silva & Clahsen (2008) used masked priming to figure out how native English speakers and German, Chinese and Japanese speakers, whose second language is English, process the English regular past-tense and derivational words. In their research, they used three priming conditions: 1) identity condition, in which the prime and the target were the same, for example, *pray* (prime)-*pray* (target); 2) test condition, the prime and the target had a morphological relationship, for example, *prayed*-*pray*; 3) unrelated condition, in which the prime and target did not have any relationship, for example, *bake*-*pray*. They used regular past tense (experiments 1 and 2, in which SOA =30 ms) and the derivational words, in which the derivational words consisted of stem plus deadjectival suffixes (-ness, -ity) in experiments 3 and 4. If mean RTs in the test condition and identity condition are not significant compared to each other but are significantly different from the unrelated condition, there is full priming effects. If mean RTs in the testing condition are between the identity condition and unrelated condition significantly, the priming is called partial priming effects. If mean RTs are not significantly different from the unrelated condition, then there are no priming effects. They also found that English native-speakers had full-priming effects in regular past tense and derivational words. That means English native-speakers used morpheme-based processing for both kinds of words. However, L2 group speakers were different in terms of inflectional word processing and derivational word processing. In regular past tense conditions (experiments 1 and 2), the second language speakers did not produce priming effects. L2 learners processed regular past tense as a whole word form, not morpheme-based processing; however, in terms of derivational words (in experiments 3 and 4), L2 learners have partial priming effects, not full priming effects as native-speakers had in experiments 3 and 4. The partial priming effects were neither semantic (if semantic, it should occur in experiments 1 and 2, because in these experiments, English regular past tense did not produce priming effects, even though the regular past tense such as *walked* had a strong semantic relationship with its stem such as *walk*.) nor orthographic (differences of orthographic overlap between experiments 3 and 4, because overlap between the target and the prime in experiment 3 was significantly different from the one in experiment 4, but results of both experiments were the same) effects; therefore, the partial priming effects were attributed to the morphological effects. They concluded that second-language speakers depended on more lexical-storage (whole word storage), instead of depending on their L1 system. L2 learners have a similar pattern of processing English inflectional and derivational words regardless of their background.

However, Lehtonen et al. (2003, 2006) and Portin et al. (2007) tried to figure out how the frequency affects morphologically complex words in monolingual and bilingual speakers. They used Finish monolinguals, early Finnish-Swedish bilinguals (Lehtonen et al, 2003) and Swedish monolinguals and early Finnish-Swedish bilinguals (2006) or Finnish-Swedish late bilinguals (Portin, et al. 2007) as their participants. Lehtonen et al. used three different level frequency words in Finnish (2003) or in Swedish (2006). They found that monolinguals and bilinguals who were processing monomorphemic words vs. inflectional words with three different frequency levels were different in their lexical decision tasks. Finnish is rich in morphology; Finnish monolinguals processed low and medium frequency inflectional nouns as morpheme-based recognition, but for high frequency inflected words, they used the full-form recognition. Finnish-Swedish bilinguals used morpheme-based processing for all different frequency levels of inflectional words. Moreover, Swedish is not rich in morphology, and Swedish monolinguals and bilinguals had different processing systems; for low-frequency

Swedish words, Swedish and Finnish-Swedish bilinguals used morpheme-based processing, but for high-frequency words, both groups used whole-word processing. However, for medium-level-frequency words, Swedish monolinguals used whole-word processing but bilinguals used both whole-word and morpheme-based processing. Lehtonen et al. (2006) concluded that not only the frequency and language background but also morphological richness affected the processing of morphologically complex words in bilingual conditions.

From the results of the two sets of researchers, two different hypotheses were obtained. Lehtonen et al. (2003, 2006) suggest that the L2 speakers depend on their L1 system; morphologically complex (inflected words) words are decomposed when they are processing the inflected nouns in L2. However, the idea of Silva and Clahsen (2008) is different than the one of Lehtonen et al. (2003, 2006). Silva and Clahsen (2008) thought the L1 and the L2 processing systems are independent. Therefore, even though English native-speakers used morphologically complex words by morpheme-based processing, the L2 speakers used English morphologically complex words by whole-word processing. There are potential reasons why they have different results on the same topic, which are discussed in the following.

First, they used different paradigms. Lehnoten et al. (2003, 2006) and Portin et al. (2007) used the simple lexical decision task (unmasked). In their experiments, asterisks came first with 500 ms and then 500 ms blank screen, and then a word came up; participants pushed the button to respond to it. When participants finished the first trial, they pushed a third button to begin the next trial. Silva and Clahsen (2008) used the masked priming paradigm with lexical decision tasks. First, a forward mask consisting of several hash markers (###) came out with 500 ms and then prime (SOA = 60 or 30 ms) came out on the screen; after that, there was a target word on the screen for 500 ms. Previously, masked priming being good for eliminating participants' strategies, (such as memory effects or any predictive strategies) was discussed. Therefore, it might be possible that Lehtonen et al.'s experiments give much more time for participants to retrieve their first and second language lexicon. This might increase the participant's strategy in the lexical decision task, and because when participants process the L2, their L1 is also activated at the same time (Sunderman & Kroll, 2006).

Second, both of the experiments focus on the second language. There is no cross-language priming between the two languages; for example, in the experiments by Lehtonen et al. (2003, 2006), participants made responses to Finnish or Swedish inflectional nouns. Moreover, in Silva and Clahsen's (2008) experiments, participants with different language backgrounds made responses to English regular past tense and derivational words. Both researches did not highlight participants' L1. If there is cross-language priming, the priming effects are clearly attributed to the L1 activation.

Third, there is language universality and language specificity. If the two languages are similar in their morphological structure, L1 might contribute something for L2 processing. If not, L1 might not do anything for L2. Portin et al. (2008) investigated the role of L1 on the L2 (Swedish inflected nouns). In their experiment, L1 speakers are from two totally different languages (Chinese and Hungarian). Chinese is an isolating language and Hungarian is very rich in morphology and is an agglutinative language. In the visual lexical decision tasks, both groups had different patterns for the three different-frequency-level inflected nouns in Swedish. The Hungarian native bilinguals had a longer time for RT (response time), and preferred decomposing the low- and middle-frequency inflected words, but processed high-frequency words as a whole word route. However, Chinese participants' responses to the monomorphemic and inflected nouns were similar regardless of the frequency. From their experiment, it could be concluded that the structure of L1 would influence the processing of L2. However, in Silva's experiments, German has a similar structure as English, but Chinese does not have the same structure as English in terms of derivational words. The pattern of processing derivational words in English was similar regardless of the morphological structure of L1. There might be a masked or unmasked paradigm that causes a different result, or the baseline of the L1 and L2 is different. It means that Chinese is rich in compound words, but Japanese and Hungarian are rich in inflectional words. If morphologically complex words are considered, the critical point is that the morphemes in both languages are at the same level. Previous research ignored this point. Therefore, it is hard to tell what is transferring from L1 to L2.

In order to discern the factors that play a role in L2 morphologically complex words, this study examines Mandarin Chinese-English bilinguals. It uses masked priming with within-language priming and cross-language priming. This study's focus is noun-noun compound words in English, (as previously mentioned). Previous studies have shown that there were also cross-language priming effects between the two languages, especially Chinese to English priming paradigm in the masked priming task (Jiang, 1999). According to Jiang's (1999) experiment, there are strong priming effects between the L1 to the L2 priming at word level. I am testing whether priming effects exist at the morpheme level. The L1 constituents and the L2 constituents share semantic meaning (they had equivalent translations from L1 to L2). My idea about using within-language priming is the same as Lehtonen et.al's and Silva & Clahsen's (2008) experiments. I put Mandarin Chinese-English participants in the L2 environment and investigated how they process the L2 morphologically complex words.

Previous research (Jiang, 1999, Kroll et al., 1994, among others) on bilinguals focused on the word level and used translation equivalents between L1 and L2. This study wanted to go one step further to ask whether there are priming effects on the morpheme level between L1 and L2. In other words, do cross-language priming effects exist on the morpheme level?

