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Dissertation

SEMANTIC AND PHONOLOGICAL ACTIVATION IN FIRST AND SECOND LANGUAGE READING

by

HUI-WEN CHENG

B.A., National Central University, 1999
M.A., National Chengchi University, 2004

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Approved by

First Reader

Catherine Caldwell-Harris, Ph.D.
Associate Professor of Psychology

Second Reader

Mary Catherine O'Connor, Ph.D.
Professor of Education and Linguistics

Third Reader

Shanley Allen, Ph.D.
Adjunct Associate Professor of Education and Linguistics

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SEMANTIC AND PHONOLOGICAL ACTIVATION

IN FIRST AND SECOND LANGUAGE READING

(Order No.)

HUI-WEN CHENG

Boston University Graduate School of Arts and Sciences, 2012

Major Professor: Catherine Caldwell-Harris, Associate Professor of Psychology

ABSTRACT

No consensus has been reached on whether phonological information is activated in reading Chinese. Further, semantic activation has not been well-studied in the context of orthographic depth. To contribute to these issues, this dissertation investigated semantic and phonological activation in reading Chinese and English. This dissertation also examined semantic and phonological activation in reading English as a second language, in order to shed light on how first language (L1) literacy experiences influence second language (L2) reading.

A priming study was carried out with native Chinese speakers and native English speakers reading their L1. Semantic priming and phonological inhibition were both found in the two language groups, suggesting a reading universal: any linguistic information encoded in orthographies will be activated in the reading process regardless the manners in which it is encoded. Results also showed some language specific properties. Semantic priming occurred in the sentence-based priming paradigm in Chinese reading, but in the single-word priming paradigm in English reading, implying different semantic processes in reading these two orthographies. Phonological inhibition appeared for only low frequency Chinese targets, but for both high and low frequency English targets, showing that phonology plays a more important role in reading English than in reading Chinese.

A repetition blindness (RB) study was conducted with the same Chinese and English groups reading their L1. One major finding is that semantic RB was observed in English word pairs. The other notable finding is that phonological RB was significantly larger in English reading than in Chinese reading, indicating stronger phonological activation in the former than in the latter.

Native Chinese speakers and native Spanish speakers who were advanced learners of English also performed a priming study and an RB study in their L2, English. In the priming study, semantic priming was found only in the Chinese group, whereas phonological inhibition was found only in the Spanish group. In the RB study, semantic RB was found only in native Chinese speakers. Phonological RB, though found in both group, was significantly larger in the Spanish group than in the Chinese group. These results clearly demonstrate orthographic transfer.

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CHAPTER 1: INTRODUCTION

1.1 Background and Rationale

Reading is a process of retrieving orthographic (word form), semantic (word meaning), and phonological (word sound) information from printed words. Psycholinguists are increasingly aware that different orthographies encode semantics and phonology with different amounts of transparency. The activation of semantic and phonological information during reading may thus differ across orthographies. The purpose of this study is to examine semantic and phonological activation in reading Chinese and English by native speakers, and to extend those findings to exploration of advanced second language learners reading English.

Based on the smallest linguistic unit which can be mapped to a grapheme/graph, the world's orthographies are categorized into three major writing systems: alphabetic (phoneme), syllabic (syllable), and logographic[1] (morpheme) (Perfetti & Dunlap, 2008). Alphabetic orthographies can be further classified as shallow orthographies and deep orthographies according to the transparency of their symbol-sound correspondence (Liberman, Liberman, Mattingly, & Shankweiler, 1980). Shallow orthographies, like Spanish and Serbo-Croatian, have relatively consistent and transparent letter-phoneme correspondences; deep orthographies, like English and Arabic, have relatively inconsistent and opaque letter-phoneme correspondences.

Visual word recognition refers to the process by which a printed word is linked to its

[1] While Chinese is frequently referred to as a logographic writing system, it is more accurately characterized as a morphosyllabic writing system (see DeFrancis, 1984; 1989).

representation in the mental lexicon via analysis of the visual input (Lupker, 2005). Existing studies on activation of linguistic information during visual word recognition mainly compare orthographic and phonological activation. For example, the Orthographic Depth Hypothesis states that when processing printed words, shallow orthographies activate more phonological information, whereas deep orthographies activate more orthographic information (Besner & Smith, 1992; Katz & Feldman, 1983; Katz & Frost, 1992). Therefore, Spanish would be predicted to activate more phonological information than English, and English would be predicted to activate more orthographic information than Spanish.

In comparison with orthographic and phonological activation, semantic activation has been less frequently studied in the context of orthographic depth. As illustrated by connectionist models (Plaut, McClelland, Seidenberg, & Patterson, 1996; Plaut & Booth, 2000; Seidenberg & McClelland, 1989), dual-route models (Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001), and the lexical constituency model (Perfetti, Liu, & Tan, 2005), the representation of a word consists of semantic, orthographic, and phonological components. Therefore, semantic information is likely to interact with orthographic and phonological information in the process of visual word recognition. This dissertation investigated semantic activation together with phonological processing in Chinese and English reading to contribute to a more complete picture of visual word recognition.

It is well known that Chinese orthography has a relatively opaque symbol-sound correspondence. If included in the continuum of orthographic depth, Chinese would be placed at the deep end. It has been estimated that 80% to 85% of Chinese characters are semantic-phonetic compounds consisting of a semantic radical and a phonetic radical (Kang, 1993; Yin, 1991; Zhou, 1978). In 79% of compound characters, the semantic radical is directly related to character meaning (Wang, 1997). In contrast, phonetic radicals are not reliable cues for pronunciation, since only 40% of compound characters are phonetically regular even when tone difference is ignored[2] (Shu, Chen, Anderson, Wu, & Xuan, 2003; Zhou, 1980). In other words, less than 35% of Chinese characters contain useful phonological information[3].

Because Chinese orthography does not contain explicit sound-symbol correspondence, there was an early assumption that reading Chinese is primarily meaning-based. This view was refuted by studies of Perfetti and his colleagues, who showed that strong phonological activation appeared at the early stage of Chinese visual word recognition (e.g., Perfetti & Tan, 1998; Perfetti & Zhang, 1991, 1995; Tan, Hoosain, & Siok, 1996). However, other research found that phonology played no role or a less important role in Chinese reading (e.g., Chen, Flores d'Arcais, & Cheung, 1995; Liu, Wu, Sue, & Chen, 2006; Shen & Forster, 1999). To shed further light on this issue, phonological activation in Chinese reading is a key focus of the current study.

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[2] If tone difference is taken into consideration, the percentage drops to between 23 and 26 (Fan, Gao, & Ao, 1984; Shu et al., 2003; Zhou, 1980).

[3] Because 80% to 85% of Chinese characters are composed of a semantic radical and phonetic radical, and in 40% of these kind of characters, the phonetic radical provides clues to the pronunciation of the whole character, only 32% (=80%*40%) to 34% (=85%*40%) of Chinese characters convey reliable phonological information.

This study also investigated whether Chinese orthography differs from alphabetic orthographies in terms of the relative activation of semantic versus phonological information. Do Chinese characters evoke greater activation of semantic information compared to phonological information? Do they trigger greater activation of semantic information than alphabetic orthographies? My prior work (Cheng & Caldwell-Harris, to appear, under review) showed that native Chinese readers regularly made semantic substitution errors when reading Chinese text aloud, something that rarely, if ever, occurs for alphabetic readers. One explanation for these errors is that Chinese orthography activates phonology so weakly that readers do not maintain a robust image of the target word in working memory while reading. A related possible explanation is that semantics may sometimes be activated so strongly that it overrides phonology, which results in the replacement of the target word with a semantically related word.

This study additionally pursued the question of transfer of reading habits from a first language (L1) to a second language (L2). When reading in L2, second language learners appear to be influenced by their L1 orthographic experiences (Koda, 2007; Koda & Zehler, 2008). In L2 visual word recognition, learners with alphabetic literacy backgrounds rely on more phonological information, while learners with non-alphabetic backgrounds rely on more orthographic information (Jarvis & Pavlenko, 2008; Koda, 2007). For example, when asked to perform a semantic category judgment task in English, Korean learners of English whose native language has an alphabetic orthography experienced interference when presented with homophones, whereas Chinese learners of

English whose native language has a non-alphabetic orthography experienced interference from words with similar spellings (Wang, Koda, & Perfetti, 2003). In the context of orthographic transfer, the current study examined whether patterns of semantic and phonological activation can be transferred from L1 literacy experiences to L2 reading in advanced second language learners whose L1 is either Chinese (a very deep non-alphabetic orthography) or Spanish (a very shallow alphabetic orthography).

1.2 Scope and Aims

This dissertation investigates first language reading as well as second language reading by examining the patterns of semantic and phonological activation in reading Chinese and English as a first language and in reading English as a second language.

The question "Is the reading process language universal or language specific?" has been a controversial issue. Some researchers proposed that there are reading universals as well as reading specifics (e.g., Koda, 2007; Perfetti, 2003). However, it remains unclear what components of the reading process are universal to all orthographies and what components are specific to each individual orthography. The L1 studies in this dissertation (including both the priming study and the repetition blindness study) explore this question by comparing the activation patterns of semantic and phonological information in two very different orthographies, Chinese and English.

Orthographic depth and the Orthographic Depth Hypothesis were originally proposed for alphabetic orthographies. Can they be extended to non-alphabetic orthographies like Chinese? The L1 studies attempt to offer an answer to this question. According to the Orthographic Depth Hypothesis, the deeper an orthography is (that is, the less transparently it encodes phonology), the less phonological information the orthography activates. Chinese is a deeper orthography compared to English, because the former encodes phonology in a less transparent manner than the latter. In consequence, Chinese should activate less phonological information than English.

Traditionally, orthographic depth and the Orthographic Depth Hypothesis mainly concerned the relationship between orthography and phonology. Can they also account for the relationship between orthography and semantics? The L1 studies investigated this question by comparing the semantic activation patterns in Chinese and English reading.

Previous studies have shown that L1 reading strategies and skills can be transferred to L2 reading. However, it is not clear what can be transferred and what cannot. The L2 studies in this dissertation try to shed some light on this question by studying whether L1 semantic and phonological activation patterns are transferrable.

Although several computational models (i.e., connectionist models, dual-route models, and the lexical constituency model) suggest that semantic information plays a role in visual word recognition, little is known about how it interacts with other linguistic information. In the current study, semantic and phonological activation are both studied in L1 reading and L2 reading, which provides a good opportunity to observe the relative contributions of semantic information and phonological information in the reading process.

1.3 Overview of Methodology

Priming is a paradigm that psycholinguists frequently use to study orthographic, phonological, and semantic activation in reading. Two priming tasks (i.e., a semantic category judgment task and a naming task) were used to investigate L1 and L2 semantic and phonological activation patterns. In each priming task, prime-target pairs were presented with the single-word priming method as well as with the sentence priming method. Chinese and English were the two orthographies under investigation[4].

Repetition blindness is the other paradigm adopted in the present study. Repetition blindness originally referred to the failure of recalling or detecting the second occurrence of one word when two identical words are presented in Rapid Serial Visual Presentation (RSVP) (Kanwisher, 1987). It has been reported that detection failure also occurs when two words partially overlap in terms of linguistic information (Bavelier, 1999). Repetition blindness is thus a methodology that can also reveal what linguistic information is activated in reading. To examine semantic and phonological activation, a naming task and a confirmation task were carried out in Chinese and English.

Three groups of participants participated in the present study. Native English speakers were tested in their L1; advanced Chinese learners of English were tested in both their L1 and L2; advanced

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[4] Transparent orthographies like Spanish were excluded from this study. Their form-sound correspondence is so regular that it is impossible to design a phonologically related prime without orthographic relation with a target word.

Spanish learners of English were tested in their L2.[5] The English L1 data and Chinese L1 data established the activation patterns for these two orthographies. The English L2 data from Chinese and Spanish participants demonstrated that activation patterns are transferable.

1.4 Significance of the Study

This cross-orthography study fills existing gaps in the literature on reading and visual word recognition in reading in L1 as well as in L2. For L1, it tests the predictive power of the Orthographic Depth Hypothesis for semantic and phonological information processing in reading alphabetic and non-alphabetic orthographies. For L2, it examines the transferability of semantic and phonological activation patterns from L1 to L2. This study also makes methodological contributions to the study of reading in different orthographies by using rhyming words as phonological primes, by comparing the single-word method with the sentence priming method in the priming study, and by comparing the naming task and the confirmation task in the repetition blindness study.

The results of the current L1 studies may have a broader impact on research in dyslexia. To understand how (most) readers succeed and why some (e.g., dyslexics) fail at the task of reading, we need to find answers to the general question of how the writing systems activate orthographic, phonological, and semantic information. The different patterns of semantic and phonological

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[5] Advanced English learners of Chinese and advanced Spanish learners of Chinese were not included in the current study, because it is extremely difficult to recruit these two groups of participants in the States as well as in Chinese-speaking countries like Taiwan and China.

activation in Chinese and English reading revealed in the present study suggest that Chinese dyslexia is likely to possess characteristics that differ from dyslexia in alphabetic orthographies.

The results of the current L2 studies may have important implications for the acquisition of L2 reading. Second language educators should be aware of how transparency differences in phonology between learners' L1 and L2 orthographies may interfere with language learning via reading.

1.5 Relevant Previous Research

A review of the literature on four topics is presented as follows. Previous studies in visual recognition when reading alphabetic orthographies are firstly reviewed to introduce the Orthographic Depth Hypothesis. Then, a review of prior studies in Chinese visual word recognition discloses the controversial issue of whether phonology plays an important role in reading Chinese. Next, a summary of some of my prior work on semantic substitution in reading Chinese and English texts aloud offers a glimpse of how semantic information is processed differently in reading these two orthographies. Lastly, previous studies involving orthographic transfer are reviewed to show how Ll literacy backgrounds influence L2 reading.

1.5.1 Visual Word Recognition Studies in Alphabetic Orthographies

The Orthographic Depth Hypothesis (weak form, Katz & Frost, 1992) argues that both the prelexical letter-phoneme mappings and lexical look-up retrieval are necessary for visual word recognition in every orthography. What differentiates shallow orthographies from deep orthographies is the relative importance of these two strategies. Shallow orthographies like Serbo-Croatian and Spanish encourage a phonological recoding strategy, and deep orthographies like English and unvoweled Hebrew encourage a visual-based direct access strategy (Seidenberg, 1992).

By conducting three naming tasks, Frost, Katz, and Bentin (1987) showed that the role of phonological recoding is more important in Serbo-Croatian than in English, and more important in English than in Hebrew. They also reported a relatively strong effect of semantic facilitation in Hebrew, a small but significant semantic effect in English, and no semantic facilitation in Serbo-Croatian. Similarly, Tabossi and Laghi (1992) found stronger semantic priming effects in English than in Italian for naming words aloud. These findings were challenged by Baluch and Besner (1991), who proposed that the absence or mitigation of semantic activation in shallower orthographies might result from the inclusion of nonwords in the stimulus lists, since nonwords encourage the use of a prelexical naming strategy. After excluding nonwords from their stimuli, they found a semantic relatedness effect on both phonologically transparent words and phonologically opaque words in Persian.

These uneven and conflicting findings indicate that additional research on semantic activation is warranted. The present study included only real words in the stimuli, and adopted a naming task as well as a semantic category judgment task to investigate semantic and phonological activation.

Repetition blindness (RB) was originally referred to as the failure of recalling or detecting the second of two identical items when it was first reported by Kanwisher (1987). However, it has been found that partial overlap between two items is sufficient to elicit RB effects. For example, Kanwisher and Potter (1990) showed RB effects in orthographically similar word pairs such as *cap-cape* and *walk-walks*; Bavelier and Potter (1992) demonstrated RB effects in homophonic word pairs such as won-one. Repetition blindness thus provides a good paradigm for studying the activation of linguistic information. To date, however, it has not been used to index activation of linguistic information across orthographies.

The majority of repetition blindness studies concern what causes RB effects (e.g., words, nonwords, pictures, digits, etc.) and in which time window (i.e., the time lag between two critical words) RB effects occur. In other words, most researchers study the phenomenon of repetition blindness per se. However, some studies have employed the repetition blindness paradigm as a tool to explore lexical representation issues in cognitive science. Harris and her colleagues examined the representation of sublexical components (Aycicegi & Harris, 2002; Harris & Morris, 2001; Morris & Harris, 1999) and the cohort effect in visual word recognition (Niedeggen, Heil, Harris, 2006; Niedeggen, Heil, Ludowig, Rolke, & Harris, 2004). Others investigated semantic representation of translation equivalents in bilinguals (e.g., Altarriba & Soltano, 1996; MacKay & Miller, 1994; Sánchez-Casas, Davis, & García-Albea, 1992). The current study is the first study using the repetition blindness paradigm to compare semantic and phonological activation between Chinese and English.

1.5.2 Visual Word Recognition Studies in Chinese Orthography

It has been assumed that readers of Chinese directly access meanings from characters without activating phonology, since characters contain only approximate clues to pronunciation (e.g. Chen et al., 1995; Liu et al., 2006; Shen & Forster, 1999; Weekes, Chen, & Lin, 1998; Zhou & Marslen-Wilson, 1996).

However, Perfetti and his colleagues found phonology is activated not only early but also strongly in Chinese reading (e.g., Perfetti & Liu, 2005; Perfetti, Liu, & Tan, 2005; Spinks, Liu, Perfetti, & Tan, 2000; Tan & Perfetti, 1998). For example, in two primed-naming experiments, orthographic, phonological, and semantic priming effects occurred at 43ms, 57ms, 85ms respectively, and the magnitudes of all priming effects were at least 50ms (Perfetti & Tan, 1998). Based on these studies, Perfetti and his colleagues have argued that phonological activation is obligatory across writing systems, and proposed what they called "The Universal Phonological Principle" (UPP; Perfetti, Zhang, & Berent, 1992; Perfetti & Dunlap, 2008). It should be noted that Chen and Shu (2001) were only able to replicate Perfetti and Tan (1998) in orthographic priming effects, but not in semantic and phonological priming effects. In one experiment with native Mandarin-speaking participants and the other experiment with native Cantonese-speaking participants, semantic priming effects appeared earlier and stronger than phonological priming effects. Wu and Chen (2000) also reported that, despite several attempts, they still could not attain similar results to Perfetti and Zhang (1991).

Williams and Bever (2010) proposed a third view in which although both semantic and phonological information are activated in reading Chinese, semantic processing plays a more important role than phonological processing. The authors showed that semantic and phonological radicals both had facilitatory effects when they were transparent and had inhibitory effects when opaque. Most interestingly, when semantic and phonological radicals were visually blurred, the former induced a higher error rate than the latter in a lexical decision task. The authors concluded that semantic path is the default route to process Chinese characters.

There is thus little consensus in theories about semantic and phonological activation in reading Chinese. Moreover, few studies have examined Chinese visual word recognition and alphabetic visual word recognition with the same experimental design. The present study rectifies methodological shortcomings in the literature by using the same method to investigate Chinese and English activation patterns.

Although repetition blindness has not been widely adopted to study Chinese reading, RB effects have been found when two characters were identical (Chen & Wong, 1997; Tzeng, 1994; Yeh & Li, 2004), when two characters were high frequency homophones (Tzeng, 1994), and when two characters shared one component (Yeh & Li, 2004). The current study expands our understanding of repetition blindness in Chinese reading by examining both semantic RB and phonological RB and by providing a direct comparison with English reading.

1.5.3 Preliminary Study of Semantic Substitution Errors

In a study that I conducted in China and Taiwan, around 80% of my participants (including both college and middle school students) made semantic substitution errors when reading aloud never-seen-before Chinese passages from a computer screen (Cheng & Caldwell-Harris, to appear). Semantic substitution errors are errors made by substituting the target word (e.g., *yell*) with a semantically related word (e.g., *shout*) (Abu-Rabia, & Taha, 2004; Béland & Mimouni, 2001). It is a type of error that deep dyslexic English readers, but not normal English readers, usually make (Barry, 1984; Coltheart, 1980a).

The 29 Chinese college students, 25 Chinese middle school students, and 25 Taiwanese middle school students were asked to read aloud 12 short Chinese passages with three types of genre (i.e. humorous stories, general current affairs articles, and technical scientific reports) on a computer screen. They were categorized into three levels of readers (i.e. excellent, good, and poor readers) based on their reading rate in a silent reading task. In the analysis of number of semantic substitution errors, a 3 (genres of articles) X 3 (groups of participants) X 3 (levels of readers) ANOVA showed that none of the three factors had a main effect, which indicates that semantic substitution error is a common type of error for Chinese readers. Regardless of whether participants were from Taiwan or China, or were college students or middle school students, or were good or poor readers, they made semantic substitution errors occasionally.

To better understand this finding, I conducted a series of experiments using the same set of stimuli with 20 native English speakers and 24 native Chinese speakers recruited from Boston University[6] (Cheng & Caldwell-Harris, under review). The Chinese group made over 30 times more semantic substitution errors than the English group ($p<.001$; 0.36 vs. 0.01 errors per person per passage). If reading a hundred passages, the Chinese group would make 36 semantic substitutions, whereas the English group would make only one semantic substitution. This big difference suggests that Chinese readers process semantic and phonological information in a different way than do English readers. Reading aloud seems to be a dual task for Chinese readers: meaning and pronunciation are accessed from visual input in a parallel way. Because silent reading is fast, the eyes may already have moved ahead in the passage while phonology for a prior word is still being retrieved. If phonology is not activated as fast and as strongly as semantics, then phonological retrieval from the visual input can sometimes produce a word discrepant from yet semantically related to the target.

The Chinese readers were also asked to read some of the passages in Pinyin or Zhuyin, two phonetic scripts that are used to label Chinese character pronunciation and do not carry any semantic information. In this task, semantic substitution errors were as few as for English readers (0.06 errors per person per passage). This result provides strong evidence that the informational qualities of Chinese characters strongly influence the relative amounts of semantic and phonological activation.

[6] In order to have a precise comparison with Chinese groups, the English group read the English translation version of the same 12 passages that Chinese groups read.