3.5 Interim summary

This study will focus on processing of noun-noun compound words in English in Mandarin Chinese-English bilinguals. In bilingual research, the priming paradigm (masked or unmasked) and priming direction (L1 to L2 or L2 to L1) always produce different results (as I discussed in the previous section). Based on Jiang (1999) and Gollan et al. (1997) research, I used the L1 to L2 priming direction and masked priming. As Kroll mentioned the proficiency is critical point of bilingual research, I used high proficiency Mandarin Chinese-English bilinguals in my research. I used Chinese-English bilinguals to process the compound words in English.

Chapter 4

Research questions

This study's first goal was to test how Mandarin Chinese-English bilinguals process morphologically complex words in English (their second language). The first question was: Do Mandarin Chinese-English bilinguals decompose English compound words?

Even though there are several types of morphologically complex words, English noun-noun compound words were used. English compound words are words composed of two free morphemes, in which both constituents are words independently. In the mental lexicon, a free morpheme exists on its own or combines with others. If compound words are decomposed before lexical access, constituents of compound words are activated and combined to make the target compound words. Therefore, in lexical decisions with masked priming, related constituent primes facilitate reaction times for compound words while unrelated word primes do not facilitate these responses. For example, if *cheekbone* is a target word, there are two conditions: in a related condition, the constituent *bone* is a prime, and in an unrelated condition, *cook* is a prime instead of *bone.*

According to the decompositional theory (full-parsing theory), I should get shorter RTs for target words in a related condition where *bone* primes *cheekbone* than the condition, in which *cook* (unrelated condition) primes *cheekbone*. When *bone,* as a prime, is already activated in the mental lexicon in the related priming condition, and when participants see *cheekbone*, *cheekbone* is decomposed into two free morphemes: *bone* that is already activated in the previous priming condition and *cheek*. Therefore, participants' responses to *cheekbone* in the related condition may be faster than the responses in the unrelated condition, in which neither of the constituents is activated in previous priming conditions. In the opaque condition, participants' response for *hallmark* in the related condition (*mark* as a prime) may be faster than the one in the unrelated condition (*term*). The priming effects may be found in both transparent and opaque compound words, because both transparent and opaque compound words are decomposed into their constituents separately.

According to the non-decompositional theory (full-listing theory), the degree of priming is different for transparent and opaque compound words. In transparent compound words, there are priming effects that are due to semantic and orthographic overlap between primes and targets. There may be fewer priming effects in the opaque compound conditions because of a lack of semantic overlap between the prime and target. There are also fewer priming effects in the orthographic conditions if it is thought that priming effects are from semantic and orthographic similarity between the prime and target. Therefore, I might get a result that priming effects in the transparent condition might be higher than the opaque one, the opaque and orthographic ones might have a smaller amount of priming effects. The decreasing effects from three types of compound word will be consistent with the connectionist model.

According to the hybrid theory, I should get priming effects in transparent compound words but not in opaque compound words, because the opaque compound words are processed through a whole word route, and the transparent compound words are processed through a morpheme-based route. There is a distinctive difference between transparent and opaque compound words in terms of lexical processing.

The present experiment used the visual masked priming paradigm with lexical decision. There are at least two reasons to use this paradigm in this research: first, I can avoid the participants' strategies, in which participants cannot use the trace of previous stimuli or episodic memory. Second, masked priming tags the early stages of processing. Therefore, I would get more precise results without interruption of participants' strategies.

In this experiment, four sets of stimuli were used:

1. Transparent condition (TT), in which both constituents are transparent; for example *cheekbone* is a kind of *bone*.
2. Opaque condition (OO), where both constituents are opaque; for example *honeymoon* is neither a kind of *honey* nor a *moon*.
3. Orthographic condition (TTortho), where both constituents are transparent, but primes are not their constituents. Instead, I use orthographically similar words as primes; for example, *housewife* is primed by *wire* instead of *wife*.
4. Chinese condition (TTchinese), where both constituents are transparent, but primes are in Chinese; for example, *newspaper* is primed by *纸 (zhi3, 'paper' in English equal translation)* instead of *paper* in English.

The reasons four types of stimuli sets were used are as follows:

Transparency is a critical problem in the processing of morphologically complex words. Some research found that transparent compound words are different from opaque compound words in representing and accessing compound words in the mental lexicon. However, the early decomposition theory (Fiorentino et al., 2007, 2009; Zwitserlood 1994; Libben, 1998) found that both transparent and opaque compound words have a similar way of being represented and accessed in the mental lexicon. It means that transparency does not matter for processing compound words. The results of the experiments are not consistent in terms of transparency. Therefore, use the transparent and opaque compound words were used to investigate whether the transparency of compound words has an effect on the representation of morphologically complex words in English. Transparency might be a very significant factor for bilinguals.

In the third condition, orthographic compound words, in which the target compound words have an orthographic relationship with the primes, was used. If, as the connectionist model said, the morphology is the accumulative result of an orthographic and semantic relationship between the target and prime, there would be limited priming effects in this condition because there are no semantic priming effects. If the current study does not get the priming effects between targets and primes (previous research found inhibited priming effects that were the opposite of what the connectionist model proposed), it would be concluded that the priming effects are not from orthographic similarity between the targets and primes.

In the fourth condition, cross language priming that is related to bilingual mental lexicon, was used. In that condition, the Chinese translation-equivalent of constituents of English primes was used. It is expected that there would be priming effects in Mandarin Chinese-English bilinguals. This critical condition is related not only to morphologically complex word processing but also to bilingual processing. In other words, the Chinese primes would activate the English equivalent translations in the mental lexicon. The English equivalent translations would activate one of the constituent of the compounds and create priming effects. If there are priming effects in this condition, it explains that the morphologically complex words are decomposed before access and also demonstrates morpheme level processing in bilingual word recognition.

Table 1 provides a list of all conditions in this experiment. In the research, the frequencies of compound words will be controlled. The related prime and unrelated prime will also be controlled in terms of frequencies and number of letters (m= morphological, o=orthographic, s=semantic relationship). See Table 1.

Table 1 Experimental Conditions

Condition types	Prime	Target
Transparent compound words (TT)	bone	cheekbone
Opaque compound words(OO)	mark	hallmark
Orthographically related compound words (TTo)	plate	birthplace
Compound words primed by translated 2nd constituents of Chinese (TTch)	纸 'paper'	newspaper

To address this question whether bilinguals decompose morphologically complex words in L2, the following three alternative hypotheses regarding outcomes were outlined:

If the semantic-independent decomposition hypothesis proposed for native speakers applies also to second language learners, there would be different results for each condition. Priming effects in the transparent and opaque relationship conditions would have been facilitated. There are negative priming (inhibited) or null priming effects in the orthographic relationship condition because, in the orthographic relationship condition, the original constituents compete with the orthographic similar ones which cause inhibition effects between primes and targets. For example, *plate* (prime) and *place* (original constituent) will compete with each other. Specifically, the opaque relationship condition will have facilitated priming effects compared to the orthographic relationship condition. The only difference between the orthographic and the opaque relationship condition is whether primes and targets share the morphological relationship. Obviously, in the orthographic condition, the priming effects between the targets and primes can be attributed to the orthographic relationship, but not the morphological relationship; in the opaque condition, the priming effects can be attributed to the orthographic, morphological relationships but not to the semantic relationship. The orthographic relationship condition produces inhibited priming effects or non-priming effects, and the opaque relationship condition produces the facilitated priming effects. This is robust evidence for the existence of independent morphological priming effects. There would be priming effects in the Chinese relationship condition because Mandarin Chinese-English bilingual speakers do activate their Chinese language if the non-selective bilingual model is correct.

If the second language learners do not decompose the compound words or the learners' behavior follows the predictions of connectionist model, more priming effects in the transparent condition would be found because, according to the connectionist model, 'morphological priming effects' are accumulated by the semantic and the orthographic relationships between targets and primes. Therefore, there will be a lesser amount of priming effects in both the opaque and orthographic conditions because, in both groups, the origins of morphological priming are the same: semantic and orthographic relationships.

If the hybrid theory is acceptable, there would be mixed results as following: I would have priming effects for the transparent condition and no priming effects in the opaque and orthographic condition. In terms of the hybrid model, transparent compound words are processed and represented by the root or morpheme-based processing and the opaque ones will are processed by whole word processing in the mental lexicon.