1.5.4. Orthographic Transfer Studies

Researchers postulated that second language learners whose L1 and L2 use the same type of writing system would process L2 words better than those whose L1 and L2 use different writing systems. Studies comparing learners of English with different L1 backgrounds did show that those with alphabetic literacy backgrounds (Arabic, Hebrew, Indonesian, Persian, Russian, and Spanish) outperformed those with non-alphabetic literacy backgrounds (Chinese and Japanese) (e.g., Akamatsu, 2003; Bialystok, Luk, & Kwan, 2005; Green & Meara, 1987; Koda, 1988; Muljani, Koda, & Moates, 1998; Wade-Woolley, 1999). Wang, Koda, & Perfetti (2003) found that English learners with alphabetic literacy background (Koreans) relied more on phonological information while English learners with non-alphabetic literacy background (Chinese) relied more on orthographic information, when they performed a semantic category judgment task and a phoneme deletion task in English. Some studies with participants who were advanced learners, however, found no or a weak L1 orthographic transfer effect in English visual word recognition (Akamatsu, 2002; Jackson, Chen, Goldsberry, Kim, & Vanderwerff, 1999; Lemhöfer et al., 2008).

Liu, Wang, and Perfetti (2007), as far as I know, is the only study on bilingual activation patterns using a priming paradigm. American English-speaking learners of Chinese performed primed-naming experiments. Orthographic priming effects were found at the end of the first semester of Chinese learning, while semantic priming effects occurred at the end of the second semester. These results suggest that when processing Chinese characters, native alphabetic readers modified their L1 activation patterns to adjust to L2 orthography. Do native non-alphabetic readers also modify their activation patterns to adjust to an alphabetic L2 orthography? Do native alphabetic readers modify their activation patterns to adjust to another alphabetic L2 orthography? The present study sought answers to these questions by examining native Chinese and Spanish speakers' activation patterns when they read in their L2 (i.e. English).

1.6 Organization of the Dissertation

This dissertation is composed of five chapters, including this introduction. Chapter 2 reports a priming study performed by native Chinese speakers and native English speakers when reading their native language. The results of this L1 priming study suggest that semantic information and phonological information are processed in different manners in reading Chinese versus reading English. To confirm this finding, a repetition blindness (RB) study was carried out in Chinese and English and is presented in Chapter 3. This L1 RB study clearly shows that phonological information is more strongly activated in English reading than in Chinese reading. After the L1 patterns of semantic and phonological activation are established, a priming study and a repetition blindness study were conducted with advanced Chinese learners of English and advanced Spanish learners of English to examine the influence of L1 literacy experience on L2 reading. Chapter 4 reports these two L2 studies which demonstrate orthographic transfer. Chapter 5 is a conclusion chapter including a summary of the major findings of the entire study, the implications for the Orthographic Depth

Hypothesis and for reading universals versus reading specifics, research limitations, and some suggestions for future research.

CHAPTER 2: THE FIRST LANGUAGE PRIMING STUDY

2.1 Background

All the world's orthographies encode at least three types of linguistic information: orthographic information, phonological information, and semantic information. The first step of reading, visual word recognition, is to decode these forms of linguistic information conveyed in a printed word and map them with the orthographic, phonological, and semantic representations of a word in the mental lexicon. However, every orthography encodes the three types of linguistic information with different amounts of transparency. "What consequences do these language specific properties bring to the reading process?" is the theme of the present study. More specifically, the current study aims to examine semantic and phonological activation in reading Chinese versus English, using a priming paradigm.

2.1.1 The Orthographic Depth Hypothesis

The most notable language specific property of the world's orthographies is the manner in which phonology is encoded. Based on the consistency and transparency of grapheme-phoneme correspondence, alphabetic orthographies form a continuum of orthographic depth ranging from shallow to deep (Liberman, Liberman, Mattingly, & Shankweiler, 1980). The orthographies whose mapping between written symbols and pronunciation is relatively consistent and transparent (e.g., Serbo-Croatian, Spanish, Italian, etc.) are shallow orthographies; the orthographies whose mapping between written symbols and pronunciation is relatively inconsistent and opaque (e.g., unvoweled Arabic, unpointed Hebrew, English, etc.) are deep orthographies.

Does the difference in orthographic depth lead to different reading processes? The answer is positive, according to the Orthographic Depth Hypothesis. The dual-route theories propose that there are two routes to reach visual word recognition: one is the direct route, and the other is the indirect route (Coltheart, 1978, 1980b; Morton & Patterson, 1980). The direct route, also known as the visual-orthographic or lexical route, refers to the process in which a reader recognizes a printed word directly from its orthographic representation. The indirect route, also known as the phonological or nonlexical route, refers to the process in which a reader recognizes a printed word by practicing grapheme-phoneme conversions. The weak form of the Orthographic Depth Hypothesis (Katz & Frost, 1992) claims that although both routes are employed in reading any orthography, the relative importance of either route varies with orthographic depth. More specifically, shallow orthographies support the indirect route, whereas deep orthographies encourage the direct route. In other words, a reader of a shallow orthography makes more use of phonological information to identify a printed word, yet a reader of a deep orthography relies more on graphic information for visual word recognition.

This hypothesis has been supported by empirical studies. For example, Frost, Katz, and Bentin (1987) showed that when naming words, the performance in Hebrew (the deepest among the three orthographies examined in the study) was affected most by the lexical status of the stimulus (i.e., a high frequency word, a low frequency word, or a nonword). The performance in Serbo-Croatian (the shallowest orthography in the study) was not affected, and the performance in English was moderately affected. Moreover, when the proportion of nonwords in the stimulus list increased from 20% to 80%, the naming errors increased for Hebrew (8.5 %) and English (2.3%) yet stayed the same for Serbo-Croatian (zero error). Other evidence comes from studies involving young readers. Comparing with English reading children, those whose native language has a shallow orthography (e.g., German, Spanish, Welsh, etc.) were more able to accurately read low frequency words and nonwords (Ellis & Hooper, 2001; Lopez & Gonzalez, 1999; Wimmer & Goswami, 1994). The difference between young readers of deep orthographies and those of shallow orthographies also manifested in the reading errors that they made. For example, English reading children's incorrect responses tended to be visually similar to the target word, while German and Welsh reading children's incorrect responses tended to be nonwords which share phonemes with the target word (Ellis & Hooper, 2001; Wimmer & Hummer, 1990). In an attempt to extend the Orthographic Depth Hypothesis to non-alphabetic orthographies, Ellis et al. (2004) included young readers of transparent syllabic Japanese hiragana, Albanian, Greek, English, and opaque Japanese kanji. Their results showed that shallower orthographies were associated with higher reading accuracy. Moreover, the shallower the orthography, the more likely that reading latency was a function of word length. When reading nonwords, the readers of shallower orthographies made more mispronunciations.

2.1.2 The Role of Phonology in Reading Chinese: A Controversial Issue

The majority of Chinese characters (80% to 85%) are compound characters composed of a semantic radical and a phonetic radical (Kang, 1993; Yin, 1991; Zhou, 1978). In 79% of compound characters, the semantic radical provides reliable clues to character meaning (Wang, 1997). In contrast, phonetic radicals only provide useful hints for character pronunciation for 40% of compound characters even when tone difference is ignored (Shu, Chen, Anderson, Wu, & Xuan, 2003; Zhou, 1980). If tone difference is taken into consideration, the percentage drops to between 23 and 26% (Fan, Gao, & Ao, 1984; Shu et al., 2003; Zhou, 1980). The correspondence between written symbols and pronunciation in Chinese is therefore considerably inconsistent and opaque compared to alphabetic orthographies. If included in the continuum of orthographic depth, Chinese must be placed at the very deep end.

Another advantage that semantic radicals have over phonetic radicals is that the number of the former is much smaller than the number of the latter (200 vs. 800, Hoosain, 1991). Because both types of radicals are learned by rote memory, a smaller number indicates a smaller learning load, a more economical representation in the mental lexicon, and more efficient processing. Given that semantic radicals have more advantages than phonetic radicals, it is not surprising that there is an assumption that reading Chinese is mainly meaning-based with minimal or no phonological activation. For example, Zhou and Marslen-Wilson (1996) claim that "[t]here is no 'prelexical' phonology in reading Chinese." Chen et al. (1995) found that homophones did not elicit more errors nor shorter response latency than the matching controls in a semantic categorization task. In Shen and Forster (1999), homophone priming effects only appeared in a naming task but not in a lexical decision task. They concluded that phonology is only activated "when the task emphasizes rapid mapping from an orthographic code to a phonological code." Weekes, Chen, and Lin (1998) reported that phonological priming only occurred to compound characters (which consist of a semantic and a phonetic radical), but not to integrated characters (which consist of no radicals). These findings suggest that phonology activation is not obligatory in reading Chinese.

Perfetti and his colleagues hold a completely opposite view because their work repeatedly demonstrated that phonological activation occurs strongly at a very early stage of the Chinese reading process (e.g., Perfetti & Liu, 2005; Perfetti, Liu, & Tan, 2005; Spinks, Liu, Perfetti, & Tan, 2000; Tan & Perfetti, 1998). Perfetti and Tan (1998), one of their classic studies, showed that orthographic, phonological, and semantic priming effects occurred when SOA was 43ms, 57ms, 85ms respectively in a naming task, each with a magnitude of at least 50ms (around 100ms for homophonic primes). Phonological activation was also found in semantic category judgment tasks. In Perfetti and Zhang (1995), participants were asked to judge whether character pairs have similar meanings. Phonological interference was observed from the results that homophonic foils led to longer response latency and higher error rate compared to control foils. Based on their findings of phonological activation in reading Chinese, Perfetti and his colleagues (e.g., Perfetti, 2003; Perfetti & Dunlap, 2008) argue that phonological information is automatically activated in reading all writing systems (known as the

Universal Phonological Principle). Nevertheless, they acknowledge that phonology is activated in cascade style for alphabetic orthographies, but in threshold style for Chinese orthography and the concept of phonological mediation[7] is not applicable for Chinese (Perfetti, 2003; Perfetti, Liu, & Tan, 2005).

By examining the effects of semantic and phonetic radicals on Chinese character recognition, Williams and Bever (2010) propose a third view: although Chinese characters can be recognized through both the semantic route and the phonetic route, the former plays a stronger role than the latter. The evidence comes from their Experiment 3 in which a character was presented with either a blurred semantic radical or a blurred phonetic radical in a lexical decision task. The results showed that character recognition was hurt more by blurred semantic radicals, since they led to higher error rate and longer response latency. Zhou and Marslen-Wilson (2000) also reported that semantic priming appeared strongly at both the short and long SOAs (i.e., 57ms and 200ms) across three different tasks (i.e., a compound word lexical decision task, a character lexical decision task, and a character naming task). Although phonological priming effects were as strong as semantic priming effects in the character naming task, they appeared only at the long SOA in the character lexical decision task, and were completely absent in the compound word lexical decision task.

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[7] Phonological mediation is the idea that access to word meaning involves activation of phonology (e.g., Lukatela & Turvey, 1994a; Perfetti & Bell, 1991; Van Orden, 1987).

2.1.3 Prelexical Semantic Activation in the Reading Process

The majority of computational models for reading such as connectionist models (Plaut, McClelland, Seidenberg, & Patterson, 1996; Plaut & Booth, 2000; Seidenberg & McClelland, 1989), dual-route models (Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001), and the lexical constituency model (Perfetti, Liu, & Tan, 2005) assume that a printed word is represented by orthographic, phonological, and semantic information. This assumption suggests that a printed word can only be identified when all these three types of linguistic information is successfully decoded.

However, some researchers appear to make no distinction between the semantic information encoded in a printed word and the meaning of the printed word. The former refers to a component that interacts with orthographic and phonological information in the reading process, whereas the latter is the final product of reading. The consequence of this conflation is to assume that semantic processing is the same across orthographies since all orthographies can be comprehended equally well (i.e., all orthographies allow readers to understand words). Therefore, semantic activation has been less studied along with orthographic and phonological activation in the context of orthographic depth.

The confusion comes from the fact that in alphabetic orthographies, semantic information of a printed word is carried by morphemes which are usually large linguistic units consisting of several letters and phonemes. Presumably, orthographic information comes into play in the reading process when a letter is identified; phonological information comes into play when a phoneme is identified.

Following this logic, semantic information cannot come into play in the reading process until a morpheme is identified. When a morpheme is identified, it is usually very close to the end stage of the reading process: the identification of the printed word. This is why it is difficult to conceptualize prelexical semantic activation in reading alphabetic orthographies.

Chinese, a non-alphabetic orthography, provides a good opportunity to understand how semantic activation may occur prelexically. The majority of Chinese characters are composed of two components: a semantic radical which carries semantic information and a phonetic radical which carries phonological information. In alphabetic orthographies, a semantic information carrier (i.e., a morpheme) usually consists of several orthographic carriers (i.e., letters) and several phonological carriers (i.e., phonemes). It is natural to assume that orthographic and phonological processing have to precede semantic processing. In contrast, a semantic radical and a phonetic radical in Chinese orthography are two independent components. Identifying a phonetic radical is not a prerequisite for the identification of a semantic radical and vice versa, although orthographic processing is required for identifying either a semantic radical or a phonetic radical. No matter whether a semantic radical is processed before, after, or in parallel with a phonetic radical, it is processed before a character is recognized. The facilitatory effects of semantic radicals have been found in lexical decision tasks (Feldman & Siok, 1999) and semantic categorization tasks (Williams & Bever, 2010), suggesting prelexical semantic activation.

2.1.4 The Reading Process in Chinese versus English Reading

There are two dimensions in the activation of orthographic, phonological, and semantic information in the reading process. One is the time course, and the other is the magnitude. The time course of linguistic activation concerns the order of the occurrence of the three types of linguistic activation. It is known that orthographic information is activated before phonological and semantic information in reading Chinese and English (Liu & Perfetti, 2003). When reading English, there is a common belief that phonological information is activated earlier than semantic information (Sasaki, 2005). One major reason is that orthographic-phonological correspondences are more consistent than orthographic-semantic correspondences in English (Van Orden, Pennington, & Stone, 1990). Another possible reason, in my opinion, is that phonological information carriers (i.e., phonemes) constitute a semantic information carrier (i.e., a morpheme). In Chinese reading, no consensus has been reached on whether phonological activation or semantic activation occurs earlier. Even though different studies use the same experimental stimuli and procedure, their findings tell different stories. With their US participants, Perfetti and Tan (1998) showed that phonological priming effects appeared before semantic priming effects (57ms vs. 85ms). With their Beijing participants, Chen and Shu (2001) found that semantic priming effects appeared across three SOAs (i.e., 43ms, 57ms, and 85ms), but phonological priming effects were only reliable at 57ms. Moreover, semantic priming effects were found at 57ms and 85ms, but no reliable phonological priming effects were found in their Hong Kong participants.

The magnitude of linguistic activation is the other dimension of the reading process. There has been convergent evidence that both Chinese readers and English readers rely heavily on orthographic information (e.g., Booth, Perfetti, & MacWhinney,1999; Peng, Li, & Yang, 1997) , since both orthographies are on the deep side of the continuum of orthographic depth. When comparing these two orthographies, English is expected to activate a larger magnitude of phonological effects because the symbol-sound correspondence is more transparent and consistent in English. In contrast, Chinese is expected to activate a larger magnitude of semantic effects because the orthography-semantics mapping is more transparent in Chinese given that Chinese semantic radicals usually have larger combinability (i.e., are more productive) than English morphemes.[8]

2.1.5 The Current Priming Study in Reading Chinese and English as a First Language

To fill in the literature gap of semantic activation in the context of orthographic depth and to shed some light on the controversial issue of phonological activation in reading Chinese, a priming study was carried out to investigate semantic and phonological activation in reading Chinese and English as a first language. As mentioned above, semantic and phonological information are encoded with different degree of transparency in Chinese and English. Therefore, it is expected to find different activation patterns of semantic and phonological information when reading these two orthographies.

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[8] There are approximately 200 semantic radicals in Chinese (Hoosain, 1991) yet 50000 morphemes in English (Weiten, 2010).

2.2 Method

Priming is the most widely used paradigm in examining the activation of linguistic information in reading. The essential components of a priming task are primes and targets, which are selected to have a specific type of linguistic relationship (e.g., semantically related, phonologically related, unrelated, etc.). If a certain type of prime allows participants to respond to the targets faster, when compared to the unrelated prime-target pairs, then that type of linguistic information is considered to be activated.

2.2.1 Some Methodological Issues

Several methodological issues must be discussed in order to lay out the rationale of the experimental design.

2.2.1.1 The Choice of Experimental Tasks

In the literature on priming studies, naming, semantic category judgment, and lexical decision are the three most frequently used tasks. The first two tasks were chosen for the current study to examine semantic and phonological priming effects. The occurrence and magnitude of priming effects vary across tasks (e.g., Neely, 1991; Shen & Forster, 1999). This suggests that it could be advantageous to adopt different tasks to study priming effects. The semantic category judgment task, a task requiring meaning access, and the naming task, a task requiring pronunciation retrieval, allow examination of semantic and phonological priming effects in different conditions. The lexical decision task was not used in the present study because it can be performed based on orthographic familiarity, bypassing meaning access and pronunciation, as has been shown in many studies (Neely, 1991; Seidenberg & McClelland, 1989).

2.2.1.2 Single-word Priming vs. Sentence-based Priming

Traditionally, only single words are presented as primes and targets in priming studies. This traditional method is useful to study visual word recognition, but is less helpful for studying normal reading. In daily reading activities, we usually read sentence by sentence instead of word by word. Sentence-based priming has been developed to study context effects and empty syntactic categories known as traces (e.g., Paul and Kellas, 2004; Swinney et al., 1979). In sentence-based priming, a prime is embedded in a sentence which is presented aurally and a target is presented visually. In other words, sentence-based priming is a cross-modal paradigm. Since the current study is a reading study, I modified sentence-based priming into a single modal paradigm in which both the target and the sentence that contains the prime are presented visually. With this modified sentence-based priming paradigm, participants read a sentence rather than a single word before they respond to a target, which is more similar to our daily reading activities.

To have a direct comparison with previous studies and to understand the differences between the traditional single-word priming and the modified sentence-based priming, both priming paradigms were adopted for a naming task and a semantic category judgment task. The current study thus includes four experimental tasks: a single-word[9] naming task, a single-word semantic category judgment task, a sentence-based naming task, and a sentence-based semantic category judgment task.

2.2.1.3 The Choice of Semantic Primes

Semantic primes allow us to examine semantic activation. If a target word is responded to faster when it is preceded by a semantic prime compared to by an unrelated prime, a semantic priming effect is observed. A semantic prime can be synonymous with (e.g., *talk-lecture*), thematically related to (e.g., *bee-honey*), or taxonomically related to (e.g., *monkey-horse*) the target. It, however, should not be phonologically or orthographically related to the target. Otherwise, it would be unclear whether an observed priming effect comes from semantic, phonological, or orthographically similarity. This concern may seem obvious, but it often does not receive enough attention in studies of Chinese in particular, perhaps because of the complex relations among orthography, sound, and meaning in the writing system. For example, in Perfetti and Tan (1998), some prime-target pairs either have an identical onset (e.g., 媽-母 [ma]-[mu]), an identical rime (臉-面 [liɛn]-[miɛn]), or an identical semantic radical (e.g., 林-松).

When choosing Chinese semantic primes, there is another issue that researchers should be aware of: whether a prime and its matching target forms a compound word. The majority of Chinese words

9 All Chinese primes and targets are free morphemes which can stand alone as words. Therefore, the term "single-word priming" can be applied to both the Chinese and English experimental tasks.

are compound words which consist of at least two characters (Arcodia, 2007), suggesting that most characters can form a compound word with other characters. This can be illustrated most clearly with an example from English. If a prime (e.g., *ice*) and its matching target (e.g., *cream*) can form a compound word (e.g., *ice cream*) and the prime occupies the first position of the compound while the target occupies the second position, then this prime-target pairs should not be included in the stimuli. The reason is that the priming effect observed in such cases might result from the frequent co-occurrence of the prime and the target instead of the semantic relationship between the two words. This concern is often neglected in previous studies. For example, several prime-target pairs in Wu and Chen (2000) are compound words (e.g., 修-理 'fix'-'organize'= 'repair'; 攪-拌 'stir'-'blend' = 'stir'; 迷-惘 'lost'-'frustrated' = 'perplexed'). Again, this is a special challenge posed by Chinese, because of the ubiquity of compounds and the high level of polysemy of many monomorphemes.

2.2.1.4 The Choice of Phonological Primes

Phonological primes allow us to examine phonological activation in a priming paradigm. If a target is responded to faster when it is preceded by a phonological prime compared to by an unrelated prime, a phonological priming effect is observed. Most previous studies use homophones to investigate phonological priming effects. Homophones can be good phonological primes when a study aims to investigate phonological priming effects only or to compare phonological priming effects with orthographic priming effects. However, in studies which aim to compare phonological priming effects with semantic priming effects like the present study, homophones are not good candidates to serve as phonological primes.

To have a meaningful comparison between both the magnitude and time course of phonological and semantic activation, it is critical to provide equivalent contexts for priming– equal chances for phonological and semantic primes to facilitate the identification of their matching targets. A homophone prime has exactly the same pronunciation with its matching target. In contrast, there is little chance that a semantic prime can have exactly the same meaning with its matching target as even synonyms have some delicate differences in meaning (Lyons, 1968). Therefore, the use of homophones as phonological primes would be biased toward phonological activation. To make the comparison between semantic and phonological activation as fair as possible, the current study use rhyming words to serve as phonological primes. A rhyming prime (e.g., *half*) and its matching target (e.g., *laugh*) share a rime yet differ in onset. For details about how I tried to make the semantic similarity between a semantic prime and a target and the phonological similarity between a phonological prime the same target as close as possible, please see section 2.2.4.2 *The Choice of Prime-target Pairs: A Norming Study*.