The second question is: does the native-language morpheme (L1) facilitate the processing of a compound word in L2, in which L2 morphemes are equally translated into the native-language morphemes? In other words, does the L1 activation during process L2 happen on the morpheme level? For example, when the target is *cheekbone* in L2, and the prime is Chinese *bone* in L1, the prime will activate the English *bone* in concept level and indirectly activate the *cheekbone* if the *cheekbone* in L2 is decomposed.

If the Chinese-English priming would provide converging evidence for decomposition in L2, there would be priming effects on the Chinese condition, in which the Chinese translated constituent will be a prime and the English compound word will be a target because, , both languages (Chinese and English) are activated and they share the concept level. Therefore, the constituents that are translated-Chinese-constituents as primes are activated and then they would facilitate the processing of the English compound words. In that case, I have two assumptions: first, if the compound words are decomposed, as Fiorentino & Fund-Reznicek (2009) proposed, and then the activation from L1, which is morpheme level, will facilitate the processing of compound words. The first assumption needs that the English compounds will be decomposed at first. The Chinese condition may explain not only the processing of the bilingual in the word recognition task as morpheme level but also may support indirectly the decomposition model of the morphologically complex words.

If the compound words are not decomposed, as Plaut (2000) mentioned, the morpheme level activation of L1 (second constituent) would not facilitate the processing of compound words. In the second assumption, the facilitated effects are due to semantic overlap between the compound words and the Chinese-translated version (one might think that the Chinese version *bone* and *cheekbone* in L2 have semantic overlap to some degree). The possibility can be consistent with a non-decompositional model. Therefore, the priming effects in the Chinese condition cannot be attributed to morphological priming.

Chapter 5

Methods

5.1 Rating task

Semantic transparency is a critical factor in the processing of morphologically complex words. Some researchers (Marslen-Wilson, et al., 1994; Taft & Forster, 1976) support the transparent and opaque compound words have different representation systems. Others suggest (Fiorentino and Fund-Reznicek, 2009; Libben, 1998; Zwitserlood, 1994) that both of them have a similar representation. In order to determine the transparency of the compound words, a rating task is conducted to confirm that the transparent and opaque selected for inclusion in the main study differ significantly from one another on rated transparency. In the rating task, I use 80 compound words with their first and second constituents.

Stimuli and Design: I used a questionnaire for a rating test, in which I have 20 compound words for each condition: transparent, opaque, orthographic and Chinese conditions. In the opaque compound condition, I used compound words from Fiorentino (2006) which were already tested as opaque compound words. For the Chinese compound condition, there were 20 compound words in English, in which the compound words were transparent and their second constituents of the compound words were in English in rating task: for example, I used *newspaper* as a target compound word, and *news* and *paper* were used in rating task for transparency test in Chinese condition. I had 80 compound words for four conditions; no morpheme was repeated in rating task. 67.5 %

compound words were from Fiorentino's (2006) research, including 20 opaque compound words and 34 transparent compound words among 80 compound words.

The 80 compound words were divided into two lists. In each list, all 80 compounds words were one of the word-pairs, and the other one was first constituents or second constituents; for example, for cheekbone, in list1, I will have *cheekbone* and *bone* and in the list 2, I have *cheekbone* and *cheek*. Each list was randomly ordered for each participant. Therefore, each participant saw different ordered versions of the list 1 or list 2. No participant saw the same ordered word list or the same compound words with both constituents. Participants were instructed to judge the relationship between the compound words with their first or second constituents respectively. The rating rage is from 1 (*very unrelated*) to 5 (*very related*) points. For example in the list 1, participants will judge the semantic relationship between *cheekbone* vs. *bone* and in list 2, another group of participants will judge the semantic relationship between *cheekbone* vs. *cheek*.

Participants: 56 undergraduate students (the age 19 to 26, mean age 20.1) from University of Kansas, who are native speakers of English, completed the rating study. They were given a consent form to sign for participating this experiment and extra credit for participating in this research.

Results: I calculated the compound with first constituent and second constituent separately to obtain position-specific transparency ratings, and also averaged the compound word with its first and second constituent and took it as the transparency of the compound. At the end, I calculated the separate constituent average and the total average by different conditions: transparent, opaque, orthographic and Chinese conditions. See Table 2.

Table 2. Mean Transparency Rating

condition	1st constituent	2nd constituent	Total
transparent	3.43	3.59	3.51
opaque	2.35	1.82	2.08
orthographic	3.22	3.19	3.2
Chinese	3.27	3.78	3.52

I separately did One-way ANOVA for four conditions on total score and I found that $F(1, 79) = 24.726$, $p < 0.001$. According to first constituent, there was significant difference between the conditions, $F(1, 79) = 5.66$, $p < 0.01$ and in terms of second constituents, the result was also the same $F(1, 79) = 24.49$, $p < 0.001$. Accordingly, I could see that the degree of transparency was different across the conditions. In order to know which conditions were different from the other, I used a post-hoc test by first constituents, second constituents and total and I found that the opaque condition was significantly different from the transparent condition ($p < 0.001$), orthographic condition ($p < 0.05$), Chinese condition ($p < 0.05$) respectively in all three levels (first constituent, second constituent and average). There were no significant differences among the transparent, orthographic and Chinese conditions in the average score. Therefore, I concluded the transparency of opaque condition was significantly lower in rated transparency from the other conditions such as transparent, orthographic and Chinese conditions.

5.2 Materials and Design: Priming Study

Participants: 60 Mandarin Chinese-English bilingual speakers with normal or corrected vision participated in the priming study. They signed an informed consent form for participating in the experiment and were paid 10 dollars for participation. The experiment took 45-60 minutes.

Proficiency tests: *The LEAP-Q* (Marian et al., 2007) test was given to all participants. Marian et al. (2007) created the language experience and proficiency test for bilinguals and multilinguals. It assesses the self evaluation and L2 proficiency of bilinguals. Participants provide language experience information such acquisition age, immersing the L2/L1 country and contribution elements for L2/L1 previous and current conditions. Beside these pieces of information, participants also evaluate their L1 and L2 in terms of speaking, comprehension and reading ability. It provides background information about L2 learners. Michigan proficiency test[1]: it is used for testing L2 learners' English level. The test includes 50 items focusing on grammar and vocabulary in English.

Among the 60 participants, 12 participants had higher error rates (25% among compound words as considered high error rate) in the lexical decision; therefore they were removed from the analysis. Table 3 provided the background information about 48 participants.

[1] Michigan proficiency test includes 50 questions from a published sample of the 2003-2004 Examination for the Certificate of Proficiency in English (University of Michigan), an advanced- level standardized test. It is also widely used in bilingual proficiency test in bilingual research (provided by Dr. Gabriele)

Table 3 LEAP-Q Results for Participants (as 48 participants)

	LI			L2		
	AVG	SD	range	AVG	SD	range
self reported proficiency						
understanding	9.28	0.71	7--10	6.81	1.54	3--10
speaking	9.21	0.88	6--10	6.66	1.65	2--10
reading	8.98	1.36	3--10	7.21	1.27	4--10
age milestones						
start learning	1.28	1.19	1--5	10.77	2.93	3--18
attend fluency	3.88	1.71	1--12	18.56	5.70	9--30
start reading	5.54	1.58	1--10	12.36	2.93	7--20
attend reading fluency	9.21	2.69	3--16	18.64	4.52	10--30
immersion duration						
in a country	22.75	5.71	8.3--37	3.53	3.27	0.08--14
in a family	23.23	6.64	0.5--37	0.25	0.75	0--4.42
in a school	18.28	7.06	3--37	4.16	3.66	0-14
contribution language learning						
from family	8.98	1.42	4--10	2.60	3.32	0--10
from friends	7.83	2.07	1--10	6.58	2.47	1--10
from reading	8.15	1.74	4--10	7.94	2.00	1--10
from TV	6.71	3.00	0--10	6.06	2.88	0--10
from radio	4.52	3.04	0--10	5.06	3.14	0--10
from self instruction	4.29	3.48	0--10	5.85	2.98	0--10
extend the language exposure						
family	6.83	3.36	0--10	1.83	2.58	0--10
friends	6.46	2.46	2--10	6.20	2.29	2--10
reading	4.69	2.57	0-10	7.67	2.10	2--10
TV	3.29	2.91	0-10	5.20	2.95	0--10
radio	3.46	2.97	0--10	4.85	2.82	0--10
independent study	2.27	2.72	0--10	3.74	3.13	0--10
self report foreign accent						
perceived by self	1.10	1.90	0--9	4.58	1.76	1--10
perceived by others	1.00	2.26	0--10	6.73	3.03	0--10

Materials: 80 compound words were selected from CELEX English database (Baayen, Piepenbrock, & van Rijn, 1993), 20 in each of four conditions. For the transparent condition, the compound target had transparently semantic relationship with its prime (*bone-cheekbone*). In the opaque condition, the compound target did not have an overtly transparently semantic relationship (*mark-hallmark*). In the orthographic condition, the compound target had orthographically but no semantically relationship with a prime (*plate-birthplace)*.The orthographically related words were created by changing one letter.