2.2.1.5 Frequency of Targets

Word frequency effects have long been discussed in studies of visual word recognition. Phonological activation plays a more important role in processing low frequency words than in processing high frequency words (Seidenberg, 1985; Besner & Hildebrandt, 1987; Hirose, 1992; Muljani, Koda, & Moates, 1998). Wu and Chen (2000) also found that semantic and phonological priming effects only occurred in processing low frequency Chinese characters for lexical decision tasks. Therefore, word frequency of the stimuli in the present study was controlled such that half of the targets were high frequency words/characters, and the other half were low frequency words/characters.

2.2.1.6 The Choice of SOA

Stimulus onset asynchrony (i.e. the time lag between the onsets of a prime and a target; SOA) was also manipulated in the present study. The shortest SOA reported where phonological priming effects occurred is 30ms (e.g., Lukatela & Turvey, 1994b; Perfetti & Bell, 1991). Homophones served as phonological primes in these prior studies, whereas rhyming words served as phonological primes in the present study. Assuming that rhyming words might not activate phonological information as early as homophones, the shortest SOA in the current study was set at 50ms. Two longer SOAs (100ms and 150ms) were also adopted because I speculated that phonological activation in reading Chinese would occur later than in reading English. An advantage compared to previous studies is that the manipulation of SOA was a within-subjects variable in this study. That is, each participant saw trials with different SOAs. This design prevented the participants from anticipating the timing course of trials.

2.2.2 An overview of the Experimental Design

The priming study included four tasks: a single-word naming task, a single-word semantic category judgment task, a sentence-based naming task, and a sentence-based semantic category judgment task. Each task had 8 versions of stimuli. The order of task performance and the version of stimuli used were both fully counterbalanced. A group of native Chinese speakers and a group of native English speaker performed the tasks in their native language.

2.2.3 Participants

A group of 165 native Chinese speakers and a group of 114 native English speakers participated in the present first language priming study. Because of technical problems with E-prime experimental control scripts, only the data of the following participants who performed on the revised E-Prime scripts were included in the data analysis: 97 native Chinese speakers (53 from Mainland China and 44 from Taiwan; 32 males and 65 females; mean age = 23.4 yrs, SD = 3.7) and 80 native English speakers (19 males and 61 females; mean age = 19.4 yrs, SD = 2.1). All participants were recruited from the greater Boston area, and the majority of them were graduate or undergraduate students. Each participant was either paid $10 per hour or given credit hours for PSY101 for their contribution of time.

All participants were under age 35, started to learn their native language at birth, and received their high school diploma from a country in which their native language is an official language. Most participants in the English group came from PSY 101 in which the majority of the students were freshmen or sophomores in their late teens or early twenties. Since the development of reading is a slow yet persistent process, an age limit was set at 35 to ensure the comparability across language groups. The second and the third criterion guarantee that all participants had either Chinese or English as their native language, and they were immersed in that language long enough to have high proficiency in reading their native language.

2.2.4 Materials

There were two sets of stimuli: one in Chinese and the other in English. The Chinese stimuli were presented in two different scripts: simplified script for participants from Mainland China, and traditional script for participants from Taiwan. All Chinese primes and targets were single-character words which bear one prominent meaning despite their polysemous nature.

2.2.4.1 The Design of Prime-target Pairs

In some previous studies (e.g., Perfetti & Tan, 1998), every type of prime has its own matching target (e.g., a semantic prime has a matching target, and a phonological prime has another matching target). The observed priming effects then may confound with the different matching targets. The matching targets for one type of primes might be more difficult to access than the matching targets for anther type of primes due to word frequency, phonetic regularity, semantic transparency, etc. To address this concern, a within-item design was adopted: all three types of primes (i.e., semantic primes, phonological primes, and unrelated primes) matched with the same set of targets. In other words, each target was paired with a semantic prime, a phonological prime, and an unrelated prime as shown in Table 1. This design would make a more valid comparison of any priming/inhibitory effects brought by semantic and phonological primes.

Table 1: Examples of Prime-target Pairs

	Target	Semantic prime	Phonological prime	Unrelated prime
Chinese	好 *hao3* "good"[10]	優 *you1* "excellent"	掃 *sao3* "sweep"	生 *sheng1* "birth"
English	build	construct	filled	worry

A semantic prime is synonymous with, thematically related to, or taxonomically related to the target, yet it does not share any orthographic or phonological similarity with the target. Cases in which a semantic prime is the first character of a compound word and a target is the second character of the same compound word were excluded. As mentioned in section 2.2.1.3 *The Choice of Semantic Primes*, the use of a prime and target that together compose a compound could result in strong priming effects deriving from the frequent co-occurrence of the two characters, rather than their

[10] The format of the gloss is as follows: Chinese character, pinyin representation with a number indicating the tone, the meaning of the character in quotation marks.

semantic relationship.

A phonological prime rhymes with the target, yet it is not orthographically or semantically related to the target. For the reason why homophones were not used as phonological primes as most previous studies on linguistic activation in reading, please refer to section 2.2.1.4 *The Choice of Phonological Primes.*

An unrelated prime has no similarity in meaning, pronunciation, or form with the target word.

2.2.4.2 The Choice of Prime-target Pairs: A Norming Study

In the early stages of the present study, I reviewed the stimuli used in previous studies and hoped to adopt them. However, none of them met the criteria stated above. I therefore decided to design my own stimuli. Different challenges emerged in designing Chinese and English stimuli due to the properties of the two orthographies. When designing the Chinese stimuli, selecting the semantic primes was the most challenging part. It was not easy to find Chinese prime-target pairs which are semantically related yet do not form a compound word and do not share a semantic radical. In contrast, when designing the English stimuli, selecting the phonological primes was the most challenging part. Since English is an alphabetic orthography, the spelling of an English word somewhat reflects the pronunciation of the word. It was thus not easy to find English prime-target pairs which rhyme yet differ in spelling.

A norming study was carried out to justify the relationship between prime and target words and the clarity of semantic category judgment questions which would be used in the semantic category judgment tasks. A total of 120 native English speakers[11] were recruited from PSY 101 at Boston University (mean age = 18.5 yrs, SD = 0.9) to fill out one of four versions of an English questionnaire (30 participants for each version of questionnaire). Each version of the questionnaire was composed of a word pair judgment task and a question judgment task.

The word pair judgment task consisted of 150 word pairs. Participants were asked to judge each word pair on similarity of meaning, pronunciation, and spelling using a 3- point scale rating (i.e., unrelated, somewhat similar, and highly similar). For judgment on semantic similarity, the participants were instructed to choose "highly similar" if the two words in a word pair were synonymous (e.g., *couch/sofa*), had semantic association (e.g., *doctor/nurse*), or fell in the same category (e.g., *lily/rose*), to choose "somewhat similar" if the two words were not strongly associated with each other (e.g., *couch/lazy*), and to choose "unrelated" if the two words did not have any association with each other in meaning (e.g., *couch/summer*).[12]

For judgment on phonological similarity, the participants were instructed to choose "highly similar" if the two words in a word pair rhymed (e.g., *chair/share*), to choose "somewhat similar" if the two words only shared the same consonant (e.g., *chair/beer*) or the same vowel (e.g., *chair/head*),

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[11] None of these participants participated in the main experiments.

[12] It could be ideal to simply ask people to use their judgment, but it is customary in the psycholinguistics literature to provide examples which look like rule. Participants still need to interpret the examples and use their judgment to rate the similarity level between words.

to choose “unrelated” if the two words did not share any sound (e.g., *chair/mug*).

For judgment on orthographic similarity, the participants were instructed to choose “highly similar” if the two words in a word pair had exactly the same spelling (e.g., bite/bite), to choose “somewhat similar” if there was only one-letter difference between the two words (e.g., bite/white), to choose “unrelated” if there was at least two-letter difference between the two words (e.g., bite/blue).

The question judgment task consisted of 37 semantic category judgment questions (e.g., Is a **pine** a type of tree?). The bolded word was a target in priming tasks. For each question, the participant had to choose between “Yes” and “No” first, and then indicated whether it was very easy, somewhat difficult, or very difficult to answer the question. They also had an option to modify the questions in a way that made more sense to them.

A total of 30 native Chinese speakers were recruited from Mainland China and Taiwan (mean age = 24.1 yrs, SD = 3.5) to fill out one of two versions of Chinese questionnaires on SurveyMonkey for the norming study. The 15 participants in Mainland China filled out the simplified script version and the 15 participants in Taiwan filled out the traditional script version. The design of the Chinese questionnaires was very similar to the design of the English questionnaires. The only difference was that the Chinese questionnaires were longer, since the number of the Chinese participants was smaller. In both simplified and traditional script versions, the word pair judgment task consisted of 600 word pairs and the question judgment task consisted of 161 semantic category judgment questions.

Participants’ ratings in the word pair judgment task were converted into numeric scores: 2

assigned to “highly similar”, 1 assigned to “somewhat similar”, and 0 assigned to “unrelated”. The average rating of semantic, phonological, and orthographic similarity was calculated for each word pair. Two cut-off points, 1.4 and 0.6, were used to choose the three types of primes. A semantic prime received 1.4 or above in the semantic similarity rating and 0.6 or below in the phonological and orthographic ratings. A phonological prime received 1.4 or above in the phonological similarity rating and 0.6 or below in the semantic and orthographic ratings. A unrelated prime received 0.6 or below in all of semantic, phonological, and orthographic ratings. A target could be included in the stimuli when all three of its primes met these criteria.

In the end, 120 English target-prime sets (i.e., one target and its three corresponding primes) and 120 Chinese target-prime sets were selected for the priming study. Half of the stimuli (i.e., 60 English and 60 Chinese target-prime sets) were used in the two naming tasks (i.e., the single-word naming task and the sentence-based naming task), and the other half of the stimuli (i.e., the other 60 English and 60 Chinese target-prime sets) were used in the two semantic category judgment tasks (i.e., the single-word semantic category judgment task and the sentence-based semantic category judgment task). In other words, the two naming tasks used the same set of stimuli, and the two semantic category judgment tasks used the same set of stimuli, which allowed direct comparison of the two priming methods (i.e., single-word priming and sentence-based priming). For sample stimuli used in the present study[13], please see Appendix A.

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[13] A complete list of the stimuli may be downloaded at http://blogs.bu.edu/hwcheng or be requested by writing to

2.2.4.3 Frequency of Targets

Half of the targets were high frequency words, and half were low frequency words. To ensure the high frequency English targets are high frequency words for native English speakers as well as for L2 learners of English reported in Chapter 4 (i.e., the Chinese group and the Spanish group), they were selected from the Essential 2000 English Words published by the Ministry of Education in Taiwan.

Table 2 presents the frequency information of the targets. The English frequency information was extracted from the Corpus of Contemporary American English (COCA) in 2010. The Chinese frequency information in simplified script was extracted from the Corpus of the Center for Chinese Linguistics at Peking University. The Chinese frequency information in traditional script was extracted from Bashiqi Nian Changyong Yuci Diaocha Baogaoshu Zipin Zongbiao [The Character Frequency List of the Survey on Frequently Used Words in Year 1998].

BUreading@gmail.com.

Table 2: Frequency of Targets

Frequency type	Task		English	Chinese (Simplified)	Chinese (Traditional)
High frequency	Naming tasks	Mean	713.4	856.7	134.7
		SD	543.4	735.5	713.9
		Range	1761.6 to 57.2	2430.6 to 113.7	2523.3 to 202
	Semantic category judgment tasks	Mean	362.3	1781.1	1778.9
		SD	285.3	2224.2	2081.4
		Range	1139.5 to 89.2	8905 to 120.1	10066 to 212
Low frequency	Naming tasks	Mean	10.9	12.1	9.4
		SD	8.9	9.8	0.6
		Range	35.2 to 1.4	55.1 to 2.2	8.7 to 10
	Semantic category judgment tasks	Mean	12.5	15.4	8.4
		SD	8.7	14.4	0.7
		Range	39.6 to 2.9	65.1 to 2.4	10.7 to 6

The unit is per million.

2.2.4.4 The Choice of Sentences for the Sentence-based Priming Paradigm

In the sentence-based priming tasks, primes needed to be embedded in sentences. The Chinese sentences were selected from the category of newspaper in the CCL Corpus of Modern Chinese created by the Center for Chinese Linguistics at Peking University (http://ccl.pku.edu.cn:8080/ccl_corpus/index.jsp?dir=xiandai). I tried to pick sentences that are lexically neutral to both Mainland Chinese people and Taiwanese people, so that no dialectal differences would influence their performance. The English sentences were selected from the category of newspaper in the Corpus of Contemporary American English (COCA) (http://www.americancorpus.org/).

Each prime word is preceded by zero to five words and is followed by 8 to 10 words. All the sentences were reviewed by two native Chinese speakers (for the Chinese sentences) and two native English speakers (for the English sentences) to ensure that 1) the sense of every prime word in the sentences is the most basic sense (for example, for the prime “drum”, it should refer to a musical instrument in the sentence); 2) all words in the sentences (except the prime) should have no similarity in meaning, pronunciation, or spelling with the target word; 3) the meaning of the whole sentence does not offer any hints about the target word. For example, when the target word is "nun", and the prime is "church", a sentence containing words like "church lady" or "bride" would not be allowed. Both "church lady" and "bride" denote "a female in church". It would be then difficult to know whether the activation of “nun” is triggered by “church” or one of the two words (i.e., “church lady” or “bride”).

Most primes are a free morpheme in the sentence instead of a bound morpheme in a compound word. If it is part of a compound word, it has to be the head of the compound (i.e., the meaning of the compound mostly comes from the prime). To prepare for the L2 study reported in Chapter 4, the English sentences were also reviewed by two native Chinese speakers who are advanced learners of

English to ensure the sentences could be understood by advanced learners of English who scored 77 and above in the MTELP test.

2.2.5 Procedure

The experimental procedure described below was the same across different language versions of stimuli. The four priming tasks were conducted on a computer with E-Prime (stimulus presentation software) and a response box (only for naming tasks). In the beginning of each priming task, a set of instructions were presented to the participants (see Appendix B for the instructions). Then, five practice trials appeared to help participants familiarize themselves with the experimental procedure of the task. The real trials only began when the participant told the experimenter that he/she had done enough practice and felt confident and comfortable to perform the task. For all four tasks, participants were instructed to respond as quickly as possible.

2.2.5.1 The Single-word Naming Task

Each trial started with a fixation mark (i.e., “+”) staying on the middle of the screen for 720 ms. Then a prime word (e.g., *palm*) showed up and stayed on the screen for the length of the designated SOA (e.g., if the SOA is 50 ms, the prime stayed on the screen for 50 ms). The target word appeared immediately after the prime and stayed on the screen until the participant named it loudly to a microphone. To help participants understand which word to say, the target word was presented in red while the other words were in black. Participants were instructed to say red words as quickly as possible. If the computer detected the participant's response, it recorded the response times and showed "Response detected" on the screen. Then the experimenter indicated whether the response was valid[14] and whether the response was correct by pressing some buttons on a response box. Participants did not receive any feedback about their performance. A digital recorder was used to record participants' responses through the task. Figure 1 illustrates the presentation of stimuli in the single-word naming task.

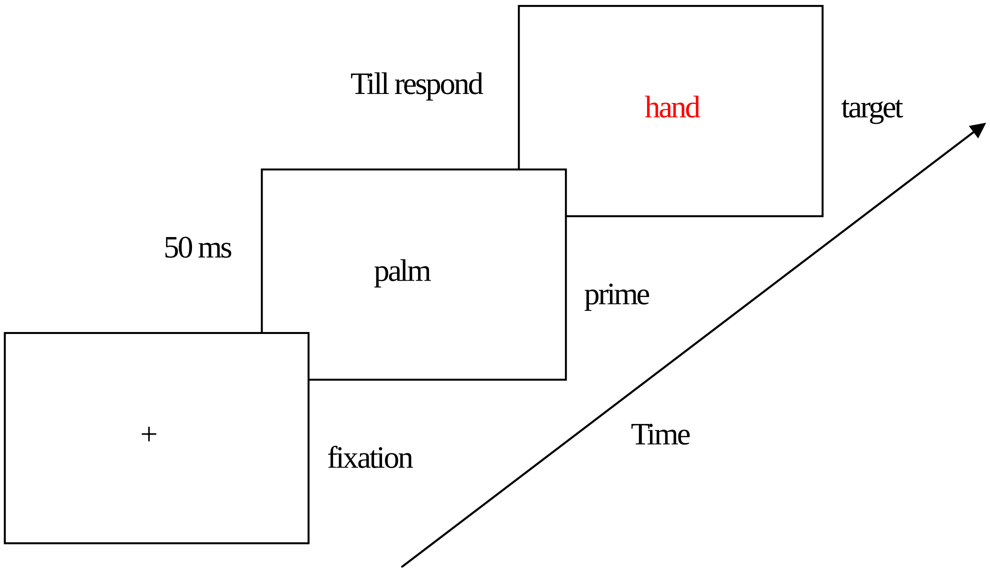

Figure 1: Trial presentation in the single-word naming task

[14] A response was considered valid only when the pronunciation of a word was detected by the computer at the participant's first attempt. Cases in which the participant said something else before his/her response was detected were considered invalid responses and were excluded from data analysis.

2.2.5.2 The Single-word Semantic Category Judgment Task

Each trial started with a fixation mark (i.e., “+”) staying on the middle of the screen for 720 ms. Then, a prime word (e.g., *planned*) showed up and stayed on the screen for the length of the designated SOA (e.g., if the SOA is 50 ms, the prime stayed on the screen for 50 ms). A semantic category judgment question (e.g., *Is a hand a body part?*) for the corresponding target word (e.g., *hand*) appeared right after the prime. The question stayed on the screen until participants answered it by pressing the “yes” key or the “no” key on the keyboard. The “z” key was designated as the “yes” key and was covered by a green sticker with the word “Yes”; the “m” key was designated as the “no” key and was covered by a red sticker with the word “NO”. In addition, under the semantic category judgment question, the word “Yes” appeared on the left of the screen and the word “No” appeared on the right of the screen to remind the participants the location of the two answer keys. The next trial came out immediately after the participants pressed one of the answer keys. The participants were told to respond as quickly as possible. Their answers and response times were recorded by the computer. Figure 2 illustrates the presentation of stimuli in the single-word semantic category judgment task.

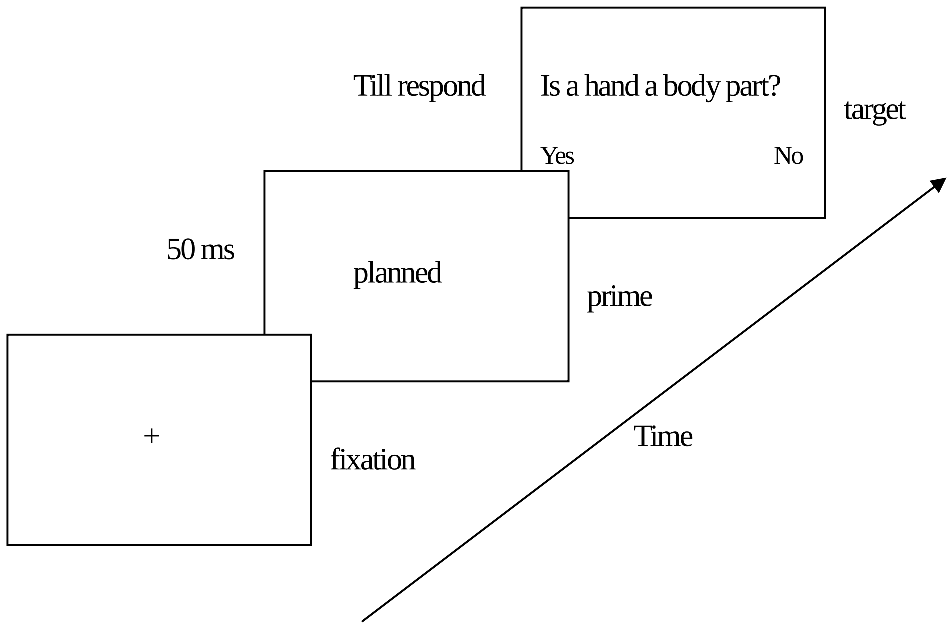

Figure 2: Trial presentation in the single-word semantic category judgment task

2.2.5.3 The Sentence-based Naming Task

Each trial started with a fixation mark (i.e., “+”) staying on the middle of the screen for 720 ms. Then a sentence appeared word by word with each word staying on the screen for 240ms (Chinese sentences for native Chinese speakers and English sentences for native English speakers) or 400ms (English sentences for native Chinese and Spanish speakers). A prime could be the first, second, third, fourth, fifth, or sixth word of the sentence. After the designated SOA passed since the appearance of the prime word, the target word showed up above the running sentence words. To help participants understand which word to say, the target word was presented in red while the other words were in black. The target word stayed on the screen until the participant pronounced it. The running sentence words continued to be displayed until the sentence ended or until participants responded, whichever came first. Figure 3 illustrates the presentation of stimuli in the sentence-based naming task.

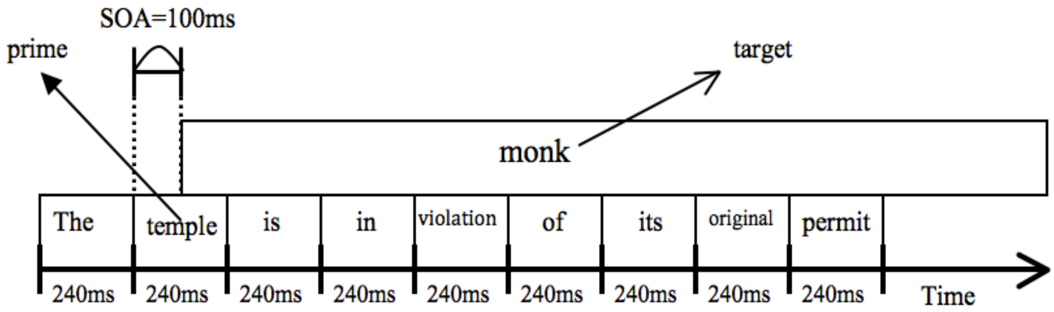

Figure 3: Trial presentation in the sentence-based naming task

2.2.5.4 The Sentence-based Semantic Category Judgment Task

The procedure of the sentence-based semantic category judgment was similar to the procedure of the single-word semantic category judgment. The only difference between the two tasks was that each prime word was embedded in a sentence which was presented with RSVP.