(there were 14 words obtained by changing last letter, the other obtained by changing one or two letters and sounded similar to each other). In Chinese condition, the compound target had a Chinese prime, in which the original English prime was equally translated into Chinese (纸 *zhi3* 'newspaper'). Test items are listed below in the Appendix A

Target compounds were matched by frequency, number of letters, neighborhood size, in which I used biphone frequency (MLBF) and orthographic neighborhood effect (N) from data CELEX (Vitevitch and Luce 1999). See Table 4.

Table 4 Sample of the Target Compound Words

property	transparent CW	opaque CW	orthographic CW	Chinese CW	ANOVA
Mean Log. Frequency	0.33	0.39	0.34	0.36	F(3, 79) = 0.05, n.s
Mean NO. Letters	8.65	8.5	8.5	8.45	F(3, 79) = 0.14, n.s
neighborhood effect					
MLBF	1.88	1.82	1.95	1.95	F(3, 79) = 0.66, n.s
N	0.05	0.05	0	0	F(3, 79) = 0.67, n.s

CW = compound words

From the One way ANOVA test, I found that there was no significant difference between the conditions in terms of log frequency ($F(3, 79) = 0.05$, $p > 0.05$), number of letters ($F(3, 79) = 0.14$, $p > 0.05$) and neighborhood effects by MLBF and N ($F(3, 79 = 0.66$, $p > 0.05$, $F(3, 79) = 0.67$, $p > 0.05$). The materials across different conditions are balanced with respect to these variables.

80 unrelated control primes were selected from CELEX English database. For example, for transparent condition in related one: *bone-cheekbone* for unrelated one: *cook-cheekbone*. I selected monomorphemic words as unrelated primes for each condition. I also controlled the related prime and unrelated prime within conditions.

Within conditions, the related prime and unrelated prime were not significantly different from each other by log frequency and number of letters. See Table 5.

Table 5. A Comparison of Related and Unrelated Prime within Conditions

	Log. frequency			No. of letters		
	related prime	unrelated prime	significance	related prime	unrelated prime	significance
transparent	1.7	1.7	t(19)= 0.077,n.s	4.45	4.45	t(19) = 1.00,n.s
opaque	1.76	1.73	t(19) = 0.84,n.s	4.25	4.2	t(19) = 1.00,n.s
orthographic	1.04	1.03	t(19) = 0.32,n.s	4.25	4.3	t(19) = -1.00,n.s
Chinese	2.56	2.6	t(19) = -0.94,n.s	7.65	7.7	t(19) = -0.57,n.s

From the paired *t-test*, I found none of the related vs. unrelated primes were significantly different within condition. For Chinese condition, I counted the stroke number of the Chinese characters (It is isolated language; number of letters are useless for Chinese) and checked frequency of each Chinese character (created by Weidong Zhan (Department of Chinese Linguistics, Peking University, unpublished version)).

In order to prevent participants' inclination for only responding to compound word, 80 derivational words were also selected from CELEX English database. I used compound words and derivational words as target real words. Derivational and compound words were matched in terms of frequency and number of letters. In derivational condition, 80 words were divided equally into related condition, in which the target and prime had morphologically relationship (*contain-container*) and unrelated condition, in which the prime and target did not have any relationship (*lemon-publicity*). Unrelated primes that included compound and derivational word targets were matched with related primes and also did not have orthographic, semantic and morphological relationship with targets. See Table 6.

Table 6. A Comparison of Compound and Derivational Words in English

property	Compounds words	Derivational words	ANOVA
Mean Log. Frequency	0.35	0.46	F(1, 159) = 1.38, n.s
Mean No. of Letters	8.52	8.38	F(1, 159) = 0.66, n.s

From the data, there was no significant differences between the whole compound targets words and derivational words in terms of log frequency ($F(1, 159) = 1.38$, $p > 0.05$) and Number of letters ($F(1, 159) = 0.66$, $p > 0.05$).

For nonwords, 80 non-target compounds were selected from CELEX. In nonword compound condition, I used four different nonword compounds. The first type was mismatched compounds (word-word, W-W), in which both constituents were real words, but when I put them together, the result became a nonexistent word in English (*bootnoon*); the second type was nonword-word compounds (NW-W), in which the second constituent kept as original, I changed the first constituent to a non word (*liwlife*); the third type was word-nonword compounds (W-NW), in which first constituent was a real word, I changed second constituent to a non word (*candletil*); the fourth type, nonword-nonword compounds (NW-NW), in which both of constituents were nonwords (*yapdoal*). 20 nonword compounds among the 80 non word compounds were matched with Chinese primes in order to render the structure similar to real compound targets. In Chinese primed nonword condition I used the same nonword structure as English primed nonword compound targets. The numbers of letters were matched across conditions.

For the derivational non-words, the new 80 derivational words were selected from CELEX. The constructing non-word was similar to constructing non-word compound words. I used real stem-real suffix but mismatched one, in which stem and suffix are real, but they cannot be combined lexically (*directism*); the second type was a real stem - pseudsuffix, in which the stem was real but suffix was nonexistent suffix in English (*followap*); the third type was non-word stem with real suffix (*litrement*); the fourth type was both stem and suffix are nonexistent ones (*tizenol*). For derivational condition, I only matched the number of letters in related and unrelated condition and with real derivational conditions. For unrelated non-word targets I used real words which were not morphologically, semantically and orthographically related to target non words. For all conditions, no morpheme was repeated in whole experiment.

Target compound words from each condition were divided randomly into two groups for counterbalancing purposes, in which the log frequency and number of letters were matched in each group. In each group, half the targets were primed by their second constituents; the other was primed by unrelated prime words. Participants received only one experimental list; in the whole experiment, participants received all conditions but saw target words only once.

Stimuli presentation and data recording were controlled by DMDX software (Forster and Forster 2003) .The refresh frequency of the computer monitor is 100 Hz. The response box, which was used for lexical decisions, was connected the computer, with the "yes" response button controlled by the index finger and "no" response button controlled by the middle finger.

5.3 Procedure

Participants were tested individually in a soundproof room. Participants were signed the consent form and then they ran experiment; after that, they took two background tests including proficiency test and LEAP-Q (created by Marian, et al. 2007). Whole experiment including computer based test, language background information and proficiency test took 45-60 minutes.

In this computer-based experiment, participants were informed that there was a set of letter strings on the center of the computer screen, and they would make response whether these letter strings were a word or not. In the each experimental trial, participants saw the 500 ms forward masking (########) and then 50 ms prime word was presented after that there was a target word. They were not informed that there were prime words before the targets but there was hash markers (########) before the stimuli. The prime words were presented by lower case and target words were presented by upper case. The target word remained until participant pressed a button to respond to it. If participants did not respond to it after 2500 ms, the target word would disappear from the screen. For each participant, the order of the target words that presented on the screen was randomized. No participants had the same order of the target words. Before the experiment, participants took the practice-test, in which twelve items that are different from experimental items were randomly presented on the computer and the design and conditions of the practice-test were exactly the same as real experiment.

Chapter 6

Results

Sixty participants participated in the experiment. At first, I ran my data analysis based on the all participants who participated in the experiment without considering their proficiency level. There were 12 participants that were removed from the data because they had high error rate (25% among compound words was considered high error rate).

6.1 Response time and error: full set of participants

In the raw data, the missing data was about 12.5 %; therefore, I used missing data imputation. Based on the raw data, at first, I found the average response time for each participant and then I found 99% confidence intervals for each participant. Secondly, based on the raw data, I removed wrong responses, in which the word was real word but participants responded to it as a non-word. Third, I input the maximum response time (upper limitation of 99% confidence intervals) at first and then the minimum response time if there was response time that was lower than the lower limitation of 99% confidence intervals. Fourth, I exchanged the response time for 2500 ms if the upper limitation of response time exceeded the 2500 ms, because target was present until 2500 ms. At the result, there was no response time that would be higher than 2500 ms.

Data was analyzed by Repeated-Measures Analysis of Variance (ANOVA) (SPSS 17.0) by item analysis and participant analysis, respectively. I had two factors: word type condition (transparent, opaque, orthographic and Chinese) and priming type (related vs. unrelated priming). Based on the 48 participants I run the repeated measure ANOVA test.

Response Time

The Table 7 shows the response time by participants.

Table 7 Mean Latencies (ms) and SE and Priming Effects by Participants

	Condition							
	transparent		opaque		orthographic		Chinese	
relatedness	Mean(ms)	SE	Mean(ms)	SE	Mean(ms)	SE	Mean(ms)	SE
related	1294	44	1312	48	1251	42	1252	41
unrelated	1346	45	1356	51	1258	42	1327	49
priming effects	52*		44		7		75**	

*is significant at the level of 0.05;** is significant at the level of 0.01

Here, Table 8 is response time by items.

Table 8 Mean Latencies (ms) and SE and Priming Effects by Items

	Condition							
	transparent		opaque		orthographic		Chinese	
relatedness	Mean(ms)	SE	Mean(ms)	SE	Mean(ms)	SE	Mean(ms)	SE
related	1299	47	1320	61	1254	52	1260	66
unrelated	1348	60	1359	70	1262	54	1335	50
priming effects	49*		39		8		35*	

*is significant at the level of 0.05

From Response Time (RT) data, I used the repeated measurement for the data and I found that prime type (related vs. unrelated) main effect was significant both by participant analysis ($F_1(1, 47) = 8.36$, $p < 0.01$), and for item analysis ($F_2(1, 76) = 6.52$, $p < 0.05$). There was a significant difference between the conditions; in the other words, the main effect of conditions (word type) was significant by participant ($F_1(3, 141) = 7.88$, $p < 0.05$), but not for item analysis $F_2(3, 76) = 0.41$, $p > 0.05$). However, the interactions of the conditions and prime type was not significant both by participant analysis and item analysis ($F_1(3, 47) = 0.82$, $p > 0.05$; $F_2(3, 76) = 0.69$, $p > 0.05$).

I run the paired t-test (1-tail t-test) for each condition, I found in the transparent condition, priming effects were significant ($t_1(47) = -1.92$, $p < 0.05$; $t_2(19) = -1.75$, $p < 0.05$), and in the Chinese condition, priming effects were significant both by participant analysis and item analysis ($t_1(47) = -2.56$, $p < 0.01$; $t_2(19) = -2.02$, $p < 0.05$). I can conclude that participants' response time for related primes are faster than the one for the unrelated primes both in Transparent and Chinese conditions. The opaque condition and orthographic condition did not produce significant priming effects (($t_1(47) = -1.26$, $p > 0.05$, $t_2(19) = -0.95$, $p > 0.05$ for opaque condition and ($t_1(47) = -.24$, $p > 0.05$; $t_2(19) = -0.32$, $p > 0.05$ for orthographic condition)).

Error Rates

Table 9 is about mean error by participants for full set of participants.

Table 9. Error (%) and SE and Priming Effects

	Condition							
	transparent		opaque		orthographic		Chinese	
relatedness	Error (%)	SE	Error (%)	SE	Error (%)	SE	Error (%)	SE
Related	12.5	1.8	14.6	2.2	9	1.7	10.2	1.3
unrelated	13.5	1.9	15.8	2.0	8.1	1.4	13.1	2.0
priming effects	1		1.2		-0.9		2.9	

For error rate, I also ran by participant and item analysis; I found that main effects of the prime type (related vs. unrelated) were not significant both by participant analysis ($F_1(1, 47) = 1.22$, $p > 0.05$), and for item analysis ($F_2(1, 76) = 1.31$, $p > 0.05$). The main effect of conditions (word type) was significant by participant ($F_1(3, 141) = 6.48$, $p < 0.05$), but not for item analysis $F_2(3, 76) = 1.06$, $p > 0.05$). Interactions between the word type and priming type were not significant both by participant and item analysis ($F_1(3, 141) = 0.45$, $p > 0.05$; $F_2(3, 76) = 0.55$, $p > 0.05$). Even though I ran paired t-test for each condition, I found that there were no significant differences between related and unrelated items for each condition.

Analyzing full set of participants, I found priming effects both in transparent condition and Chinese priming condition for reaction time data. However, I did not find any kind of priming effects both in opaque condition and orthographic conditions. I was able to conclude that transparent and Chinese conditions behaved differently from the other two types of conditions that are opaque and orthographic.

6.2 Response time and error of highest proficiency subset of participants

I also thought proficiency level might influence their performance in word recognition. The hypothesis was that high proficiency bilinguals might have similar word recognition processing as native English speakers. The research aimed to obtain high proficiency level Mandarin Chinese-English bilinguals, because one potential concern is that different results may hold if the highest-proficiency participants were tested. Therefore, I divided the highest proficiency level bilinguals into more advance level groups in both versions. I had proficiency test for each participant. In order to divide the participants into advanced level rather than relative high-proficiency level, I ranked all 48 participants according to the proficiency test results. I selected participants based on the proficiency test result of 30 (participants correctly answer more than 30 items among 50 items). If participant did 30 items correctly among the 50 items, then participants did correctly at least 60% items (30/50). I found 11 participants fit the criterion that I selected, and based on the criterion, I selected first 11 participants from version 1, in which all of them had higher than 30 in their proficiency test. So far, I kept 11 participants for each version and the average of proficiency level in both versions are not significant ($t(10) = 0.89$, $p > 0.05$). Thus, the highest-proficiency subset included 22 participants in total. I did ANOVA for these participants by item and participant and found the result was the same pattern with the one I used ungrouped data.

Response Times

Table 10 is about response times by participants.

Table 10. Mean Latencies (ms) and SE and Priming Effects by Participants

	Condition							
	transparent		opaque		orthographic		Chinese	
relatedness	Mean(ms)	SE	Mean(ms)	SE	Mean(ms)	SE	Mean(ms)	SE
related	1272	56	1320	63	1274	53	1247	54
unrelated	1363	42	1354	64	1234	57	1340	61
priming effects	91*		34		-40		93*	

*is significant at the level of 0.05

Here, Table 11 is about response times by items.

Table 11. Mean Latencies (ms) and SE and Priming Effects by Items

	Condition							
	transparent		opaque		orthographic		Chinese	
relatedness	Mean(ms)	SE	Mean(ms)	SE	Mean(ms)	SE	Mean(ms)	SE
Related	1283	57	1337	73	1281	61	1261	71
Unrelated	1366	61	1360	69	1240	49	1355	62
priming effects	83*		23		-41		94*	

*is significant at the level of 0.05

From RT data, I conducted a repeated-measure ANOVA and I found that the main effect of the prime type was just significant by subject analysis ($F_1(1, 21) = 4.34$, $p = 0.05$), but item analysis was marginally significant ($F_2(1, 76) = 3.54$, $p = 0.064$).The main effects of conditions (word type) were significant by subjects analysis ($F_1(3, 63) = 3.77$, p

< 0.05) but not for item analysis $F_2(3, 76) = 0.39$, $p > 0.05$). However, the interaction between the conditions and prime types were not significant by subjects and items (F_1 (3, 63) = 1.95, $p > 0.05$; $F_2(3, 76) = 2.20$, $p > 0.05$) respectively. I run the paired t-test (one tail t-test) for each condition, and I found in the transparent condition, the priming effects were significant ($t_1(21) = -2.15$, $p < 0.05$; $t_2(19) = -2.09$, $p < 0.05$). It means that subjects responded for related prime condition faster than the one in the unrelated condition. In the Chinese condition, priming effects were significant by subject analysis ($t_1(21) = -2.33$, $p < 0.05$); but for item analysis it was marginal significant ($t_2(19) = -2.06$, $p < 0.05$). The opaque condition and orthographic condition did not produce significant priming effects ($t_1(47) = -0.66$, $p > 0.05$, $t_2(19) = -0.54$, $p > 0.05$ for opaque condition and ($t_1(47) = 0.95$, $p > 0.05$; $t_2(19) = 1.04$, $p > 0.05$ for orthographic condition).