Each trial started with a fixation mark (i.e., "+") staying on the middle of the screen for 720 ms. Then a sentence appeared word by word with each word staying on the screen for 240ms (Chinese sentences for native Chinese speakers and English sentences for native English speakers) or 400ms (English sentences for native Chinese and Spanish speakers). A prime could be the first, second, third, fourth, fifth, or sixth word of the sentence. The SOA started to count at the moment the prime word appeared. After the designated SOA, a semantic category judgment question for the corresponding target word appeared above the running sentence words. The question stayed on the screen until participants pressed the "Yes" or "No" key on the keyboard. The running sentence words continued to be displayed until the sentence ended or until the participant responded, whichever came first. To remind participants of the position of the "Yes" and "No" keys, the word "Yes" stayed on the left bottom of the screen and the word "No" stayed on the right bottom of the screen through each trial. Figure 4 illustrates the presentation of stimuli in the sentence-based semantic category judgment task.

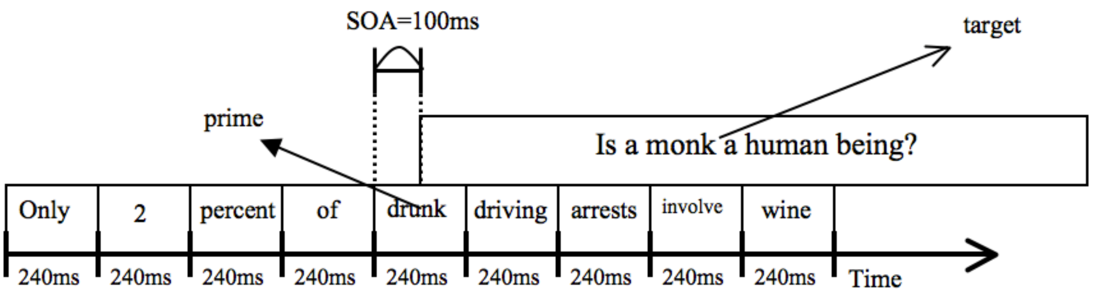

Figure 4: Trial presentation in the sentence-based semantic category judgment task

2.2.6 Data Analysis

The dependent measure for all the four tasks was response time (RT). The unrelated prime trials served as the reference. The RTs in the semantic and phonological prime trials were compared to the RTs in the unrelated prime trials respectively. If RTs in one prime type trials were shorter than the RTs in the unrelated prime trials, a priming effect was observed. This indicates that the prime type facilitated the recognition of targets. If RTs in one prime type trials were longer than the RTs in the unrelated prime trials, an inhibitory effect was observed. This indicates that the prime type inhibited the recognition of targets.

The RTs which were smaller or larger than two standard deviations from the mean were considered outliers and thus were excluded from the following data analyses. Many factors were manipulated in the current study, so the data analyses could become very complicated if all the factors were taken into consideration. Recall that the purpose of this study is to investigate semantic and phonological activation in each task in the Chinese group and the English group. Therefore, only the analyses that provided information about comparisons between unrelated primes trials and semantic or phonological prime trials were conducted.

The Chinese group and the English group were separately analyzed for each priming task with linear mixed models using SPSS. Firstly, an omnibus analysis was conducted to include participant group as a random effect and SOA (i.e., 50ms, 100ms, and 150ms), frequency (i.e., high frequency and low frequency), and prime type (i.e., semantic prime, phonological prime, and unrelated prime) as fixed effects. The result of the omnibus analysis determined whether different SOA trials and different frequency trials could be combined in a further analysis to increase statistical power. The omnibus analysis across tasks and participant groups resulted in three patterns of results. The following subsections detail the further analysis that each pattern of results led to.

2.2.6.1 Main Effect of SOA but not Frequency Found in the Omnibus Analysis

A main effect of SOA indicated that response times varied across the three different SOAs (i.e., 50ms, 100ms, and 150ms). No main effect in word frequency indicated that no difference occurred between high frequency and low frequency trials. This allowed high and low frequency trials to combine in the further analysis to increase statistical power. Therefore, the file was split into 3 separate analyses based on SOA. This additional analysis would then show separately for each SOA, whether the RTs in the semantic/phonological prime trials were significantly shorter or longer than the RTs in the unrelated prime trials. To avoid Type I error, statistical significance was adjusted with the Bonferroni correction. The formula for the Bonferroni correction is α/n, in which α refers to the original significance level (which is .05 in the current study), and n refers to the number of separate analyses. As a result, the new significance level for the further analysis was .05/3 = .017.

2.2.6.2 Main Effect of Frequency but not SOA Found in the Omnibus Analysis

A main effect of frequency indicated that response times varied in the high and low frequency trials. No main effect in SOA indicated that no difference occurred among the three different SOAs. This allowed the trials in each SOA to combine in the further analysis to increase statistical power. Therefore, the file was split into 2 separate analyses based on frequency. The further analysis would then show separately for high and low frequency trials, whether the RTs in the semantic/phonological prime trials were significantly shorter or longer than the RTs in the unrelated prime trials. To avoid

Type I error, statistical significance was adjusted with the Bonferroni correction. The formula for the Bonferroni correction is α/n, in which α refers to the original significance level (which is .05 in the current study), and n refers to the number of separate analyses. As a result, the new significance level for the further analysis was .05/2 = .025.

2.2.6.3 Main Effects of SOA and Frequency Found in the Omnibus Analysis

Main effects of both SOA and frequency indicated that response times varied across the six different SOA and frequency combinations (i.e., 50ms in high frequency, 100ms in high frequency, 150ms in high frequency, 50ms in low frequency, 100ms in low frequency, and 150ms in low frequency). Therefore, the file was split into 6 separate analyses based on the combination of SOA and frequency. The further analysis would then show separately for each combination, whether the RTs in the semantic/phonological prime trials were significantly shorter or longer than the RTs in the unrelated prime trials. To avoid Type I error, statistical significance was adjusted with the Bonferroni correction. The formula for the Bonferroni correction is α/n, in which α refers to the original significance level (which is .05 in the current study), and n refers to the number of separate analyses. As a result, the new significance level for the further analysis was .05/6 = .008.

2.3 Results and Discussion

Table 3 displays, for each participant group in each priming task, whether main effects for either

SOA or frequency were found in the omnibus analysis. It also shows how the number of separate analyses and the adjusted significance level were computed. The last column presents the semantic priming and phonological inhibition found in the further analyses. If no priming or inhibition reached the adjusted significance level, "n.s." was put in the cells.

Table 3: Results of the L1 Priming Study

Task	Participant group	Main effect in omnibus analysis	Number of separate analyses	Bonferroni correction	Results of further analyses
Single-word naming	Chinese	SOA frequency	3X2 = 6	.05/6 = .008	n.s.
	English	SOA frequency	3X2 = 6	.05/6 = .008	n.s.
Sentence-based naming	Chinese	SOA frequency	3X2 = 6	.05/6 = .008	Semantic priming in high frequency at SOA = 50 (p<.001, magnitude = 45.5ms); Phonological inhibition in low frequency at

					SOA = 100 (p=.001, magnitude = -66.8ms)
	English	frequency	2	.05/2 = .025	Phonological inhibition in high frequency (p=.015, magnitude = -15.4ms) and low frequency (p=.003, magnitude = -20.3ms)
Single-word semantic category judgment	Chinese	frequency	2	.05/2 = .025	n.s.
	English	frequency	2	.05/2 = .025	Semantic priming in high frequency (p=.007, magnitude = 87.5ms)
Sentence-based semantic category judgment	Chinese	frequency	2	.05/2 = .025	n.s.
	English	SOA frequency	3X2 = 6	.05/6 = .008	n.s.

2.3.1 Chinese Reading

Semantic priming was found in the sentence-based naming task at SOA = 50ms when the Chinese group named high frequency targets. A naming task does not require access to meaning. Therefore, the occurrence of semantic priming in a naming task illustrates the important role that semantic information plays in Chinese reading. Semantic primes facilitated the identification of high frequency targets but not low frequency targets. This is probably because it was easier to access the meaning of high frequency characters due to familiarity.

Phonological inhibition was found in the sentence-based naming task at SOA = 100ms when the Chinese group named low frequency targets. In contrary to semantic primes, phonological primes had effects on the identification of low frequency targets but not high frequency targets. Phonological activation usually occurs after the whole Chinese character is identified (Perfetti & Zhang, 1991). When reading low frequency characters, however, identifying the phonetic component might be sufficient to retrieve the pronunciation of the character, since low frequency characters tend to be more phonologically regular (Shu, Chen, Anderson, Wu, & Xuan, 2003). A result of this is that indentifying low frequency Chinese targets may involve more phonological activation than identifying high frequency targets. The activation of phonological information in these low frequency Chinese targets means greater interference with the phonological information activated by the primes, resulting in slower naming latencies (i.e., inhibition).

Another notable finding is that semantic priming occurred at 50ms and phonological inhibition occurred at 100ms. This result implies that semantic activation might appear earlier than phonological activation when reading Chinese.

2.3.2 English Reading

Semantic priming was found in the single-word semantic category judgment task when the English group responded to high frequency targets as shown in Table 3. Like the Chinese group, semantic primes facilitated the identification of high frequency targets but not low frequency targets. This result again indicates that it is easier to access the meaning of high frequency words.

Phonological inhibition was found in the sentence-based naming task when the English group responded to high and low frequency targets. The phonological information in the prime was activated, as was the phonological information of the target. The prime's activation interfered with participants' ability to name the target, leading to longer naming latency relative to the unrelated prime condition, manifesting as phonological inhibition.

2.3.3 A Summary of Results

Table 4 summarizes the semantic priming and phonological inhibition effects found in the current study. Although not many effects reached statistical significance, the results still provide some interesting insights into the patterns of semantic and phonological activation in reading Chinese and English. There are three notable findings. Firstly, semantic activation (semantic priming at 50ms) appeared before phonological activation (phonological inhibition at 100ms). Secondly, the occurrence of semantic priming effects in a naming task suggests that semantic information plays an important role in reading Chinese. Thirdly, the appearance of phonological inhibition effects in both high and low frequency trials demonstrates the important role that phonology plays in reading English.

Table 4: Priming and Inhibitory Effects in the L1 Priming Study

Priming/inhibition type	Participant group	Task	Condition
Semantic priming	Chinese L1	Sentence-based naming	high frequency at SOA = 50 (p<.001), magnitude = 45.5ms
Semantic priming	English L1	Single-word semantic category judgment	high frequency (p=.007) magnitude = 87.5ms
Phonological inhibition	Chinese L1	Sentence-based naming	low frequency at SOA = 100 (p=.001), magnitude = -66.8ms
Phonological inhibition	English L1	Sentence-based naming	high frequency (p=.015), magnitude = -15.4ms; low frequency (p=.003), magnitude = -20.3ms

2.4 General Discussion

Semantic priming and phonological inhibition were both found in the Chinese group and the English group, indicating that semantic information and phonological information were both activated when native Chinese speakers and native English speakers read in their first language. Given that Chinese and English encode semantic and phonological information in very different manners, this result suggests support for a language universal in reading: any linguistic information encoded in an orthography will be activated when reading the orthography regardless of in which manner it is encoded.

2.4.1 Semantic Priming

As Table 4 shows, the significant latency differences between semantic prime trials and unrelated prime trials in the Chinese group and in the English group were both facilitatory effects, which is what one expects in a priming paradigm.

Semantic priming was observed in sentence-based priming for native Chinese speakers, whereas it was found in single-word priming for native English speakers. The different semantic activation patterns imply that semantic information is not processed in the same way in Chinese and English.

No semantic priming was found in the single-word priming tasks when native Chinese speakers performed the tasks in Chinese. This result is different from most previous studies (e.g., Perfetti & Tan, 1998; Wu & Chen, 2000) which typically found semantic priming effects, although strength of semantic priming varied. One possible cause of this discrepancy is that the semantic primes in the current study were selected under stricter criteria than those in previous studies. Some semantic primes in previous studies (e.g., Wu & Chen, 2000) formed a compound with their matching targets (e.g., 修

-理 'fix'-'organize'= 'repair'; 攪拌 'stir'-'blend' = 'stir'; 迷惘 'lost'-'frustrated' = 'perplexed'). Since the prime and the target co-occur frequently to form a compound, after seeing the prime, the participants would expect to see the target. The facilitation caused by this expectancy is referred to as strategic priming instead of automatic priming (McNamara 2005). To minimize strategic processes, the current study did not include semantic primes which form a compound with their targets and occupy the first position of the compound.

Some other semantic primes in previous studies (e.g., Perfetti & Tan, 1998) had either the same phonemes in the same position (e.g., 媽-母 [ma]-[mu] share the onset [m]; 臉-面 [liɛn]-[miɛn] share the rime [iɛn]) or the same orthographic component (e.g., 林-松 share the semantic radical 木) as the targets. The priming effects found in these stimuli might come from phonological similarity, orthographic similarity, or a combination of phonological, orthographic, and semantic similarity between the primes and the targets instead of pure semantic similarity. It is thus questionable to consider these facilitations semantic priming. To ensure that facilitation effects arise from semantic similarity but not other types of similarities, no semantic primes in this study shared any phonemes, tones, or orthographic components with the targets.

Another cause for the absence of semantic priming in the single-word priming paradigm in the Chinese group might be the polysemous nature of Chinese characters. Chinese characters usually have multiple meanings and require contextual information for disambiguation. Although every semantic prime in the current study has a salient meaning, all possible meanings might automatically get activated during the process of visual word recognition. The time it takes to suppress the unintended meanings would then cancel out the increase in processing efficiency from the prime word, resulting in no facilitation. This explanation is supported by the finding of semantic priming in the sentence-based priming paradigm. When a semantic prime was embedded in a sentence, the neighboring characters provided help to specify the intended meaning of the prime. The specified meaning of the prime then facilitated the access of the meaning of the target.

In contrast, English words are not as polysemous as Chinese single-character words. The English semantic primes selected for this study usually had a specific meaning, so less effort were required to suppress unintended meanings. As a consequence, an English semantic prime was able to facilitate the identification of its matching target when it was presented alone. Semantic priming was found in high frequency trials across three short SOAs (i.e., 50ms, 100ms, and 150ms) in reading English, which is consistent with the statement that "[semantic] facilitation is commonly found for SOAs less than 200ms" (McNamara, 2005).

Semantic priming, however, did not appear in the sentence-based priming paradigm in the English group. It is known that semantic facilitation decays rapidly in reading English (McNamara 2005). When a semantic prime is embedded in a sentence, it is possible that the meaning of the prime was rapidly washed away by the following words in the sentence. As a result, the activated meaning of the semantic prime could not sustain long enough in the working memory to facilitate the identification of the matching target.

Although semantic priming could be sustained in a well-constructed sentence as reported in some previous studies (Foss, 1982; O'Seaghdha, 1989; Simpson, Peterson, Casteel, & Burgess, 1989), the effect might be constrained by the tasks employed and the way stimuli were presented. The phoneme monitoring task in Foss (1982), the lexical decision task in O'Seaghdha (1989), and the naming task in Simpson et al. (1989) did not demand as much semantic activation as the semantic category judgment task adopted in the current study. The semantic priming effects observed in those tasks thus might not have been strong enough to facilitate performance in a semantic category judgment task.

If English semantic priming is restricted to some experimental tasks that demand less semantic activation as mentioned above, why were no semantic priming effects observed in the sentence-based naming task which demands less semantic activation than the sentence-based semantic category judgment task? The answer lies in the way stimuli were designed and presented. In the previous studies, both the prime and the target were embedded in the same sentence. In that kind of experimental design, the prime and the target have to fit in the sentence context, which gives rise to the suspicion that the priming effects might come from the sentence context instead of the prime (Keenan & Jennings, 1995). In contrast, in the current study, only the prime was embedded in a sentence. The target was presented alone above the sentence. When designing the stimuli, I also tried to make sure that the sentence context was minimally related to the meaning of the target. Therefore, the absence of semantic priming in the sentence-based priming paradigm in the English group does not constitute a failure. On the contrary, it delimits the context in which semantic priming, a vulnerable effect, can be elicited.

2.4.2 Phonological Inhibition

The significant differences between phonological prime trials and unrelated prime trials were inhibitory effects instead of facilitatory effects in the Chinese and English groups. This result might seem surprising at first, since phonological priming is what one expects in a priming study. Recall that the phonological primes in most previous priming studies were homophonic with their matching targets, yet the phonological primes in the current study rhymed with their targets. It was likely the use of rhyming primes instead of homophonic primes resulted in phonological inhibition. Some researchers have reported that rhyming primes led to phonological inhibition in naming tasks as well as in lexical decision tasks (Lukatela & Turvey, 1996; Lupker & Colombo, 1994). Although different models have been proposed to explain the cause of phonological inhibition, they all share the view that it is the phonological processing of the rhyming primes that leads to the inhibition effect for targets (Colombo, 1986; Lupker & Colombo, 1994; Segui & Grainger, 1990). In other words, phonological inhibition, like phonological priming, is an index of phonological activation.

Previous studies on rhyming primes and phonological inhibition all focus on English reading. It is notable that the current study showed that when reading Chinese, rhyming primes also brought phonological inhibition. Furthermore, for both Chinese and English, phonological inhibition appeared only in the sentence-based priming paradigm, but not in the single-word priming paradigm. This result is consistent with two previous studies. Lukatela and Turvey (1996) found that phonological inhibition appeared in a naming task when one mask was presented before a rhyming prime and another mask was presented between the rhyming prime and the target. In other words, participants saw a mask first, then a rhyming prime followed by another mask, and the target in the end of the trial. However, phonological inhibition did not appear when rhyming primes and targets were presented without any masks in a naming task conducted by Lupker and Colombo (1994). The sentence-based priming paradigm in the current study is similar to the masked priming paradigm in Lukatela and Turvey (1996), because the words preceding the prime could function as masks which reduce the perception of the prime. The current single-word priming paradigm is the same as the standard priming paradigm in Lupker and Colombo (1994), since no other word appeared before the prime. The masked priming paradigm is particularly useful to reveal priming effects that are difficult to elicit with visible primes (Forster et al., 1987). Therefore, the result that phonological inhibition was observed only in the sentence-based priming but not in the single-word priming suggests that it is a delicate effect resulting from unconscious processing of phonological information.

Phonological inhibition occurred in both Chinese and English reading, and for both orthographies, it only appeared in the sentence-based priming paradigm. Do these results imply that the reading processes in reading Chinese and English are the same? In my opinion, these results at best suggest that some part of processing phonological information (e.g., the processing of onset and rime) is similar in reading Chinese and English. In fact, phonological inhibition also exhibits some differences in reading these two orthographies. For example, for Chinese, phonological inhibition only occurred in naming low frequency targets, whereas it occurred in naming both high and low frequency targets for English. This shows that phonology plays a more important role in reading English than in reading Chinese.

Although the use of rhyming primes is the essential component for phonological inhibition, it requires some specific condition to elicit phonological inhibition. Some previous priming studies have explored this topic and reported that rhyming primes led to inhibitory effects when the targets were high frequency words (Colombo, 1986; Lupker & Colombo, 1994), when the frequency of a target was higher than the frequency of its prime (Segui & Grainger, 1990), or when the SOA was short (Lukatela & Turvey, 1996). In the current study, phonological inhibition was found not only in high frequency targets (in the English group) but also in low frequency targets (in the Chinese and English groups). Moreover, it was found across all three short SOAs (i.e., 50ms, 100ms, and 150ms) in the English and when SOA was 100ms in the Chinese group. Therefore, the results presented here lend support to Lukatela and Turvey's (1996) claim that short SOA is the key factor that imposes inhibitory influence of rhyming primes on targets.

The inhibitory effects of rhyming primes can be explained in several ways. Phonological inhibition could be, as Forster and Davis (1991) suggest, a Stroop-like interference effect coming from the onset differences between a rhyming prime and its matching target (Lukatela & Turvey, 1996).

The onset of the target is in conflict with the onset of the prime. It takes time to resolve this conflict which in turn slows the naming of the target. In other words, the inhibitory effects arise from the different onsets instead of the identical rhymes.[15] In the interactive activation model proposed by O'Seaghdha, Dell, Peterson, Juliano (1992), the phonological code of the prime is activated when the prime is presented, and later it competes with the phonological code of the target. This competition slows the naming of the target, and the inhibitory effects thus are observed. Following the phonological coherence hypothesis (Van Orden & Goldinger, 1994; Van Orden, Pennington, & Stone, 1990), Lukatela and Turvey (1996) argue that the phonological representation of the prime is reinforced in the process of establishing the phonological representation of the target, resulting in a strong competition which delays of the naming of the target.

All the explanations above share the same view that it is the differences between the prime and the target that result in inhibitory effects. In my opinion, however, it might be the similarities between the prime and the target that lead to inhibitory effects. The processing time for a target might be the same no matter whether it is preceded by a rhyming prime or by an unrelated prime. The delay of naming the target results from a surprise effect at the moment when participants are about to say the target preceded by a rhyming prime. It is not until then do they realize that the target rhymes with the prime. They are surprised at this finding and thus have some hesitation to say the target aloud as soon as they identify it. In the future, experiments could be designed to test between this explanation and the

[15] See Lukatela and Turvey (1996: 832) for arguments against this explanation.

interference explanations proposed by other researchers.

2.5 Conclusions

The present study employed four priming tasks (i.e., a single-word naming task, a single-word semantic category judgment task, a sentence-based naming task, and a sentence-based semantic category judgment task) to investigate the patterns of semantic and phonological activation in reading Chinese and English as a first language. Although the results did not provide a clear picture of time course and magnitudes of the activation of semantic and phonological information in Chinese and English reading, they still demonstrate that semantic and phonological information are processed in different manners in reading these two orthographies. Semantic activation was observed in sentence context in reading Chinese, but in single-word context in reading English. Phonological activation is required for processing both high and low frequency English words, but occurs only for low frequency Chinese words.

CHAPTER 3: THE FIRST LANGUAGE REPETITION BLINDNESS STUDY

3.1 Background

Chapter 2 demonstrated that the patterns of semantic and phonological activation differed in Chinese reading and English reading in terms of priming paradigm (sentence priming vs. single-word priming) and word frequency of target (low frequency vs. both high and low frequency). To more deeply understand the process of reading Chinese and English from the perspective of the magnitude of semantic and phonological activation, a repetition blindness paradigm was employed in the present study.

3.1.1 Repetition Blindness (RB) and Its Mechanism

When two words appear in close succession, the second word is usually easier to identify if it is identical to the first word than if it is not. This is the well-known repetition priming. However, Kanwisher (1987) found that if two identical words are presented in rapid serial visual presentation (RSVP), one of the identical words usually fails to be reported. This phenomenon is repetition blindness (RB).

Several theories have been proposed to explain the mechanism of RB. To report a word one sees on a computer screen, one has to perceive the word, encode the representation of the word into the working memory, and retrieve it from the working memory. Some theories argue that RB results from perception and/or encoding impairment, while others maintain that RB is caused by memory retrieval impairment (Neill, Neely, Hutchison, Kahan, & VerWys, 2002). Proponents of the perception-encoding impairment account assume that the report of the occurrence of a word is attributed to the activation of the representation of the word in the mental lexicon. Their studies showed that RB appears across stimuli, task, and context with minimal memory load. Proponents of the memory retrieval account hold the view that the report of the occurrence of a word is a product of the interactions between stimuli and display formats. Their work demonstrated that RB fluctuates as memory load changes.

The major theories of the perception impairment account include the token individuation hypothesis (Kanwisher, 1987, 1991; Kanwisher & Potter, 1989, 1990), the type refractoriness hypothesis (Luo & Caramazza, 1995, 1996), and the competition hypothesis (Morris, Still, & Caldwell-Harris, 2009). In the token individuation hypothesis, every word is a type and each occurrence of a word is a token. When a word appears twice, the second occurrence of the word fails to be distinguished from the first occurrence as a separate token although it is accurately recognized as the same type as the first occurrence. In other words, RB occurs because of the failure of token individuation. According to the type refractoriness hypothesis, however, RB occurs due to the failure of type recognition. The second occurrence of a word fails to activate the representation of the word which is just activated by the first occurrence and is not ready to be activated again in such a short period of time. Distinct from the notions of type recognition and token individuation, the competition hypothesis assumes that any words in close temporal proximity compete for the reader's conscious awareness. A repeated word is less competitive than a nonrepeated word because the former has less neurological activity than the latter (i.e., the neuron is fired less for the former than for the latter).

Fagot and Pashler (1995), Whittlesea, Dorken, and Podrouzek (1995), and Whittlesea and Masson (2005) are the major proponents of the memory retrieval account. According to Fagot and Pashler (1995), RB, similar to the Ranschburg effect,[16] can be explained either by the tendency of guessing an unreported word if the second occurrence of a word is not seen (a guessing bias) or the reluctance of reporting the same word twice even though a word is indeed seen twice (a censorship bias). The construction/ attribution theory proposed by Whittlesea and Masson (2005), consistent with Whittlesea, Dorken, and Podrouzek's (1995) memory migration, states that RB is a reconstructed memory error. From their points of view, memory retrieval is a process of memory reconstruction in which errors may occur. When the second occurrence of a word is misattributed to the first occurrence, RB occurs. In other words, the second occurrence of a word fails to be distinguished from the first occurrence at the time of retrieval instead of at the time of encoding.

3.1.2 Repetition Blindness: A Useful Tool to Study Visual Word Recognition

Other than identical words, RB has been also found in orthographically similar words like *cap* and *cape* (Bavelier & Segui, 1990; Kanwisher & Potter, 1990) and homophones like *one* and *won*

[16] The Ranschburg effect, known in the memory literature, refers to the tendency of less accurate reporting of a repeated word when a full report of a series of words is required and all the words are presented at a slow rate in either visual or auditory modalities.

(Bavelier & Potter 1992) in English reading. Similarly, RB has been found in Chinese reading, when two characters were identical (Chen & Wong, 1997; Tzeng, 1994; Yeh & Li, 2004), when two characters were high frequency homophones (Tzeng, 1994), and when two characters shared one orthographic component (Yeh & Li, 2004). These findings show that partial overlap between two items is sufficient to elicit RB effects. The activated linguistic information of the prime[17] prevents the linguistic information encoded in the target from being activated or from being stabilized in the working memory due to the overlap of the linguistic information encoded in the prime and the target.

In contrast to priming, RB is an interference of a prime word on the target word. When the linguistic information encoded in one word only minimally distinguishes it from another word, RB may occur. RB, like priming, can thus be considered an index of activation of linguistic information. Orthographic RB indicates the activation of orthographic information; phonological RB indicates the activation of phonological information; semantic RB indicates the activation of semantic information; identical RB indicates the activation of all three types of information although orthographic information plays a major role (Bavelier, 1999). RB is therefore a useful tool for studying the activation of linguistic information. To date, however, it has not been used to compare activation of linguistic information across orthographies.

The majority of repetition blindness studies focus on what causes RB effects (e.g., words, nonwords, pictures, digits, etc.) and in which time window (i.e., the time lag between two critical

[17] In the literature of RB, C1 (C stands for critical) and C2 are usually used to refer to the two key words. For the ease of the discussion in this study, prime and target will be used to refer to the two words under investigation.

words) RB effects occur. In other words, most researchers study the phenomenon of repetition blindness per se. However, some studies have employed the RB paradigm as a tool to explore lexical representation issues in cognitive science. Harris and her colleagues examined the representation of sublexical components (Aycicegi & Harris, 2002; Harris & Morris, 2001; Morris & Harris, 1999) and the cohort effect in visual word recognition (Niedeggen, Heil, Harris, 2006; Niedeggen, Heil, Ludowig, Rolke, & Harris, 2004). Others investigated semantic representation of translation equivalents in bilinguals (e.g., Altarriba & Soltano, 1996; MacKay & Miller, 1994; Sánchez-Casas, Davis, & García-Albea, 1992). The current study is the first study using the RB paradigm to compare semantic and phonological activation between Chinese and English reading.

3.1.3 The Current Repetition Blindness Study in Reading Chinese and English as a First Language

The current study employed the RB paradigm to investigate the magnitudes of semantic and phonological activation in reading Chinese and English as a first language. It not only provides a different perspective from priming to examine the Chinese and English reading processes, but also expands our understanding of RB effects in Chinese and English reading.

3.2 Method

3.2.1 Some Methodological Issues

Two methodological issues are discussed below to lay out the rationale of the experimental design.

3.2.1.1 The Choice of Exposure Duration

The majority of repetition blindness studies employed the same exposure duration (i.e., the length of the time that each item stays on the screen) for all participants. Harris and Morris (2004) noted that size of RB effects varies with the accuracy of participants' reporting unrepeated words (i.e., the unrelated words in the present study). That is, although RB effects usually occur at SOA[18] ranging from 80ms to 300ms, every reader has his/her unique "RB window". Only when the stimuli are presented during that participant's RB window will strong RB effects appear. Following Harris and Morris (2004)'s practice, each participant's exposure duration was chosen from 5 options ranging from 68ms to 153ms[19] based on their performance on 12 practice trials.

3.2.1.2 RB Naming vs. RB Confirmation

Immediate full verbal report of all stimuli in the RSVP sequence is the task most frequently used in the RB paradigm. Participants see a string of words flash on the computer screen one word at a time, and then orally report all the words they see; I will refer to this as the naming task. This task demands the retrieval of phonology. As Chapter 2 suggests, phonological information might not be activated in

[18] Note that SOA is different from exposure duration. SOA refers to the time lapse between a prime and its target, while exposure duration refers to the length of time that each word stays on the screen. In the RB paradigm, there is usually at least one intervening word between the prime and the target. Therefore, SOA is usually longer than exposure duration.

[19] These 5 duration times span the typical ability of the diversity of normal adult readers.

Chinese reading as often as in English reading. The naming task thus may bias against Chinese orthography which encodes phonology in an opaque way. To address this concern, I adapted a forced-choice verification procedure that has been used in other RSVP paradigms, which I will refer to as a confirmation task. In this task, participants indicate with a keyboard press 'yes' or 'no' for whether a displayed target word appeared in the prior RSVP sequence. The RB naming task and the RB confirmation task were both conducted in the current study.

3.2.2 An Overview of the Experimental Design

The two RB tasks were preceded by the four priming tasks discussed in Chapter 2. The participants whose ID number was odd were assigned to perform the RB naming task first, and those whose ID number was even were assigned to perform the RB confirmation task first. The two tasks were separated by a 5-minute break to refresh visual perception and concentration.

3.2.3 Participants

The same Chinese group and English group in the priming study also participated in this RB study. The Chinese group included 165 native Chinese speakers (85 from Mainland China and 80 from Taiwan; mean age = 24.3 yrs, SD = 3.9); the English group included 114 native English speakers (mean age = 19.3 yrs, SD = 1.9). For the selection criteria of participants, please see section 2.2.3 *Participants* in Chapter 2.

3.2.4 Materials

Two language versions of stimuli were designed for the RB study: Chinese and English. The Chinese stimuli were prepared in both simplified script (for participants from Mainland China) and traditional script (for participants from Taiwan). All Chinese words in the stimuli were single-character words.

All prime-target pairs were the same as those in the priming study reported in Chapter 2. In addition to the three types of prime (i.e., semantic, phonological, and unrelated), the RB naming task included one additional type of prime: identical prime. An identical prime (e.g., *cost*) is the same word as the target (e.g., *cost*). Because identical RB is the most robust type of RB, identical primes were included to verify the experimental design of the current RB study. Half of the targets were high frequency words, and the other half were low frequency words.

Each trial consisted of a prime and a target with one intervening filler, and a second filler following the target. The trials in the RB confirmation task additionally included a probe which appeared at the end of each trial for participants to respond to. The RB naming task was composed of 48 trials (i.e., 12 trials for each prime type). The RB confirmation task was composed of 36 real trials and 24 foil trials. In a real trial, the probe is the same word as the target; in a foil trial, the probe is a word which had not appeared in the immediately preceding sequence. The inclusion of the foil trials is to balance the ratio of the Yes/No responses in the RB confirmation task. The sample stimuli used in the present study[20] is presented in Appendix C.

Exposure durations (i.e., the duration that each word stayed on the computer screen) were set individually for each participant, and for each of the two RB tasks in order to ensure that stimuli could be perceived and reported with 70%-80% probability for reliable RB, as advocated by Harris & Morris (2004). The best stimulus exposure duration for each participant was selected based on the performance on 12 practice trials allocated in three different exposure durations (i.e., four practice trials in each exposure duration). In the RB naming task, the first and the third practice trials in the shortest exposure duration included identical primes. All the other trials included unrelated primes. In the RB confirmation task, each exposure duration consisted of three real trials with unrelated primes and one foil trial. Please see Appendix D for all the practice trials.

In most previous RB studies, the same stimulus exposure duration was used for all participants. The drawback of this traditional design is that no RB effect might be found in fast readers, and the RB effect found in slow readers might be stronger than it should be. Moreover, the same participant might have different reading rates for different tasks due to the different demands of each task. The current study alleviates this concern by providing five options of exposure duration for each RB task. The five options in the RB naming task were 85ms, 102ms, 119ms, 136ms, and 153ms.[21] The five options in the RB confirmation task were 68ms, 85ms, 102ms, 119ms, and 136ms.[22]

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[20] A complete list of the stimuli may be downloaded at http://blogs.bu.edu/hwcheng or be requested by writing to BUreading@gmail.com.

[21] These five options for exposure duration were calculated by the computer refresh rate.

[22] The options of exposure duration are shorter for the RB confirmation task than for the RB naming task because the former

3.2.5 Procedure

The experimental procedure described below was the same across different language versions of stimuli. The two RB tasks were conducted on computer with E-Prime; a response box was also used for the naming task. In the beginning of each RB task, instructions were presented to the participants (see Appendix E for instructions). Then, each participant completed 12 practice trials to become familiar with the tasks and to allow the experimenters to chose the exposure duration that best fit the participant's reading rate for the actual experiment.

3.2.5.1 The Repetition Blindness Naming Task

Each trial started with a line of fixation marks displayed on the center of the computer screen for 1000ms. Then a blank screen appeared for 500ms. Next, a prime, a filler, a target, a second filler, and another blank appeared in order for the designated exposure duration. Following a 250ms-long postmark page, a response page saying "Please say out aloud all the words in the order that you saw them" showed up. Not until the response page appeared did participants start to orally report the words they saw to their experimenter. In other words, for each trial, participants reported the words they saw after all four words were presented. In addition, participants were instructed to report one word twice if they saw it twice. The experimenter circled all the words reported on a hard copy of answer sheet first, and then pressed the buttons on the response box to indicate whether the participant correctly

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task is expected to take less time to respond than the latter task.

reported the prime, the target, both or neither. The procedure of the trial presentation is illustrated in Figure 5.

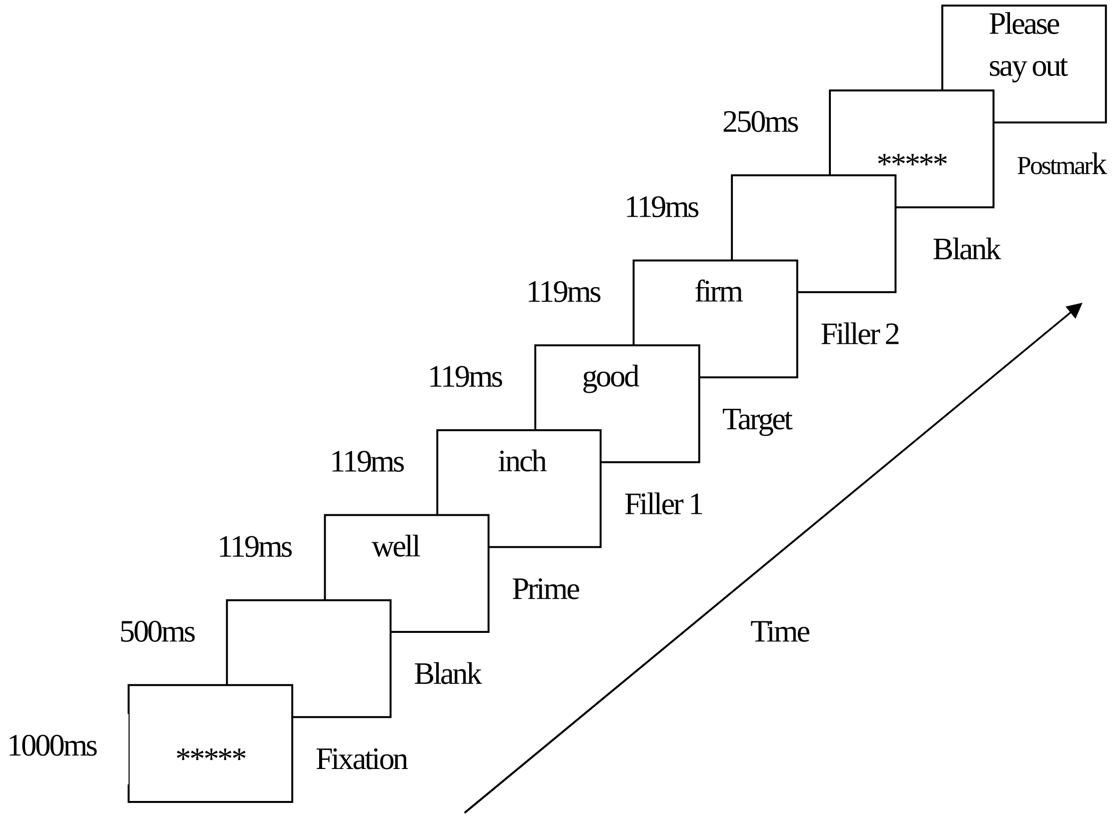

Figure 5: Trial presentation in the RB naming task

The stimulus exposure duration for the actual experiment was determined by participants' performance on the 12 practice trials. The practice trials were presented in three different exposure durations, starting with 136ms followed by 119ms and 102 ms. Please see Appendix F for the guidelines used to decide the stimulus exposure duration for the actual experiment.

3.2.5.2 The Repetition Blindness Confirmation Task

The procedure of stimulus presentation was similar to the RB naming task. The only difference is that instead of reporting all the words they saw, participants pressed a key on the keyboard to indicate whether the probe word on the response page appeared before in the same trial. The probe word on the response page was either a target word (real trials) or a word which had not appeared before (foil trials). A "Yes" and a "No" also appeared at the left bottom and the right bottom respectively on the response page to remind participants of the positions of the answer keys on the keyboard. The procedure of the trial presentation is illustrated in Figure 6.

The stimulus exposure duration for the actual experiment was determined by participants' performance on the 12 practice trials. The practice trials were presented in three different exposure durations, starting with the longest exposure duration and ending with the shortest exposure duration. The three exposure durations were 119ms, 102ms, and 85ms. Participants were instructed to orally report their answers to their experimenter before pressing the keyboard, so the experimenter was able to score their performance on a hard copy of answer sheet. Participants were told to do the oral report only for the practice trials but not for the actual experiment. For the guidelines used to determine the stimulus exposure duration, please see Appendix F.

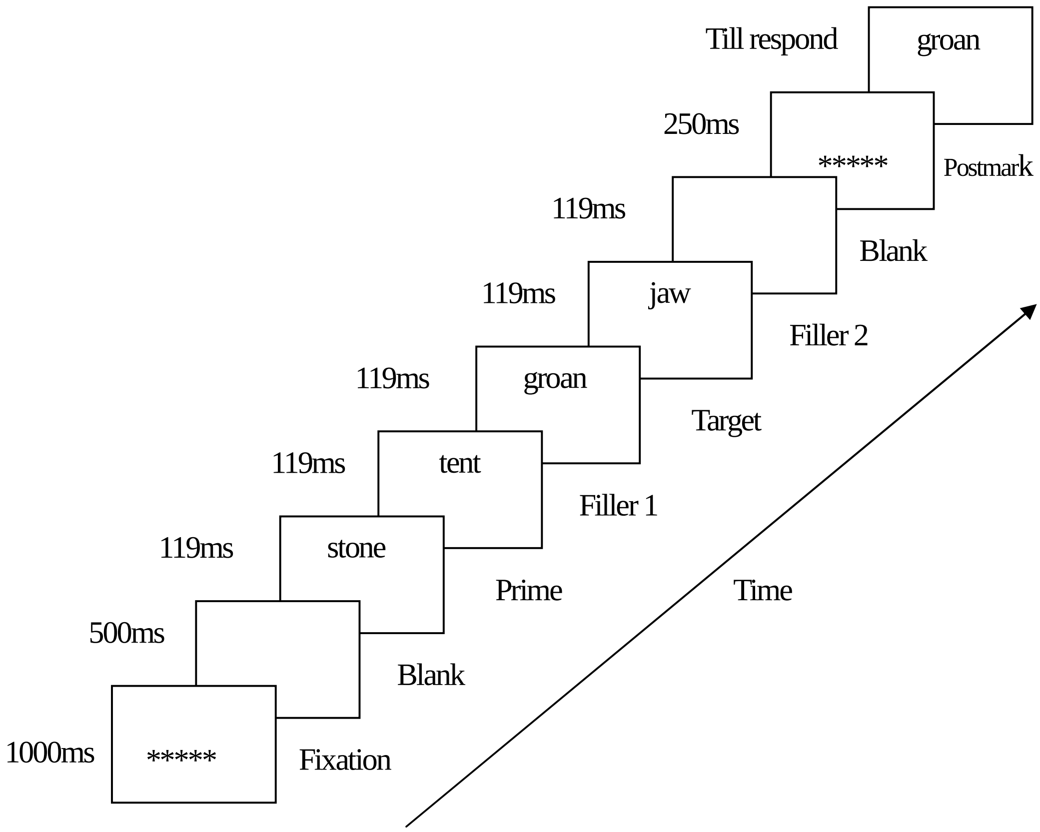

Figure 6: Trial presentation in the RB confirmation task

3.2.6 Data Analysis

The first step of the data analysis is to calculate the accuracy rate of each type of prime trials (i.e., the identical prime trials, the semantic prime trials, the phonological prime trials, and the unrelated prime trials). In the RB naming task, a correct oral report of both the prime and the target is considered an accurate response. In the RB confirmation task, an accurate response is a "Yes" response to a real trial whose probe word is the same as the target word.

The next step is to compare the accuracy rate of the unrelated prime trials to the accuracy rate of each of the other three types of prime trials. In other words, the unrelated prime trials served as the reference. The rationale is that there is no overlap between an unrelated prime and its matching target in terms of the linguistic information they encode. Therefore, the prime-target pairs in the unrelated prime trials are expected to be more easily perceived and more accurately reported than the prime-target pairs in any other type of prime trials. If the accuracy rate of the unrelated prime trials is significantly higher than the accuracy rate of a given type of prime trials, an RB effect is found; if the accuracy rate of the unrelated prime trials is significantly lower than the accuracy rate of a given type of prime trials, a priming effect is found.

3.3 Results and Discussion

3.3.1 The Repetition Blindness Naming Task

The dependent measure is the percentage of trials in which both the prime and the target were correctly reported. A 4 (prime type: identical, phonological, semantic, and unrelated) X 2 (frequency: high and low) repeated measures ANOVA was conducted for both the Chinese group and the English group.

3.3.1.1 The Chinese Group

As shown in Figure 7, there was a main effect of frequency ($F(1, 163) = 22.8$, $p < .001$, partial eta squared = .12) for native Chinese speakers. The high frequency trials were responded to more accurately than the low frequency trials[23] across prime type. Phonological information is usually not reliably encoded in Chinese orthography, so the ease of phonological retrieval depends on familiarity of characters. This might be the reason why it is easier for native Chinese speakers to access pronunciation in high frequency characters than in low frequency characters.