Error rates

Table 12 is mean error by participants in relatively high proficiency level participants.

Table 12. Error (%) and SE and Priming Effects

	Condition							
	transparent		opaque		orthographic		Chinese	
relatedness	Error (%)	SE	Error (%)	SE	Error (%)	SE	Error (%)	SE
related	11.8	3.0	12.7	2.9	6.8	2.1	8.6	1.7
unrelated	11.8	2.4	14.1	3.3	5	1.4	11.3	3.0
priming effects	0		1.4		-1.8		2.7	

For error rate, I also ran by subject and item analysis; I found that prime type main effects were not significant both by subject analysis ($F_1(1, 21) = 0.24$, $p > 0.05$), and for item analysis ($F_2(1, 76) = 0.17$, $p > 0.05$). The main effect of conditions (word type) was significant by subject ($F_1(3, 63) = 4.45$, $p < 0.01$), but not for item analysis $F_2(3, 76) = 1.42$, $p > 0.05$). Interactions between the word type and priming type were not significant both by subject and item analysis ($F_1(3, 63) = 0.34$, $p > 0.05$; $F_2(3, 76) = 0.50$, $p > 0.05$). Using paired t-test for each condition, I found that there were no significant differences between related and unrelated item for each condition.

Chapter 7

Discussion

In this experiment, the role of morphology in bilingual word recognition was investigated. The Mandarin Chinese-English bilinguals made visual lexical decisions to English compound words in masked priming conditions, in which English compound words were primed respectively by four different words that are: (1) second constituent of the compound words in a transparent condition, (2) second constituent in an opaque condition, (3) orthographically similar to second constituent in an orthographic condition, and (4) a direct translation in Chinese of the second constituent of the target in Chinese condition. The results showed that the transparent and Chinese conditions had priming effects. In other words, participants' responses were faster in the related priming condition compared to the unrelated priming condition in both transparent and Chinese condition. However, in the opaque and orthographic conditions, the priming effects were not found when comparing the reaction time for related prime versus unrelated prime. The results will be discussed in terms of the within-language condition, in which English prime precedes English target, and cross-language condition, in which the Chinese prime precedes English compounds.

7.1 Within-Language Condition

The within-language condition included the transparent (TT) condition, opaque (OO) condition, and orthographic (TTortho) condition because, in these conditions, Mandarin Chinese-English bilingual made lexical decisions to the English compound words with English primes.

In these conditions, only the transparent condition produced priming effects. As discussed in Chapter 4, these priming effects might be a morphological relationship between target and prime, or a semantic relationship between target and prime, or an orthographic relationship between prime and target. However, no priming effects were obtained in the opaque and orthographic conditions. Even though the opaque condition had 44 ms priming effects (by participants) or 39 ms priming effects (by items) for full set of participant analysis, and 34 ms and 23 ms priming effects, respectively, by participant and item analysis in high-level participants, it did not reach the significant level. As is known in the transparent condition, the semantic relationship between the target and prime was very strong; in the opaque condition, there is less semantic relationship or no semantic relationship; and in the orthographic condition, there was no semantic relationship.

The result might be explained either by the decomposition model or by the connectionist model. Looking first at the connectionist model, according to my hypothesis, if the connectionist model explains the result, there should be stronger priming effects in the transparent condition and less strong priming effects in the orthographic and opaque conditions. Even though there were strong priming effects in the transparent condition in high proficiency level and as full set of subject analysis, there were not significant priming effects either in the opaque or orthographic conditions. This was inconsistent with my expectation based on the connectionist model. Second, from the perspective of the decomposition model to explain the result, I was supposed to get priming effects in both the transparent and opaque conditions, but not in the orthographic condition. Even though I had priming effects in the transparent condition, I did not obtain priming effects in the opaque condition. Marslen-Wilson et al. (1994) also obtained priming effects in transparent derivational words but not in opaque derivational words. They concluded that transparency is a critical point for processing of morphologically complex words.

Transparency might be different for the computation in the lexical level and the concept level. At the lexical level, both opaque and transparent constitutions will facilitate the access of the compound words. However, the problem occurs in the concept level, in which the transparent compound and the opaque compound behave differently. Transparent compound words are decomposed, and each constituent will be activated in the lexical level and then, when they combine together (compose), each constituent still keeps its activated meaning. Overall, the facilitated effects still survive and transform the facilitated priming effects on the recognition of whole compound words. However, the opaque compound words, if it is assumed that they are decomposed, the constituents of the opaque compound words will be accessed in the lexical level and have a facilitation on the whole opaque compound words. However, in the concept level, the meanings of the constituents could not survive because the opaque compound constituents are no longer the same as the semantic meaning of opaque compound. Therefore, decomposed constituents cannot contribute facilitated effects on the whole opaque compound recognition at the concept level. As the result, the facilitation effects on the lexical level and non-facilitation effects, or inhibition effects, on the concept level will affect the processing of compound words (Ji, 2009; Gagne & Spalding, 2009).

There are different results in opaque compound word processing. Fiorentino and Fund-Reznicek (2009) used the compound words as primes and the constituents as targets.

If it is assumed that a compound word, *cheekbone*, which is a prime, is decomposed into *cheek* and *bone*, and in the target, in which participants respond *bone*, which is a target and second constituent of the previous compound, the decomposed *bone* in the prime stage will facilitate the processing of *bone* in the target stage. Therefore, there is a decomposition stage and no, or less, integration (composition) stage in the mental lexicon. However, in the present experiment, targets (second constituents) served as primes and compound words served as targets. This means that *bone*, as a prime, is already activated in the mental lexicon, and participants respond to the compound word (target) such as *cheekbone*, which is decomposed as *cheek* and *bone,* as a word or non word. Participants 'pick up' *bone* from the activated position (at the prime stage) and combine it with *cheek* at the response stage. The second-step combination of the already activated *bone* and the non-activated *cheek* took time for integration. The integration (composition) step might be very hard or time consuming in the opaque condition. Therefore, the second constituents will facilitate the processing of the decomposed compound words, but in the composition or integration step, the semantic meanings of the constituents in the opaque condition cannot contribute any facilitate priming on the compound words in the processing. This case does not happen in the experiment when compound words serve as primes and their constituents serve as targets, for example in Fiorentino & Fund-Reznicek (2009). Shoolman and Andrews (2003) obtained the priming effects both in the partially opaque condition and the truly transparent condition in native English speakers, even though they used the same paradigm as was used in this study. The participants in the present study are L2 (English) speakers. For non-native English speakers, the computation of the opaque constituents to whole compound words might be harder.

Therefore, they acquire the transparent compound words, such as 'cheekbone' is 'a kind of *bone* at the top of cheek,' but for opaque compound words, they directly memorize the meaning of the whole words.

In the orthographic group, I had the non priming effects which converges with the Fiorentino and Fund-Reznicek (2009), in which they did not obtain facilitated or positive priming effects on compound words that were orthographically related to prime words. Shoolman and Andrews (2003) used pseudo-compound words, in which two constituents stand as free morphemes but do not serve as constituents in that context . They found that pseudo-compound words did not produce the priming effects.