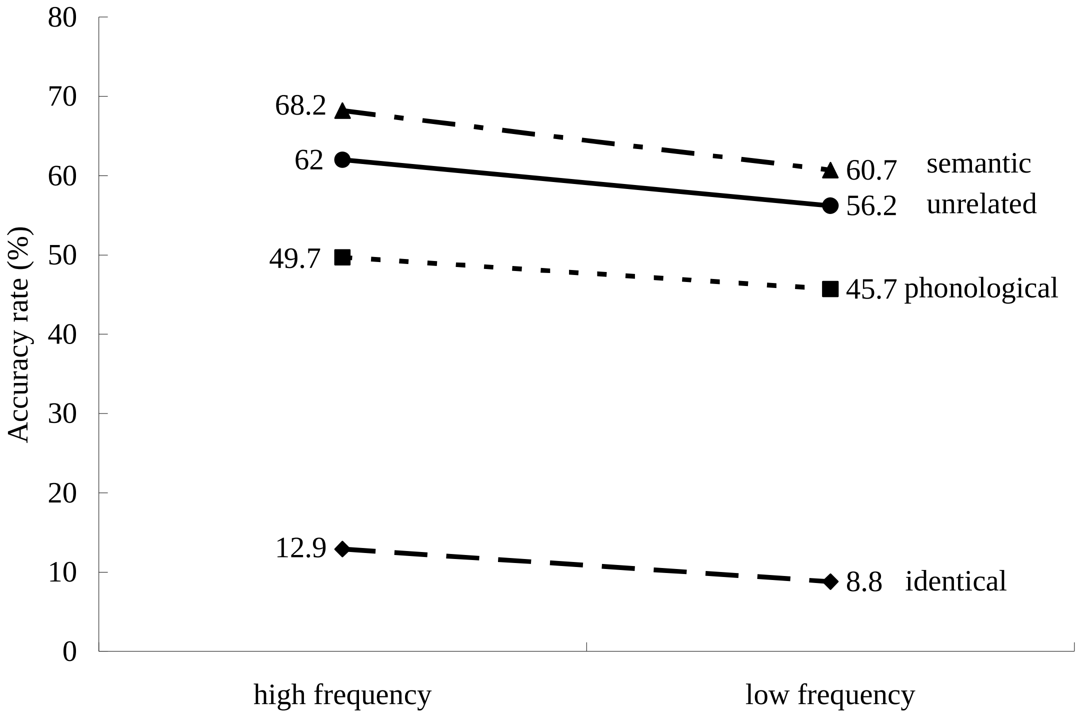

Figure 7: Report accuracy in the L1 RB naming task for the Chinese group

A main effect of prime type (F (3, 161) = 278.2, *p* <.001, partial eta squared = .84) was also

[23] The high frequency trials are those whose targets are high frequency words; the low frequency trials are those whose targets are low frequency words.

found. Post hoc analyses showed that, regardless of the frequency of targets, the identical prime trials were responded to significantly less accurately than the unrelated prime trials (both *p*s < .001), manifesting identical RB effects (magnitude in high frequency trials = 62% - 12.9% = 49.1%; magnitude in low frequency trials = 56.2% - 8.8% = 47.4%). The first appearance of one word (i.e., the identical prime) impaired the identification of the second occurrence of the same word (i.e., the target). The phonological prime trials were also responded to significantly less accurately than the unrelated prime trials regardless of the frequency of targets (both *p*s < .001), manifesting phonological RB effects (magnitude in high frequency trials = 62% - 49.7% = 12.3%; magnitude in low frequency trials = 56.2% - 45.7% = 10.5%). The phonological information of the phonological primes was activated and it interfered with the stabilization of targets when reading Chinese characters.

On the other hand, semantic priming effects emerged in the post hoc analyses, which showed that the semantic prime trials were responded to significantly more accurately than the unrelated prime trials regardless of the frequency of targets ($p < .01$ in high frequency; $p < .05$ in low frequency). This unexpected finding will be discussed later in section 3.5 *General Discussion*.

3.3.1.2 The English Group

The results for native English speakers are shown in Figure 8. A main effect of frequency ($F(1, 113) = 18.4$, $p < .001$, partial eta squared = .14) was found. In contrast to the Chinese group, the English group was more accurate on the low frequency trials than on the high frequency trials. Low frequency words usually encode phonology in a more transparent and consistent manner than high frequency words (Strauss, 2011). This might explain why it is easier for native English speakers to access pronunciation of low frequency words than high frequency words. The differences between high frequency trials and low frequency trials were larger for phonological primes and semantic primes than for identical and unrelated primes, which resulted in an interaction of prime type and frequency (F (3, 111) = 8.5, p <.001, partial eta squared = .19).

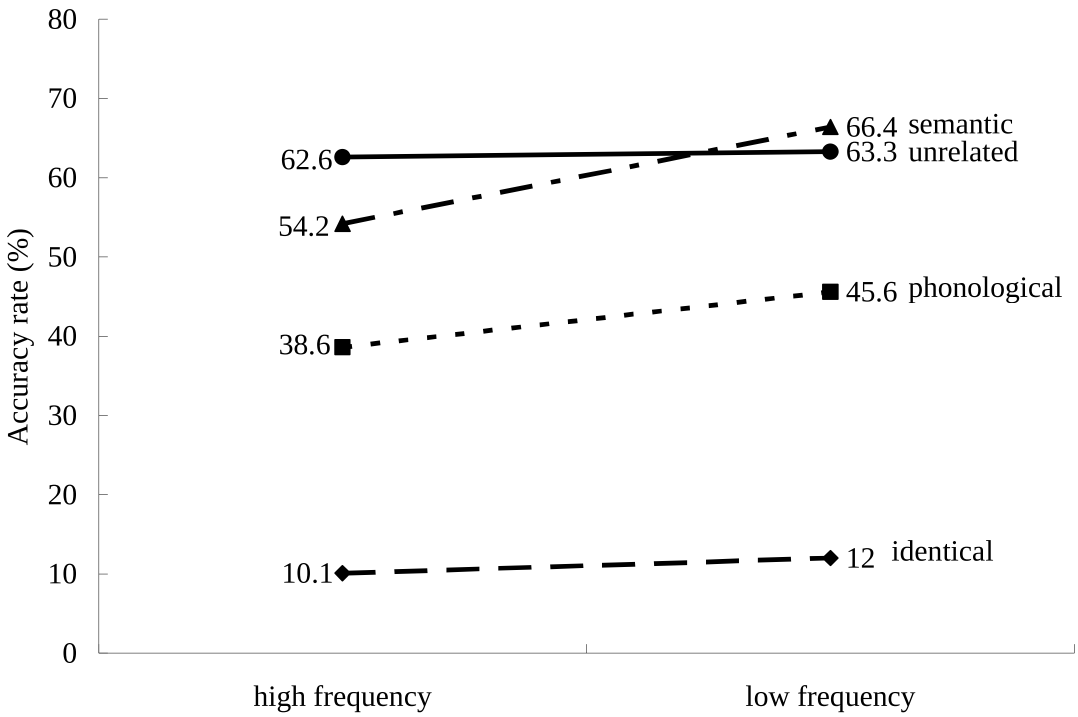

Figure 8: Report accuracy in the L1 RB naming task for the English group

A main effect of prime type (F (3, 111) = 193, p <.001, partial eta squared = .84) was also found.

Regardless of the frequency of targets, the identical prime trials and the phonological prime trials were responded to significantly less accurately than the unrelated prime trials (all *p*s < .001 as shown by post hoc analyses), manifesting identical RB effects (magnitude in high frequency trials = 62.6% - 10.1% = 52.5%; magnitude in low frequency trials = 63.3% - 12% = 51.3%) and phonological RB effects (magnitude in high frequency trials = 62.6% - 38.6% = 24%; magnitude in low frequency trials = 63.3% - 45.6% = 17.7%). The phonological RB effects indicate that phonological information was activated in reading English. Moreover, the semantic prime trials were responded to significantly less accurately than the unrelated prime trials when the targets were high frequency words ($p < .001$), manifesting a semantic RB effect (magnitude = 62.6% - 54.2% = 8.4%). The activated semantic information of the semantic primes interfered with the semantic representation of high frequency targets in working memory. The finding of the semantic RB effect is striking. In the existing literature, semantic RB effects have been found when both the prime and the target were pictures (Kanwisher, Yin, & Wojiulik, 1999) or when one was a picture and the other was a word (Bavelier, 1994), but not when both were words (Kanwisher & Potter, 1990). The semantic RB effect was absent in low frequency trials. It is likely that native English speakers did not access the meaning of low frequency words since meaning retrieval is not required for a naming task and there was large time pressure in performing the RB task.

3.3.2 The Repetition Blindness Confirmation Task

The dependent measure is the percentage of the "Yes" response to the real trials (i.e., the percentage of the target words that were seen). A 3 (prime type: phonological, semantic, and unrelated) X 2 (frequency: high and low) repeated measures ANOVA was conducted for both the Chinese group and the English group.

3.3.2.1 The Chinese Group

For the Chinese group, a main effect of frequency (F (1, 164) = 42.9, *p* <.001, partial eta squared = .21) was found. As Figure 9 illustrates, the low frequency targets were seen more frequently than the high frequency targets across prime type. Although this result is contrary to the result in the naming task, it is by no means counterintuitive. Low frequency Chinese characters usually have more strokes (i.e., the internal structure is more complicated) (Shu et al., 2003), so they are more easily recognized in the confirmation task which demands a large amount of orthographic information.

A main effect of prime type (F (2, 163) = 7.4, *p* =.001, partial eta squared = .08) was also found. Post hoc analyses showed that the low frequency targets were harder to identify when they were preceded by the phonological primes than when preceded by the unrelated primes (*p* < .05), manifesting a phonological RB effect (magnitude = 81.4% - 77.7% = 3.7%). The activated phonological information of the phonological primes hindered the low frequency Chinese characters from stabilizing in the working memory.

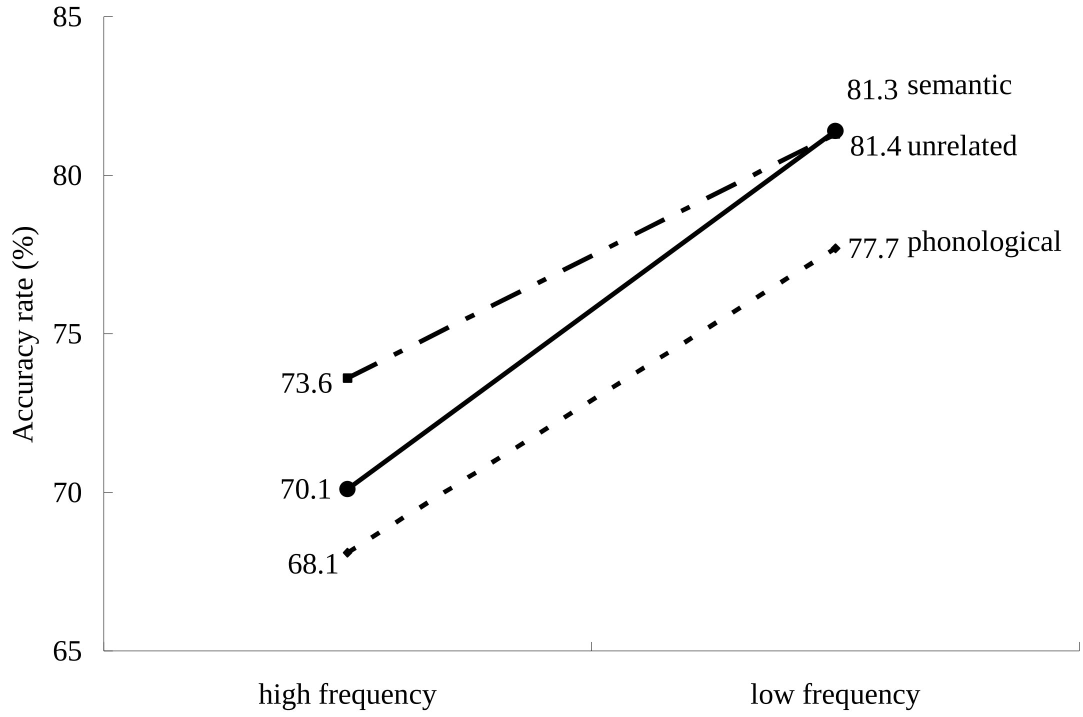

Figure 9: Accuracy rate in the L1 RB confirmation task for the Chinese group

3.3.2.2 The English Group

A main effect of frequency (F (1, 113) = 71, *p* <.001, partial eta squared = .39) was found in native English speakers. The high frequency targets were seen more frequently than the low frequency targets across prime type, as illustrated in Figure 10. Probably due to their idiosyncratic orthographic forms, low frequency words were easier for native English speakers to recognize when performing the confirmation task which required the processing of orthographic information. This frequency effect was larger for the unrelated prime trials and the semantic prime trials than for the phonological prime trials, resulting in an interaction of prime type and frequency (F (2, 112) = 14.7, *p* <.001, partial eta squared = .21).

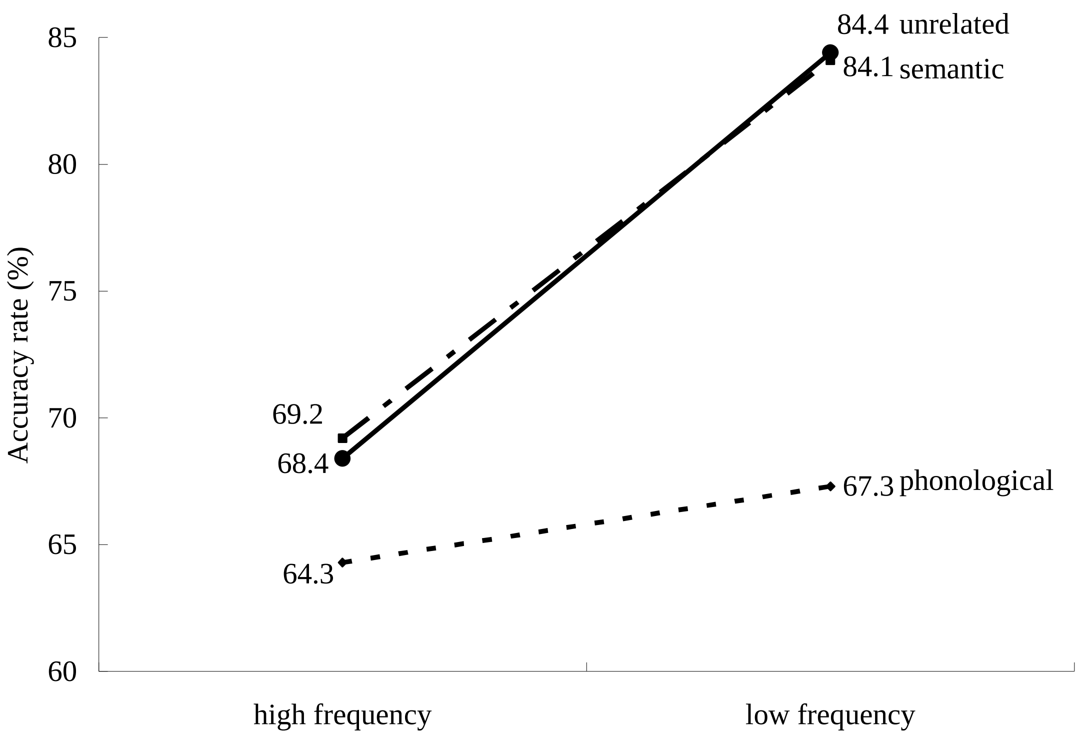

Figure 10: Accuracy rate in the L1 RB confirmation task for the English group

A main effect of prime type (F (2, 112) = 25.5, *p* <.001, partial eta squared = .31) was found. Post hoc analyses showed that the high frequency targets and the low frequency targets were harder to see when they were preceded by the phonological primes than when preceded by the unrelated primes (*p* = .05 in high frequency; *p* < .001 in low frequency), manifesting phonological RB effects (magnitude in high frequency trials = 68.4% - 64.3% = 4.1%; magnitude in low frequency trials = 84.4% - 67.3% = 17.1%). The phonological RB effect was larger for low frequency targets than for high frequency targets, suggesting stronger phonological activation in reading low frequency words compared to reading high frequency words. This is likely because grapheme-phoneme conversion is more frequently employed in decoding low frequency words than in decoding high frequency words.

3.3.3 A Summary of Results

The magnitudes of RB/priming effects in the RB naming tasks and the RB confirmation tasks are summarized in Table 5. For the Chinese group, identical RB, phonological RB, and semantic priming were found in the naming task; phonological RB was found in the confirmation task. For the English group, identical RB, phonological RB, and semantic RB were found in the naming task; phonological RB was found in the confirmation task.

Table 5: Magnitudes of RB and Priming Effects in the L1 Repetition Blindness Study

	RB naming task						RB confirmation task	
	identical		phonological		semantic		phonological	
	high	low	high	low	high	low	high	low
Chinese	49.1%	47.4%	12.3%	10.5%	-6.2%	-4.5%	n.s.	3.7%
English	52.5%	51.3%	24%	17.7%	8.4%	n.s.	4.1%	17.1%

3.5 General Discussion

In both the RB naming task and the RB confirmation task, the accuracy rates of the unrelated prime trials and the exposure durations in the Chinese group and the English group were not significantly different (all *p*s > .05), showing that the two groups of participants were comparable in their ability to read in their native language. In addition, when performing the RB naming task, the identical RB effects in the native Chinese speakers and the native English speakers were also not significantly different (*p* > .05 for both the high and low frequency trials).

3.5.1 Semantic RB and Priming

One of the major findings of the current study is the appearance of semantic RB in the English group. It has been widely assumed that semantic RB does not occur between two semantically related words in the same language, even though it has been found between pictures representing associated items (Kanwisher, Yin, & Wojciulik, 1999), between a word and a picture referring to the same item (Bavelier, 1994), and between words denoting the same meaning in two different languages[24] (i.e., translated words) (McKay & Miller, 1994).

The widespread assumption that semantic RB cannot occur in words is surprising, because only two studies have been attempted to investigate this issue. I speculate that Kanwisher and Potter (1990)

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[24] It is controversial whether translation semantic RB existed. Several studies (Altarriba & Soltano, 1996; Coltheart & Ling, 1998; MacKay, James, & Abrams, 2002; Sanchez-Casas, Davis, Garcia-Albea, 1992) reported either semantic priming or no effect instead of semantic RB.

and Buttle, Ball, Zhang, and Raymond (2005) failed to find semantic RB in word pairs because of their experimental methodology.

In Kanwisher and Potter (1990), the accuracy rate of the synonymous word pairs was 7% lower than the unrelated word pairs. In my opinion, the reason why this difference was not statistically significant is because their study contained only 24 participants and 20 synonymous word pairs, the minimal number of participants and trials required for an experiment. Semantic RB is a weak effect (weaker than any other known RB effects), and thus requires good statistical power, as can be obtained with more participants and trials. With 114 participants and 48 semantically related word pairs, semantic RB was statistically reliable in the current study.

Buttle et al. (2005) found semantic RB when presenting brand names of the same category of products in pictures but not in words. I speculate that the disappearance of semantic RB in their word conditions (the brand names were even presented in stylized fonts and color) is due to the distinctive nature of brand names. Brand names are created to help consumers distinguish similar products. Therefore, when seeing two brand names, we are more likely to make a distinction between them instead of classifying them under one category. If this is the case, then why was there semantic RB when brand names were presented in pictures? The answer is that, as the author admitted, the RB effects in the picture condition might result from visual similarities. In other words, it might be the similarities between the pictures, not the references or concepts carried by the pictures, that produced the RB effects.

No semantic RB effect was found in the RB confirmation task. When performing this task, participants indicated whether they saw the target word in the preceding four words in each trial. They could make judgments without accessing word meaning, which might be the reason why a semantic RB effect did not appear.

The magnitudes of semantic RB in the current study were much smaller than phonological RB and identical RB (8.4% vs. 24% vs. 52.5% in high frequency trials in native English speakers), indicating that semantic RB is more fragile than other types of RB effects. This probably has something to do with the time course of reading English. As phonological mediation theory (e.g., Lukatela & Turvey, 1994a; Perfetti & Bell, 1991; Van Orden, 1987) suggests, semantic activation starts later than phonological activation. It is thus possible that semantic information does not have the opportunity to be activated as much as phonological information in the short time window of the repetition blindness paradigm.

It was a surprise to find semantic priming effects instead of semantic RB effects in native Chinese speakers when they performed the RB naming task. The semantic priming effects might come from one particular strategy used in the task. In an after-task interview, many Chinese participants mentioned that in order to keep the words they saw in their mind long enough to report to their experimenter, they tried to make the words in each trial a meaningful constituent. In this strategy, semantic primes and their matching targets would be easier than other types of prime-target pairs to form a meaningful constituent for the participants to remember. This would mean that the Chinese participants would report the prime-target pairs in the semantic prime trials more accurately than those in the other types of prime trials, resulting in semantic priming.

3.5.2 Phonological RB

The rhyming primes did not impede the occurrence of phonological RB in the current repetition blindness study. In fact, the phonological RB effects were robust in both the Chinese group and the English group. Since RB is an interference of a prime on its matching target, it appeared when rhyming primes inhibited the activation of phonological information encoded in their matching targets.

Two 2 (group: Chinese and English) X 2 (frequency: high and low) repeated measures ANOVAs were conducted for the RB naming and the RB confirmation task to compare the magnitudes of phonological RB effects in the two groups of participants. Results showed that there is a main effect of group in both tasks (for the RB naming task: $F(1, 277) = 11.89$, $p = .001$, partial eta squared = .04; for the RB confirmation task: $F(1, 277) = 14.6$, $p < .001$, partial eta squared = .05). In the RB naming task, the phonological RB effects in native English speakers were almost twice as large as those in native Chinese speakers (24% vs. 12.3% in high frequency; 17.7% vs. 10.5% in low frequency). In the RB confirmation task, the phonological RB effect in the English group (17.1% in low frequency) was four times larger than that in the Chinese group (3.7% in low frequency). An interaction of group and frequency was also found in the RB confirmation task ($F(1, 277) = 9.5$, *p*

< .01, partial eta squared = .03), indicating a larger frequency effect for the English group (4.1% in high frequency trials vs. 17.1% in low frequency trials) than for the Chinese group (no phonological RB in high frequency trials vs. 3.7% in low frequency trials). These results together reveal that phonology was activated more strongly in native English speakers than in native Chinese speakers when they read in their native language. This can be attributed to the fact that English encodes phonology in a more transparent and consistent way than Chinese.

Bavelier et al. (1994) also found phonological RB in native English speakers when the two critical words (i.e., the prime and the target in the present study) differed in one phoneme. However, the magnitude reported in their experiment 4, condition Lag 1 (one intervening word between the two critical words) was relatively small (7%). The magnitudes of the phonological RB in the native English speakers in the current study were 24% in high frequency trials and 17.7% in low frequency trials. The differences in the magnitude of phonological RB might be due to the fact that stimulus durations were individually titrated per subject in the present study to ensure that timing parameters were optimal to achieve RB, and more importantly, might be due to the different stimuli used in the current study and in Bavelier et al. (1994).

Single-syllable rhyming primes were used in the present study, so the primes and the targets always differ in consonants (up to three due to the English phonological rules). In Bavelier et al. (1994), some critical word pairs (5 out of 24) differed in one vowel (e.g., *missile-muscle*) although the others differed in one consonant. It has been reported that consonants and vowels have asymmetric status in visual word recognition (Carreiras, Duñabeitia, & Molinaro, 2009; Duñabeitia & Carreiras, 2011; Lee, 1999; Vergara-Martinez, Perea Marin, & Carreiras, 2011). For example, in a masked priming semantic categorization task, Carreiras et al. (2009) had primes whose first, third, and fifth letters were all occupied either by consonants (consonant primes) or by vowels (vowel primes). They found that the consonant primes produced similar effects to identical primes, while the vowel primes produced similar effects to unrelated primes. Recall that in the present repetition blindness study, the identical primes produced the strongest RB effects, and the unrelated primes served as the baseline. The results of Carreiras et al. (2009) therefore suggest that consonant primes (primes that differ from targets in consonants) would cause stronger phonological RB than vowel primes (primes that differ from targets in vowels).

3.6 Conclusions

The present study employed the repetition blindness paradigm to examine semantic and phonological activation when native Chinese speakers and native English speakers read in their native language. One striking finding is that semantic RB occurred for native English speakers when they responded to high frequency trials in the RB naming task. This is the first study that demonstrates semantic RB in word pairs in the same language. The other important finding is that the phonological RB effects in native English speakers were significantly larger than in native Chinese speakers. This finding suggests that phonological information is activated more strongly in English reading than in

Chinese reading and might results from the fact that phonological information is encoded in a more transparent and consistent manner in English than in Chinese.

CHAPTER 4: THE SECOND LANGUAGE PRIMING AND REPETITION BLINDNESS STUDIES

4.1 Background

The two first language (L1) studies reported in Chapter 2 and 3 showed that the patterns of semantic and phonological activation in reading one's native language are shaped by the manners in which semantic and phonological information are encoded in the orthography of the language. How much do the L1 literacy experiences influence second language (L2) reading? More specifically, do second language learners transfer their L1 activation patterns to their L2 reading even when they have high proficiency in the second language? A priming study and a repetition blindness study were carried out with advanced learners of English whose native language was either Chinese or Spanish to investigate this research question.

4.1.1 Orthographic Transfer in Visual Word Recognition

Second language learners tend to apply the linguistic knowledge of their first language to the use of their second language, a phenomenon known as transfer. Similarly, when reading a second language, the learners are inclined to resort to their L1 reading experiences to decipher the less familiar orthography (Koda, 2007; Koda & Zehler, 2008). According to Contrastive Analysis, second language learners would read better when their L1 and L2 orthographies are in the same writing system than when the two orthographies are in different writing systems. This prediction is supported by studies which demonstrated that second language learners of English whose first language has an alphabetic orthography (e.g., Arabic, Hebrew, Indonesian, Persian, Russian, and Spanish) outperformed their counterparts whose first language has a non-alphabetic orthography (e.g., Chinese and Japanese) in recognizing English words (see Cook & Bassetti, 2005, p. 37-38 for a list of relevant studies). For example, Bialystok, Luk, and Kwan (2005) found that Hebrew-English and Spanish-English bilingual children were more advanced English readers than Chinese-English bilingual children because the former scored higher than the latter in an English phoneme counting task and an English nonword decoding task. Muljani, Koda, and Moates (1998) showed that native Indonesian speakers made lexical decisions for English words and nonwords faster than native Chinese speakers although both participant groups' accuracy rates were equally high.

4.1.2 Orthographic Transfer and the Orthographic Depth Hypothesis

The Orthographic Depth Hypothesis, though originally proposed for first language reading, has been found useful in explaining orthographic transfer (Wang, 2011). Previous studies have shown that when reading their second language, learners with alphabetic backgrounds (e.g., Arabic, Korean, and Spanish) relied more on phonological information, while those with non-alphabetic backgrounds (e.g., Chinese and Japanese) relied more on orthographic information, which is consistent with the prediction of the Orthographic Depth Hypothesis. For example, Wang, Koda, & Perfetti (2003) reported that when performing a semantic category judgment task in English, native Korean speakers experienced interference from homophones whereas native Chinese speakers experienced interference from words with similar spellings. Moreover, native Chinese speakers responded less accurately overall and produced more phonologically incorrect but orthographically plausible responses than native Korean speakers in an English phoneme deletion task. The authors concluded that Chinese learners of English were more attentive to orthographic information and Korean learners of English were more attentive to phonological information in identifying English words, which is clearly a transfer from their first language reading experiences. Similar results were also found in second language learners of Japanese. Chikamatsu (1996) showed that when making lexical decisions for Japanese kana words, native English speakers depended more on phonological information but native Chinese speaker depended more on orthographic information.

Like the literature in first language reading, the role that semantic information plays in the reading process has drawn less attention in second language reading research. Liu, Wang, and Perfetti (2007) had second language learners of Chinese whose first language has an alphabetic orthography (the majority is English) perform a Chinese character naming task in a priming paradigm. Although appearing later than an orthographic priming effect, a semantic priming effect was indeed found at the end of the second term of the Chinese course. This finding suggests that semantic information plays a role in second language reading.

4.1.3 Orthographic Transfer and Second Language Proficiency

It is widely believed that first language transfer occurs when second language learners are not equipped with enough knowledge of their second language, and they thus utilize the readily available knowledge of their first language to process the second language. This view implies that the effects of first language, though possibly strong in the beginning of second language acquisition, should diminish as proficiency in second language increases. Some previous studies showed that no orthographic transfer was found in advanced second language learners (e.g., Akamatsu, 2002; Jackson et al., 1999; Lemhöfer et al., 2008). Akamatsu (2002) showed that the effects of word frequency and regularity on English word recognition were the same across advanced learners of English with different L1 backgrounds (Chinese, Japanese, and Persian). In Lemhöfer et al. (2008), native speakers of French, German, and Dutch demonstrated a high degree of similarity in identifying monosyllabic English words. However, some other studies found that the appearance of orthographic transfer in advanced second language learners may depend on whether the stimuli were presented out of context or not (e.g., Chikamatsu, 2006; Haynes & Carr, 1990; Miller, 2011). For example, Chikamatsu (2006) showed that when making lexical decisions for Japanese kana words, orthographic transfer, though found in less advanced learners, diminished in advanced learners (both groups were native English speakers). In contrast, orthographic transfer was found in both groups of participants when performing a paragraph comprehension task. Similarly, Miller (2011) observed orthographic transfer in advanced Chinese learners of English when they performed a sentence comprehension task but not when they performed a lexical decision task. These findings suggest that second language learners might be able to master some skills for second language reading as their L2 proficiency improves and thus do not need to resort to their experiences in L1 reading for help. There are, however, some other skills that second language learners might never be able to master and may still need to make use of what they have learned from their L1 literacy experiences to help reading their L2 even when they possess high proficiency in the L2. The current study will reveal whether orthographic transfer can be observed in advanced second language learners of English when it comes to the patterns of semantic and phonological activation.

4.1.4 The Current Priming and Repetition Blindness Studies in Reading English as a Second Language

Previous studies have shown that the relative reliance on orthographic and phonological information can be transferred from L1 reading to L2 reading. The present study investigated whether reliance on semantic information can also be transferred. Moreover, this study also examined whether the transfer of semantic and phonological activation patterns can be observed in advanced second language learners. Two groups of advanced second language learners with different first language backgrounds (Spanish and Chinese) were recruited to perform a priming study and a repetition blindness study. Spanish is known for its consistent and transparent correspondences between graphemes and phonemes, and is a representative of transparent orthographies (Defior, Martos, & Cary, 2002). Chinese, as mentioned earlier in Chapters 1 and 2, encodes phonology in a considerably opaque manner, which places Chinese at the deep end of the orthographic depth continuum. According to the Orthographic Depth Hypothesis, native Spanish speakers would highly rely on phonological information to recognize words. If phonological activation is found in native Spanish speakers reading English, orthographic transfer is observed. Semantic cues are more reliable than phonetic cues in Chinese characters, so native Chinese speakers would make more use of semantic information than phonological information to identify words. If semantic activation is found in native Chinese speakers reading English, orthographic transfer is observed.

4.2 The Second Language Priming Study

This second language priming study is similar to the first language priming study reported in Chapter 2. It included the same set of English stimuli and the same four priming tasks (i.e., the single-word naming task, the single-word semantic category judgment task, the sentence-based naming task, and the sentence-based semantic category judgment task. The procedure of each task was also the same. The only difference between this L2 priming study and the L1 priming study is that in the sentence-based priming paradigm, each word of the sentences stayed on the screen longer for second language readers than for first language readers (400ms vs. 240ms).

4.2.1 Method

4.2.1.1 Participants

A group of 165 native Chinese speakers and a group of 39 native Spanish speakers participated in the present second language priming study. Because of technical problems with E-prime experimental control scripts, only the data of the following participants who performed on the revised E-Prime scripts were included in the data analysis: 97 native Chinese speakers (53 from Mainland China and 44 from Taiwan; mean age = 23.4 yrs, SD = 3.7) and 30 native Spanish speakers (mean age = 21 yrs, SD = 3.6). All participants were recruited from the greater Boston area, and the majority of them were graduate or undergraduate students. Each participant was either paid $10 per hour or given credit hours for PSY101 for their contribution of time. All participants were under age 35, started to learn their native language at birth, and received their high school diploma from a country in which their native language is an official language. Since the development of reading is a slow yet persistent process, an age limit was set at 35 to ensure the comparability across language groups. The second and the third criterion guarantee that all participants started to learn their native language at birth and were immersed in that language long enough to have high proficiency in reading their native language. Both the Chinese group and the Spanish group had learned English as a second language.

All participants were required to complete an online survey on Survey Monkey before they visited the lab. The survey was composed of 10 questions regarding language background and schooling experiences (see Appendix G) and a retired version of the Michigan Test of English Language Proficiency (MTELP, form P)[25]. The 10 questions allowed a better understanding of each participant's language and education background. They also helped to filter out people who did not

[25] MTELP is good alternative to TOEFL when it comes to standardized English proficiency test. It has 100 multiple-choice items: 40 grammar items, 40 vocabulary items, and 20 reading comprehension items.

meet the criteria mentioned above. All participants also filled out an online language background questionnaire (see Appendix H) before performing the experimental tasks.

Although most of the participants in this sample had previously taken the TOEFL or IELTS, prior TOEFL or IELTS scores may not represent their current English proficiency level. In some cases, people took the TOEFL or IELTS several years ago, and their proficiency level has changed after living in the States for years. In other cases, TOEFL or IELTS scores merely reflected the test taking skills people learned from cram schools and how much practice they had on retired tests. Therefore, the test scores may not represent their actual English proficiency level. Having participants take an MTELP before their lab visits provided a solution to these issues. The MTELP on the online survey allowed an accurate and updated measurement of all participants' English proficiency[26]. It also provided an English proficiency assessment for the participants who did not take any standardized test before. The manual of MTELP and the established practice at University of Pittsburg and Oakland University all use score 80 as an index of advanced level. Due to the difficulty of recruiting enough Chinese participants, the cut-off score was lowered to 77. Therefore, participants who scored 77 or above were considered advanced learners of English, otherwise they were considered intermediate learners. The present study included only advanced learners and excluded intermediate learners. In the end, the Chinese group consisted of 74 participants, and the Spanish group consisted of 30 participants. Table 6 shows the two groups of participants' background information which was collected from the

[26] To my knowledge, no cram schools in Mainland China and Taiwan taught test taking skills for MTELP. None of my Spanish-speaking participants went to a cram school for standardized English proficiency exams.

language background questionnaire.

Table 6: Language Background Information for the L2 Priming Study

Language group	Chinese	Spanish
English proficiency level	Advanced N = 74	Advanced N = 30
Average Age	23.3	21
Sex (male/female)	22/52	11/19
How many languages learned	2.7	2.9
At what age started learning English	9.3	4.7
At what age came to the States	22.2	19.6
Average TOEFL iBT score[27]	96.4	94.6
Average MTELP score (SD)	84 (3.6)	90.6 (3.7)

4.2.1.2 Materials

The stimuli were the same as the English stimuli used in the L1 priming study. Please see section 2.2.4 *Materials* for details.

[27] Some participants reported that they took paper-based TOEFL, CBT TOEFL, or IELTS. For ease of statistical analysis, their scores were converted into iBT TOEFL scores according to the conversion tables released by ETS.

4.2.1.3 Procedure

The procedure of each priming task was very similar to the L1 priming study. The only difference is that in the sentence-based priming paradigm, each word of the sentences stayed on the screen for 400 ms instead of 240ms, since second language readers usually could not read as fast as first language readers. Please see section 2.2.5 *Procedure* for detailed information regarding the procedure of each task.

4.2.2 Results and Discussion

The two groups of participant were separately analyzed for each priming task with linear mixed models using SPSS. The analysis procedure was the same as the L1 priming study (see section 2.2.6 *Data Analysis*). The results are presented in Table 7.

Table 7 shows that, as in the L1 priming study, the significant difference between semantic prime trials and unrelated prime primes was a semantic priming effect; the significant difference between phonological prime trials and unrelated prime trials was a phonological inhibition effect. In addition, semantic priming was found in a semantic judgment task and phonological inhibition was found in a naming task. This is not surprising since semantic judgment tasks demand the access to word meaning, whereas naming tasks demand the retrieval of pronunciation.

Table 7: Results of the L2 Priming Study

Task	Participant group	Main effect in omnibus analysis	Number of separate analyses	Bonferroni correction	Results of further analyses
Single-word naming	Chinese	SOA frequency	3X2 = 6	.05/6 = .008	n.s.
	Spanish	frequency	2	.05/2 = .025	n.s.
Sentence–based naming	Chinese	frequency	2	.05/2 = .025	n.s.
	Spanish	frequency	2	.05/2 = .025	Phonological inhibition in high frequency (p=.006)
Single-word semantic category judgment	Chinese	SOA frequency	3X2 = 6	.05/6 = .008	n.s.
	Spanish	frequency	2	.05/2 = .025	n.s.
Sentence–based semantic category judgment	Chinese	SOA	3	.05/3 = .017	Semantic priming at SOA = 50 (p=.008)
	Spanish	SOA frequency	3X2 = 6	.05/6 = .008	n.s.

Semantic priming was found only in the Chinese group, whereas phonological inhibition was found only in the Spanish group. This finding is a manifestation of orthographic transfer because it reflects the unique properties of Chinese and Spanish orthographies: semantic information is encoded more reliably than phonological information in Chinese, while phonological information is encoded more transparently than semantic information in Spanish. It, however, does not imply the absence of phonological activation in native Chinese speakers or the absence of semantic activation in native Spanish speakers when reading English (see the results of the RB study below in section 4.3). Because priming is a rather weak effect in general, only the most prominent properties of the first written language could result in priming/inhibition in second language reading.

Both the semantic priming effect in the Chinese group and the phonological inhibition effect in the Spanish group were found in the sentence-based priming paradigm, but not in the single-word priming paradigm. This might be because the two groups of participants performed the tasks in their second language, and the sentence context allowed them to benefit from the primes when identifying the targets. All the primes were displayed for a short period of time (ranging from 50ms to 150ms) across the priming tasks. When the primes were presented alone in the single-word priming tasks, the second language learners might not have enough time to recognize them. In this case, the primes could not facilitate the participants' identification of the targets, since little linguistic information was extracted from the primes. In contrast, when a prime was presented in a sentence, the sentence context made it easier for the second language learners to decode the prime. The linguistic information encoded in the prime could thus be utilized by the participants to identify the target.

Semantic priming occurred in the Chinese group when SOA was 50ms, showing that semantic activation occurred quite early even when native Chinese speakers were reading English. Phonological inhibition in the Spanish group occurred in high frequency trials only. This is probably because native Spanish speakers were more familiar with the pronunciation of high frequency English words than the pronunciation of low frequency English words. Therefore, they were more sensitive to the phonological relationship between rhyming primes and high frequency English words than to the phonological relationship between rhyming primes and low frequency English words. As a consequence, a rhyming prime was a stronger interference for native Spanish speakers when they identified a high frequency English word.

4.2.3 A Summary of Results

Table 8 summarizes the semantic priming and phonological inhibition effects found in this L2 priming study. There are three major findings. Firstly, semantic priming was found only in the Chinese group. Secondly, phonological inhibition was observed only in the Spanish group. Thirdly, both the semantic priming effect and the phonological inhibition effect were found in the sentence-based priming paradigm.

Table 8: Priming and Inhibition Effects in the L2 Priming Study

Priming/inhibition type	Participant group	Task	Condition
Semantic priming	Chinese	Sentence semantic judgment	SOA = 50 (p=.008) magnitude = 198.5ms
Phonological inhibition	Spanish	Sentence naming	high frequency (p=.006), magnitude = -40ms

4.3 The Second Language Repetition Blindness Study

This second language repetition blindness study is similar to the first language repetition blindness study reported in Chapter 3. It included the same set of English stimuli and the same two repetition blindness tasks (i.e., the RB naming task and the RB confirmation task). The procedure of each task was also the same. The only difference between this L2 RB study and the L1 RB study is that in the confirmation task, the five options for exposure duration were shorter for first language readers (68ms, 85ms, 102ms, 119ms, and 136ms) than for second language readers (85ms, 102ms, 119ms, 136ms, and 153ms).

4.3.1 Method

The two RB tasks were preceded by the four priming tasks discussed in section 4.2 *The Second Language Priming Study*. The participants whose ID number was odd were assigned to perform the RB naming task first, and those whose ID number was even were assigned to perform the RB confirmation task first. The two tasks were separated by a 5-minute break to refresh visual perception and concentration.

4.3.1.1 Participants

The same two groups of participants in the L2 priming study also participated in this L2 RB study. The Chinese group included 165 native Chinese speakers (85 from Mainland China and 80 from Taiwan; mean age = 24.3 yrs, SD = 3.9); the Spanish group included 39 native Spanish speakers (mean age = 21.9 yrs, SD = 4.1). Only those who scored 77 or above in the MTELP English proficiency test were considered advanced learners of English and included in the present L2 RB study. Therefore, the Chinese group was composed of 135 participants and the Spanish group was composed of 39 participants. Table 5 shows the average MTELP score of the two language groups. Table 9 shows the two groups of participants' background information which was collected from the language background questionnaire.

Table 9: Language Background Information for the L2 RB Study

Language group	Chinese	Spanish
English proficiency level	advanced n = 135	advanced n = 39
Average Age	24.3	21.9
Sex (male/female)	49/86	14/25

How many languages learned	2.8	2.8
At what age started learning English	9.5	5.1
At what age came to the States	22.7	20.3
Average TOEFL iBT score	96.3	96.2
Average MTELP score (SD)	84.3 (3.9)	89.6 (4)

4.3.1.2 Materials

The stimuli were the same as the English stimuli used in the L1 RB study. Please see section 3.2.4 *Materials* for details.

4.3.1.3 Procedure

The procedure of each RB task was very similar to the L2 RB study. The only difference is that in the confirmation task, the five options for exposure duration were shorter for first language readers (68ms, 85ms, 102ms, 119ms, and 136ms) than for second language readers (85ms, 102ms, 119ms, 136ms, and 153ms), since first language readers usually read as faster than second language readers. Please see section 3.2.5 *Procedure* for detailed information regarding the procedure of each task.

4.3.2 Results

The two groups of participant were separately analyzed for each RB task. The analysis procedure was the same as the L1 RB study (see section 3.2.6 *Data Analysis*).

4.3.2.1 The Repetition Blindness Naming Task

In the RB naming task, the dependent measure is the percentage of trials in which both the prime and the target were correctly reported. A 4 (prime type: identical, phonological, semantic, and unrelated) X 2 (frequency: high and low) repeated measures ANOVA was conducted for both the Chinese group and the Spanish group.

4.3.2.1.1 The Chinese group.

A main effect of frequency (F (1, 134) = 20.8, *p* <.001, partial eta squared = .14) was found in the Chinese learners of English, as illustrated in Figure 11. As reading in Chinese, the Chinese learners of English responded more accurately to the high frequency trials than to the low frequency trials when reading in English. This is presumably because the participants were more familiar with high frequency words than with low frequency words in their second language, English. The frequency effect was larger for phonological, semantic, and unrelated prime trials than for identical prime trials, resulting in an interaction of prime type and frequency (F (3, 132) = 3.8, *p* <.05, partial eta squared = .08).