Silva and Clahsen's (2008) research used English derivational and past tense regular verb processing from L1 in German, Chinese and Japanese bilinguals. This study's results are different from Silva and Clahsen's (2008) results. They obtained priming effects in English participants whose native language is English, but not in German, Chinese and Japanese bilinguals whose second language is English. They concluded that L2 learners process the English derivational and inflected word in different ways than English native-speakers. English native-speakers process the derivational and inflectional words using a morpheme-based route. L2 learners process the English derivational words and inflectional words using a more lexical storage (whole-word based) and less of a morpheme-based route. It might work in derivational and inflected words but might not work for compound words. As discussed in Chapter 1, compound words provide a unique way to test the morphologically complex words in the mental lexicon (Fiorentino and Fund-Reznicek, 2009), because compound words consist of open-class words and processing of compound words might be the best way to test the morphologically complex words.

Secondly, derivational and inflected words in English might not be derivational and inflectional words in German, or in Chinese or in Japanese respectively. For example, at least some derivational words in English are not derivational in Chinese, and these words might be compound words. However, in this research, typological characters of both languages were exactly matched. Noun-noun compound words are productive in both Chinese and English. For English compound words, I used noun-noun compound words in English, and for Chinese prime words, I used the single characters in Chinese. That provided a relatively equal baseline from which to compare the influence of L1 to L2. However, in Silva and Clahsen's (2008) research, it is unknown how bilinguals' L1 influences their L2. It is assumed that when bilinguals are processing their L2, their L1 will be activated and involved in the processing (Sunderman and Kroll, 2006). That is one of merits of using compound words. Overall, transparent compounds were decomposed in bilingual word recognition.

I can answer my first question: do Mandarin Chinese-English bilinguals decompose English compound words? If I take the priming observed in this study to reflect morphological processing, then the answer is yes (I will return to the issue of whether this priming is indeed morphological, or instead may be semantic, in section 7.3 below). Only transparent compound words were decomposed, but opaque compound words were not. Mandarin Chinese-English bilinguals treat the transparent and opaque compound words different ways. They used a morphemes-based processing route for transparent compound words but a whole word processing route for opaque compound words.

7.2 Cross Language Condition

Now I will discuss the results from the Chinese -English priming condition and explain it using the bilingual theories I proposed in Chapter 3. The Chinese condition is a cross-language condition, in which I wanted to investigate the role of bilinguals' first language in processing of their L2. It is a critical condition for us because it will relate to not only morphologically complex word processing, but also it is related to bilingual word recognition.

I found strong priming effects in the cross language condition; it is consistent with the non-selective model in bilingual word recognition. The non-selective model (BIA+) (Dijskrta et al., 2002) proposed that when bilinguals are processing the L2 words, the semantic representation of L1 are activated. In other words, semantic processing occurs in both languages regardless of target languages. In the Chinese priming condition, even though the prime words were not translation equivalents from English compound words, there were still semantic overlaps between Chinese prime words and English compound words. There was a significant priming effect (75 ms) for subject analysis, 34 ms for item analysis in full participant analysis and 94 ms. and 93 ms. respectively by participant and item analysis in high proficiency participants). These results can converge with the results of Gollan et al. (1997) and Jiang (1999). In their research on Hebrew-English bilinguals and Mandarin Chinese-English bilingual studies, the priming effects from L1 to L2 were observed.

Secondly, the results can be explained using RHM theory (Kroll 1994). In the present study design, there was the partial semantic relationship between the Chinese prime and the English target. It was supported that words in bilinguals' L1 will activate the related concepts and the activated concepts will facilitate the recognition of the English compound words in lexical decision. Since the connection between the concept level to L1 is stronger that the one between the concept to L2, some researchers may question the strength of the priming effects from the concept to L2, and claim that the strength is inadequate to be significant.

There can be strong semantic priming effects between-language and within-language: Perea et al. (2008) used semantic priming across highly proficient Basque-Spanish/Spanish-Basque bilinguals, in order to investigate the degree L1 semantic representation influences L2. Their results were consistent with both RHM and BIA+, because both theories suggested the early automatic semantic priming effects between languages among the highly proficient bilinguals (id.). Based on their results, I concluded that Mandarin Chinese-English bilinguals likewise might have semantic priming effects between Chinese primes and English targets and the participants are moderately high proficient bilinguals.

7.3 *Significance of the current work to previous research*

My research found that Mandarin Chinese-English bilinguals treat transparent and opaque compound words differently. For the Opaque compound words, they used whole-word based processing and for transparent compound words, they used morpheme-based processing. These results provided evidence for morpheme-based processing in Mandarin

Chinese-English bilinguals when they processed the English noun-noun compound words. However, Silva & Clahsen's (2008) research suggested that L2 speakers don't use the morpheme-based route in the processing of regular past tense and derivational words in English. They also suggested that language background doesn't matter for processing of morphologically complex words in their L2. Our results were consistent with the results of Lehtonen et al. (2003, 2006) in which they examined the processing of Finnish and Swedish inflected words in Finnish-Swedish bilingual group, and they suggested that language background does influence processing of morphologically complex words in L2, because in the processing of Finnish inflected words, Finnish-Swedish bilinguals used morpheme-based processing for low frequency Finnish words, but for whole-word processing for high frequency words; however in the processing of Swedish inflected words, Finnish-Swedish bilinguals used morpheme-based processing regardless of the frequency of the Swedish inflected words; they suggested there is a morpheme-based processing in bilinguals in the processing of Finnish inflected words and Swedish inflected words.

We used compound words as stimuli instead of derivational or inflected words. Unlike derivational and inflected words, compound words consist of two or more free morphemes. Compound words provide an opportunity for cross-language studies in terms of typologically matching the compound words cross languages. Especially, we used noun-noun compound words, which are productive both in English and Chinese. However, both of these studies (Lehtonen et al., 2003, 2006; Silva & Clahsen, 2008) used inflected or derivational words, not compound words. The relative baseline for L1 and L2 was not matched. For example derivational words in L1 may or may not be derivational words in L2.

7.4 Are the priming effects in the transparent and in the Chinese conditions semantic or morphological?

Combining the within-language condition and cross-language condition, one might think that the priming effects occur only when there is a semantic relationship between the prime and target, regardless of language conditions. It was true. One might have a conclusion that the Mandarin Chinese-English bilinguals' processing of morphologically complex words in L2 is attributed to semantic instead of morphological effects. Based on this experiment I cannot deny both explanations: one is that the priming effect might be semantic based or it might be a combination of semantics and morphology. The results that the L2 speakers obtained the priming effects from the partially related L1 prime via concept level can be explained by two ways: the decomposition and hybridity.

In the decompositional way, if I assumed that bilinguals process the compound words in a morpheme-based route (decomposition), the previously presented L1 prime, an equally translated second constituent of English compound words, will activate the concept level and indirectly prime the L2 compound words. However, if bilinguals decompose the English compound words, the activated concept that is from L1 will prime the L2 processing. According to my previous explanation, decomposition occurs at the early stage; at the lexical level both constituents are activated, and at the concept level only the transparent compound words' constituents still survive but the ones from opaque compound words do not. In the Chinese-English condition, all English compound words are transparent, meaning they are not significantly different from the transparent condition but significantly different from the opaque condition (see the method section). Therefore, I can posit that in Chinese condition, the equally translated Chinese constituents still survive both in the lexical and the concept level and indirectly prime English compound words. If I think that bilinguals do not decompose the English compound words, the activated concept from L1 will have partial semantic priming and still prime English compound words.

In contrast, according to hybrid theory, the transparent compound words will be processed in a morpheme based route and opaque one will be processed by whole-word route. In this case, the results support the dual-route model, in which morpheme-based route and whole-word route exist in morphologically complex word processing.

However, the results still remain unclear for us in terms of the precise mechanism of processing of morphologically opaque compound words. This result was different from Fiorentino and Fund-Reznicek's (2009). I only obtained priming effects in a transparent condition, not in an opaque condition in bilingual group. I do not have clear evidence on the following issue about opaque compound processing. There are two possible explanations:

1) It might be the result in which opaque compound words are decomposed at the retrieval stage, but composed again at the composition stage. In other words, opaque compound words have two stages, retrieval and access, in which the opaque compound words are decomposed and composed. The retrieval stage is similar to the one in transparent compound words, but the access stage, in which

constituents of compound words are integrated to create whole compound words, is different for opaque and transparent compound words. In that stage, the activated meanings of constituents still cause the facilitated effects for transparent compound words, but not for opaque compound words. Therefore, the result is not significant for opaque compound words.

There is no decomposition in opaque compound words, and they are processing as whole-word at the retrieval and access stages. There is also no decomposition of transparent, and the priming effects are semantic priming from whole word “bone” to semantically related whole word “cheekbone”.

7.5 Summary

Mandarin Chinese-English bilinguals process transparent compound words and opaque compound words differently, with no orthographic overlapping priming effects. Mandarin Chinese-English bilinguals decompose the transparent compound words and may or may not decompose opaque compound words. I also found strong L1 to L2 priming effects in the Chinese condition. I also suggest that cross-language priming effects occur in recognition of the morphologically complex words.

7.6 Future directions

These results are just the tip of the iceberg. Since there is a potential role of morphology or semantics, I intended future research to tease apart morphological and semantic effects.

First, we would add another condition, which bears only semantic relationship; for example, *racehorse* as the target compounds word, we used *cow* instead of *horse* as the prime, because *horse* and *cow* have the semantic relationships. If we obtain the priming effects in this condition, and the amount of priming is not significantly different from the one in the transparent condition, I would attribute the priming effects in the transparent condition to the semantic effects. If not, the priming effects in the transparent condition would be pure morphological priming effects. Now, we come to the question: why opaque compounds that have morphological relationships with constituents, which are primes in this experiment, do not produce the priming effects? In order to answer this question we will review Fiorentino & Fund-Reznicek's (2009) study again. They included the use of masked compound words as primes and constituents as targets such as *toothpaste-paste.* In that situation, there is only decomposition, but not composition stage. For example, *toothpaste* will decomposed at the prime stage and the decomposed *paste* will facilitate the recognition of *paste* in target position. The facilitation effects are the same in opaque compound words, because in opaque compound word such as *honeymoon*, the decomposed *moon* will facilitate the recognition of *moon* on the target position. However, we used the different priming pattern in this study, in which we used the masked constituents as primes and compound words as targets. In this situation, we had both decomposition and composition stages. For example, *paste* is activated at the prime stage and at the target we see the compound *toothpaste*, which is decomposed as *tooth* and *paste*. The activated *paste* in the prime stage will facilitate the decomposed *paste* on the target stage. In order to recognize the compound word, we have extra composition-stage in which the facilitated *paste* composed with *tooth* and creates *toothpaste*. The facilitation effects exist in processing of the transparent compound words, but not the processing of the opaque compound words. Therefore, even though opaque compound words are decomposed at the early stage, but in the composition stage the activated constituent cannot contribute facilitation priming effects on the composition stage. The results look like that there are no priming effects. For example, the prime *moon* will facilitate the *honey* and *moon* at the decomposed stage but in composition stage, because of semantic meaning, the *moon* cannot contribute the priming effects on composition of *honey* and *moon* again. In sum, the transparent and opaque compound words behave differently in decomposed and composed stages. Using the priming paradigm that is compound words vs. constituent will help to test early stages of decomposition.

Secondly, in the Chinese condition, the compound words are mostly transparent. There are potentially semantic and morphological roles in the priming effects. I should manipulate the transparency in the Chinese condition, in which I put opaque compound words in English. If I do have priming effects in that opaque Chinese-English priming condition, I will attribute the priming effects in the Chinese condition to purely morphological effects in this study. If I don't have priming effects in the Chinese condition, I will conclude that there is no morphological priming effects in the cross-language condition and also support the non-decomposition theory in L2. All priming effects in transparent condition would be attributed to semantic priming in this study. In that case I might conclude that L2 speakers process morphologically complex words using a whole word route.

Thirdly, in this experiment, I used the second constituents as the prime. In the next step, I will focus on the first constituents as primes. I will test whether position of constituent does matter for processing in bilinguals. Fiorentino (2006) showed that the recognition of first and second constituents primed by transparent and opaque compound words produced the same priming effects both in transparent and opaque conditions. He suggested that position is also doesn't matter for processing the compound words in that priming paradigm in which he used masked compound prime and target constituents. I will examine the non-position effects in L2.

I should test English native speakers as a base line comparison. In processing of English compound words, there are several theories. The processing of compound words in English native speakers is also unclear. For example, Shoolman and Andrews (2003) have the priming effects in both transparent and opaque conditions; on the other hand, Plaut and Gonnerman et al. (2000) suggested that there were gradient priming effects based on the semantic and orthographic similarities between primes and targets. In order to get precise results for native speakers of English, I will use the same materials to test English native speakers to compare to the L2 bilinguals.

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Appendix: Word list

experimental stimuli			
condition	*target*	*related prime*	*unrelated prime*
transparent	cheekbone	bone	cook
transparent	bathrobe	robe	poll
transparent	paintbrush	brush	stamp
transparent	toothpaste	paste	yacht
transparent	doorknob	knob	jazz
transparent	snowflake	flake	yeast
transparent	sandstorm	storm	coach
transparent	heartbeat	beat	care
transparent	flagpole	pole	jean
transparent	airplane	plane	crime
transparent	congressman	man	own
transparent	footnote	note	cost
transparent	bodyguard	guard	twice
transparent	stopwatch	watch	voice
transparent	earphone	phone	judge
transparent	padlock	lock	actor
transparent	keyboard	board	river
transparent	beehive	hive	duel
transparent	postcard	card	trip
transparent	grapefruit	fruit	cell
opaque	hallmark	mark	term
opaque	joystick	stick	truth
opaque	pineapple	apple	crown
opaque	honeymoon	moon	diet
opaque	hamstring	string	clock
opaque	bandwagon	wagon	stool
opaque	jailbird	bird	hell
opaque	landlord	lord	toll
opaque	windfall	fall	view
opaque	crackpot	pot	pen
opaque	bottleneck	neck	wine
opaque	bombshell	shell	queen
opaque	soundtrack	track	bread
opaque	doughnut	nut	ton
opaque	rainbow	bow	mud
opaque	armpit	pit	bat
opaque	brainchild	child	state
opaque	fortnight	night	party
opaque	passport	port	rice

condition	*target*	*related prime*	*unrelated prime*
opaque	treadmill	mill	zero
orthographic	birthplace	plate	novel
orthographic	schoolgirl	gird	jade
orthographic	hairstyle	stile	quash
orthographic	fairytale	teal	coca
orthographic	waistcoat	coax	saga
orthographic	sidewalk	wall	bank
orthographic	railroad	roam	curb
orthographic	seafood	fool	tone
orthographic	campfire	file	name
orthographic	freeway	wax	rag
orthographic	playgroup	grope	virus
orthographic	ice cream	creak	eagle
orthographic	videotape	tame	buck
orthographic	lawsuit	sweat	author
orthographic	wheelchair	cheer	gloom
orthographic	barnyard	yarn	dupe
orthographic	bullfight	fiat	blur
orthographic	haywire	wile	node
orthographic	framework	word	face
orthographic	guidebook	boom	glow
Chinese	newspaper	纸(paper)	技(skill)
Chinese	ringworm	虫(worm)	血(blood)
Chinese	cornfield	田(field)	功(merit)
Chinese	skyline	线(line)	轮(turn)
Chinese	inkwell	井(well)	厅(room)
Chinese	sailboat	船(boat)	蛮(rough)
Chinese	tablecloth	布(cloth)	白(white)
Chinese	sunflower	花(flower)	军(army)
Chinese	racehorse	马(horse)	口(mouth)
Chinese	handbag	包(bag)	龙(dragon)
Chinese	daydream	梦(dream)	盗(thief)
Chinese	rattlesnake	蛇(snake)	斑(spot)
Chinese	basketball	球(ball)	象(elephant)
Chinese	hometown	镇(town)	整(whole)
Chinese	headache	疼(ache)	泽(damp)
Chinese	streetcar	车(car)	今(today)
Chinese	waterhole	洞(hole)	春(spring)
Chinese	heat wave	波(wave)	枚(stalk)
Chinese	goldfish	鱼(fish)	卷(volume)
Chinese	sickbed	床(bed)	乱(chaos)