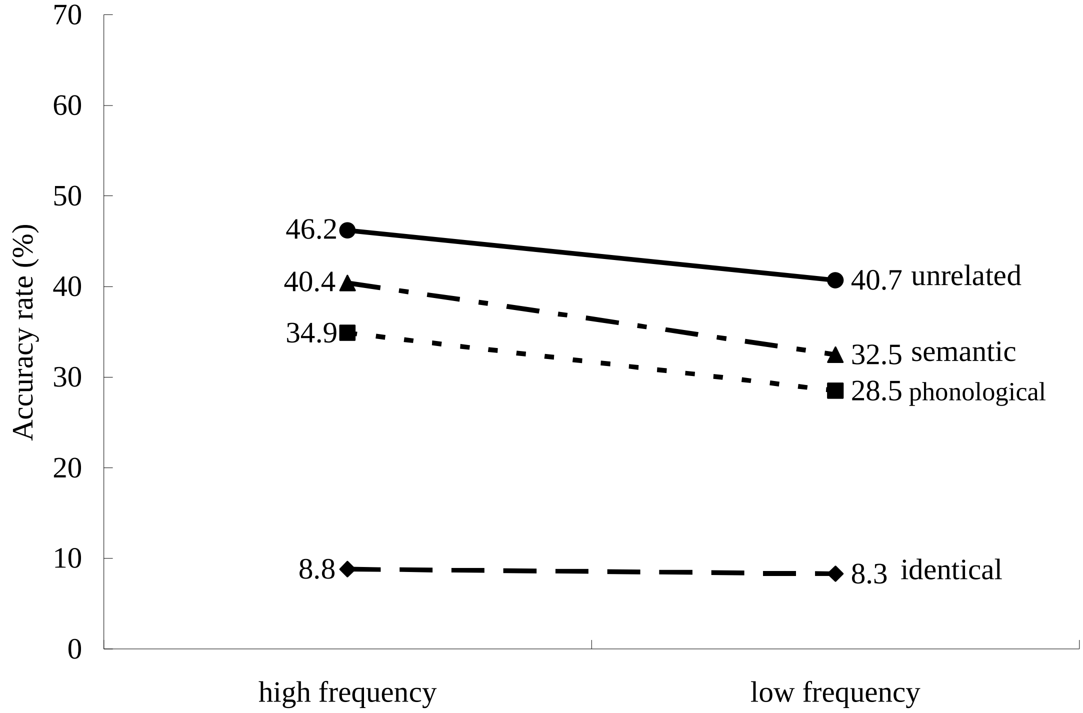

Figure 11: Report accuracy in the L2 RB naming task for the Chinese group

A main effect of prime type (F (3, 132) = 111.6, *p* <.001, partial eta squared = .72) was also found. Post hoc analyses showed that regardless of the frequency of targets, the identical prime trials, the phonological prime trials, and the semantic prime trials were all responded to significantly less accurately than the unrelated prime trials (all *p*s < .001 except semantic prime in high frequency *p* < .05), manifesting identical RB effects (magnitude in high frequency trials = 46.2% - 8.8% = 37.4%; magnitude in low frequency trials = 40.7% - 8.3% = 32.4%), phonological RB effects (magnitude in high frequency trials = 46.2% - 34.9% = 11.3%; magnitude in low frequency trials = 40.7% - 28.5% =

12.2%), and semantic RB effects (magnitude in high frequency trials = 46.2% - 40.4% = 5.8%; magnitude in low frequency trials = 40.7% - 32.5% =8.2%). The phonological RB effects and the semantic RB effects indicate that phonological information and semantic information were activated when native Chinese speakers read English.

4.3.2.1.2 The Spanish group.

A main effect of prime type (F (3, 36) = 119.4, p <.001, partial eta squared = .9), but no main effect of frequency, was found in the Spanish learners of English. Figure 12 clearly shows that the identical prime trials and the phonological prime trials were responded to significantly less accurately than the unrelated prime trials regardless of the frequency of targets (all *p*s < .001 as shown by post hoc analyses), manifesting identical RB effects (magnitude in high frequency trials = 54.7% - 9% = 45.7%; magnitude in low frequency trials = 53% - 10.3% = 42.7%) and phonological RB effects (magnitude in high frequency trials = 54.7% -28.2% = 26.5%; magnitude in low frequency trials = 53% - 35.9% = 17.1%). The phonological RB effects indicate that phonological information was activated when native Spanish speakers read English.

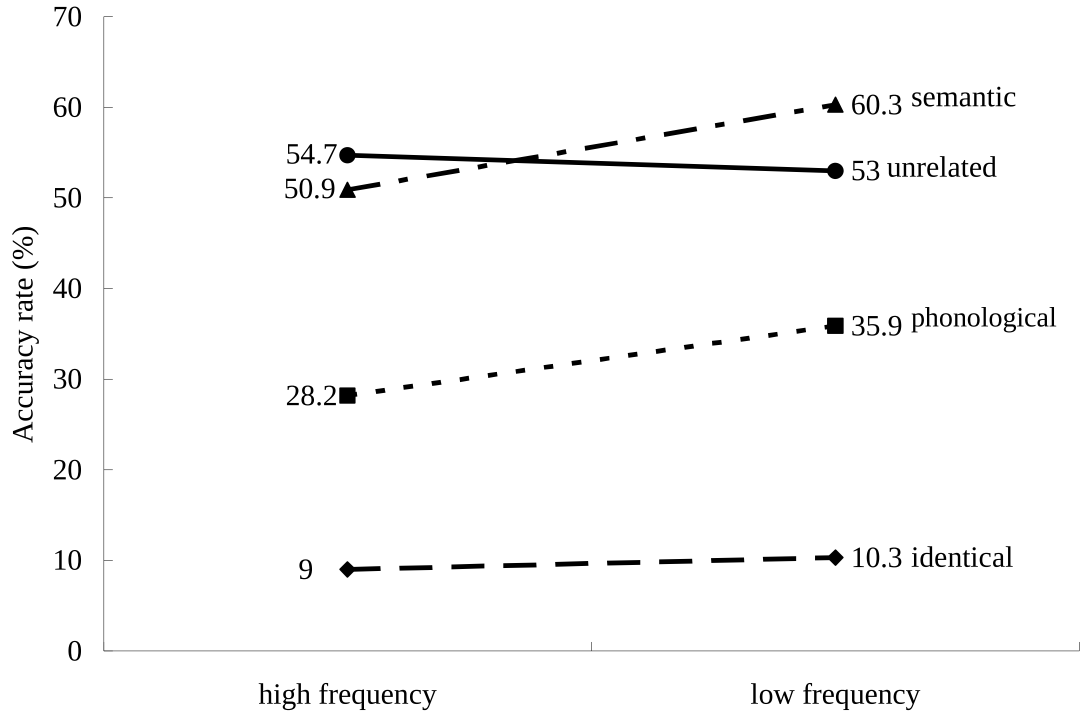

Figure 12: Report accuracy in the L2 RB naming task for the Spanish group

4.3.2.2 The Repetition Blindness Confirmation Task

The dependent measure is the percentage of the "Yes" response to the real trials (i.e., the percentage of the target words that were seen). A 3 (prime type: phonological, semantic, and unrelated) X 2 (frequency: high and low) repeated measures ANOVA was conducted for both the Chinese group and the Spanish group.

4.3.2.2.1 The Chinese group.

For native Chinese speakers responding in English, a main effect of frequency ($F(1, 134) = 6.7$, $p < .05$, partial eta squared = .39) was found. As Figure 13 illustrates, the low frequency targets were perceived more frequently than the high frequency targets when they were preceded by the phonological primes and the unrelated primes.

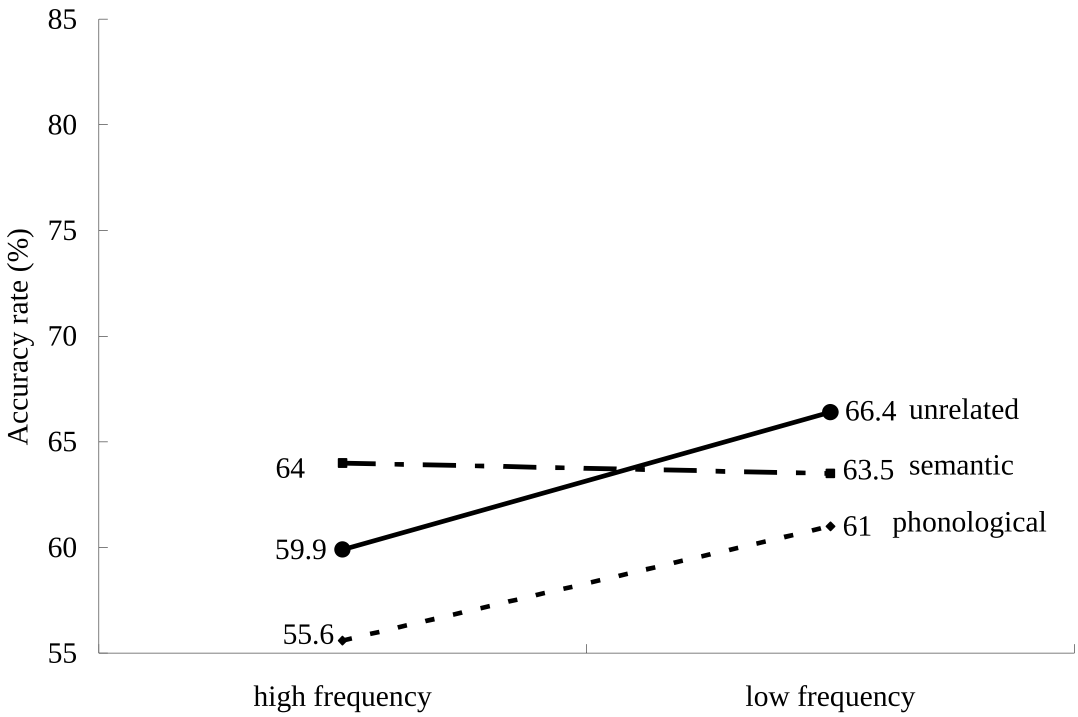

Figure 13: Accuracy rate in the L2 RB confirmation task for the Chinese group

A main effect of prime type ($F(2, 133) = 6.5$, $p < .01$, partial eta squared = .09) was also found.

Post hoc analyses showed that the low frequency targets were harder to perceive when they were preceded by the phonological primes than preceded by the unrelated primes ($p < .05$), manifesting a phonological RB effect (magnitude = 66.4% - 61% = 5.4 %). The phonological RB effect indicates that phonological information was activated when native Chinese speakers read low frequency English words.

4.3.2.2.2 The Spanish group.

A main effect of frequency ($F(1, 38) = 14$, $p = .001$, partial eta squared = .27) was found in the Spanish learners of English. As Figure 14 illustrates, the low frequency targets were perceived more frequently than the high frequency targets across prime type.

Post hoc analyses showed that the low frequency targets were harder to perceive when they were preceded by the phonological primes than preceded by unrelated primes ($p < .05$), manifesting a phonological RB effect (magnitude = 80.3% - 70.5% = 9.8 %). Phonological information was activated when native Spanish speakers read low frequency English words. There was no main effect of prime type.

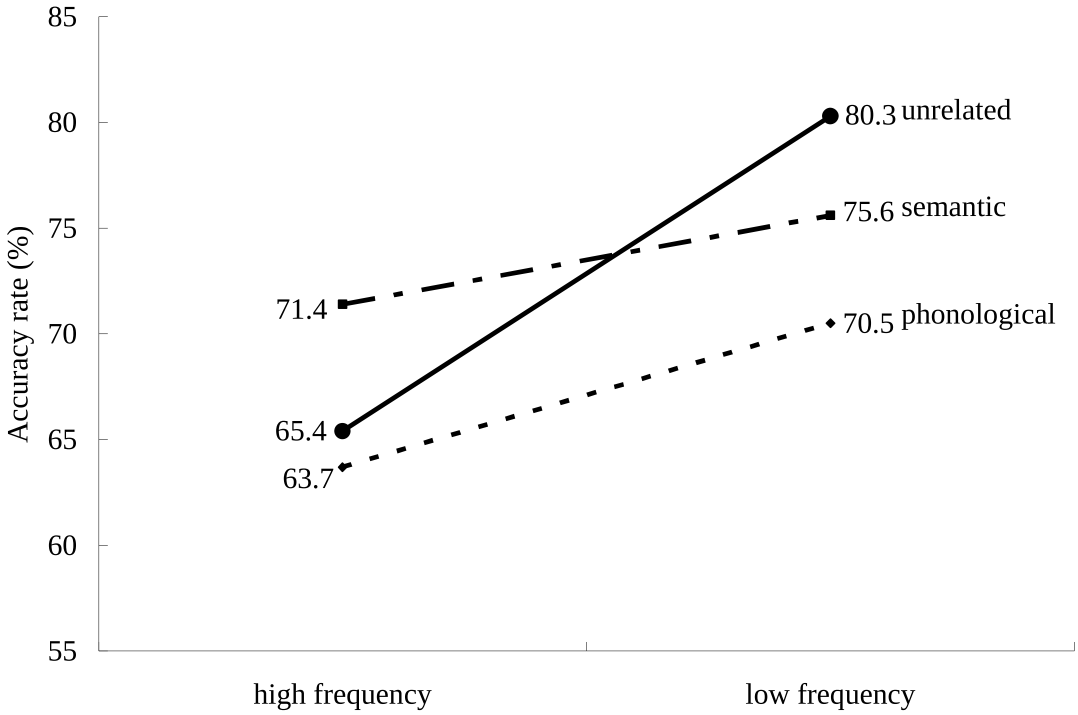

Figure 14: Accuracy rate in the L2 RB confirmation task for the Spanish group

4.3.3 Discussion

Two 2 (group: Chinese and Spanish) X 2 (frequency: high and low) repeated measures ANOVAs were conducted for the RB naming and the RB confirmation task to compare the magnitudes of phonological RB effects in the two groups of participants. Results showed that there was a main effect of group in the RB naming task (F (1, 172) = 7.46, $p < .01$, partial eta squared = .04), but not in the RB confirmation task.

In the RB naming task, the phonological RB effects in native Spanish speakers were twice as large as those in native Chinese speakers (26.5 % vs. 11.3% in high frequency; 17.1% vs. 12.2% in low frequency), indicating that phonological activation was stronger in native Spanish speakers than in native Chinese speakers when naming English words. This can be accounted for by the fact that Spanish is a transparent orthography, whereas Chinese is a very deep orthography. In other words, this result came from orthographic transfer. It is not surprising that the magnitudes of phonological RB effects were not significantly different in the two language groups in the confirmation task. As mentioned earlier in Chapter 3, the confirmation task is similar to a lexical decision task which does not demand access to word pronunciation nor word meaning. Therefore, no strong phonological activation could be observed in both groups of second language learners.

Another (group: Chinese and Spanish) X 2 (frequency: high and low) repeated measures ANOVA was conducted for the RB naming task to compare the magnitudes of semantic RB effects in the Chinese group and in the Spanish group. A main effect of group was found ($F(1, 172) = 5.58$, $p < .05$, partial eta squared = .03). In the Chinese group, the magnitudes of semantic RB effects for high frequency and low frequency trials were 5.8% and 8.2% respectively. In contrast, no significant semantic RB effect was found in the Spanish group. This difference between the two language groups again demonstrates orthographic transfer. Semantic information is usually reliably encoded in Chinese orthography, which encourages native Chinese speakers to depend on it to recognize words. The Chinese group carried this reliance on semantic information for word reorganization over to English reading, although semantic information is encoded in a different manner in English.

The appearance of semantic RB in the Chinese group when they read in English confirms that my finding of semantic RB in the native English speakers (reported in Chapter 3) is not accidental, since it is replicated in the native Chinese speakers. Semantic RB does exist in word pairs which are in the same language. Although semantic RB effects are delicate, compared to identical RB effects and phonological RB effects, they can be observed in reading deep orthographies if there are enough experimental trials and participants.

No semantic RB effect was found in the RB confirmation task. This is again due to the nature of the task. When performing this task, participants indicated whether they saw the target word in the preceding four words in each trial. They could make judgments without accessing word meaning, which might be the reason why a semantic RB effect did not appear.

4.3.4 A Summary of Results

Table 10 summarizes the magnitudes of RB effects in this second language repetition blindness study. The two main findings are both in the RB naming task. One finding is that phonological RB effects were larger in the Spanish group than in the Chinese group, suggesting stronger phonological activation in the former than in the latter. The other finding is that semantic RB effects were observed in the Chinese group yet absent in the Spanish group. Both findings demonstrate orthographic transfer.

Table10: Magnitudes of RB Effects in the L2 Repetition Blindness Study

	RB naming task						RB confirmation task	
	identical		phonological		semantic		phonological	
	high	low	high	low	high	low	high	low
Chinese	37.4%	32.4%	11.3%	12.2%	5.8%	8.2%	n.s.	5.4%
English	45.7%	42.7%	26.5%	17.1%	n.s.	n.s.	n.s.	9.8%

4.4 General Discussion and Conclusions

A priming study and a repetition blindness study were carried out with advanced Chinese learners of English and advanced Spanish learners of English to examine the influence of L1 literacy experiences on L2 reading from the perspective of the activation patterns of semantic information and phonological information. The results in both studies told a consistent story and clearly demonstrate orthographic transfer.

Spanish is a typical transparent orthography. Except a silent letter *h*, each of the other 24 graphemes maps to a single phoneme. Although some graphemes (*c*, *g*, *r*, *x*, and *y*) are allowed to map to two or more phonemes in certain contexts, the grapheme-phoneme conversion are predictable (Defior, Martos, & Cary, 2002). Since phonology is encoded in such a transparent and consistent manner in Spanish orthography, it is natural that native Spanish speakers are accustomed to using phonological information to identify words. The results in the priming study and the repetition blindness study showed that the native Spanish speakers brought this habit to reading English, an orthography whose grapheme-phoneme correspondence is less consistent and transparent. Phonological inhibition, completely absent in Chinese learners of English, was found in Spanish learners of English in the priming study. In the repetition blindness study, the phonological RB effects in the Spanish group were nearly twice as large as those in the Chinese group.

Chinese is a very deep orthography, in which semantic information usually provides more reliable cues for character meaning than phonological information for character pronunciation. It is thus presumed that native Chinese speakers would count more on semantic information than on phonological information for word recognition. This presumption is evidenced even when the native Chinese speakers read English, as shown in the current second language study. In the priming study, semantic priming, though absent in the Spanish group, was found in the Chinese group. Similarly, semantic RB was found in the native Chinese speakers, but not in the Spanish speakers, when they performed a repetition blindness naming task. These two findings in Chinese learners of English has an important implication: semantic processing, like orthographic processing and phonological processing mentioned in the existing literature of second language reading, can be transferred from L1 reading experiences to L2 reading.

Transfer is prevalent in second language learners. However, it is not clear whether it occurs only when the learners do not have enough competence in their second language or even when they have high proficiency in that language. It has been found that in advanced second language learners, orthographic transfer can occur in one experimental task yet attenuate or disappear in another experimental task (e.g., Chikamatsu, 2006; Haynes & Carr, 1990; Miller, 2011). This suggests that some aspects of L2 reading can develop to such a high level that second language learners do not need to resort to their L1 reading experiences, but some aspects are strongly tied with the learners' L1 literacy experiences regardless their L2 proficiency level. In the current second language study, orthographic transfer is observed in the advanced learners of English, implying that the activation patterns of semantic and phonological information in L2 reading are mainly shaped by the readers' L1 orthography. This finding echoes Tan et al.'s (2003) fMRI study which showed that advanced Chinese learners of English applied the same brain areas for Chinese and English phonological processing.

CHAPTER 5: GENERAL DISCUSSION AND CONCLUSIONS

5.1 Background

Word recognition, the first step of successful reading, is the process of matching a printed word with a word in the mental lexicon using its semantic, phonological, and orthographic representation. In the early stage of this process, the reader has to decode the semantic, phonological, and orthographic information conveyed in the printed word. It is known that phonological information is not encoded in an invariant manner across the world's orthographies: shallow orthographies encode phonology in a relatively transparent manner, whereas deep orthographies encode phonology in a relatively opaque manner. Do these different manners of encoding phonology influence the process of word recognition? The answer is positive, according to the Orthographic Depth Hypothesis (Katz & Frost, 1992), which states that the more transparently and consistently an orthography encodes phonology, the more phonological information it activates in reading.

In contrast, the question of whether every orthography activates the same amount of semantic information has long been neglected in the literature. Some researchers do not consider it a research question, because they do not distinguish the semantic information encoded in a printed word and activated in the reading process from the meaning represented by the printed word (the former is analogous to phonemes that constitute a printed word, and the latter is analogous to the pronunciation of the printed word). The consequence of this conflation is to believe that strong semantic activation leads to good reading comprehension, while weak semantic activation leads to poor reading comprehension. Since it is implausible that reading comprehension varies from one orthography to another, people who hold this view presumably assume that the amount of semantic information that is activated in the reading process is the same across orthographies.

The confusion between semantic information and word meaning might arise from the fact that, in alphabetic orthographies, the carriers of semantic information (i.e., morphemes) are usually a larger unit than the carriers of phonological information (i.e., phonemes). By the time a morpheme is identified and the semantic information it carries comes into play in the reading process, it is very close to the end of the process of word recognition. Chinese, a non-alphabetic orthography, makes it clear to us that semantic information is not equivalent to word meaning. In the majority of Chinese characters, semantic information is carried by a semantic radical which provides clues to the character meaning (i.e., semantic attributes of the character meaning but not the character meaning per se). Phonological information, on the other hand, is carried by a phonetic radical which is a separate component from the semantic radical. With this unique configuration of a semantic radical and a phonetic radical, Chinese orthography provides a good opportunity to understand how semantic information and phonological information are processed in visual word recognition.

This dissertation started with a priming study conducted in the first language of native Chinese speakers and native English speakers. The purpose of this L1 priming study was to investigate whether the patterns of semantic and phonological activation are different in reading Chinese versus reading English, since semantic and phonological information are encoded in different manners in these two orthographies. A repetition blindness study was also conducted with the same participants to further explore the magnitudes of semantic and phonological activation in reading Chinese and English.

To extend our understanding of semantic and phonological activation to second language reading, another priming study and repetition blindness study adopting the same stimuli and similar experimental procedures from the L1 studies were carried out in English with native Chinese speakers and native Spanish speakers. The two groups of participants, though both were advanced learners of English, had different L1 literacy backgrounds. The Chinese group read a very deep orthography as a first language, whereas the Spanish group read a transparent orthography as a first language. Having them perform priming tasks and repetition blindness tasks in their shared second language (i.e., English) allows us to investigate the influence of first language reading experience on second language reading, a phenomenon known as orthographic transfer.

5.2 A Summary of Major Findings

In the L1 priming study and the L1 repetition blindness study, different activation patterns of semantic and phonological information were found in Chinese and English reading, reflecting the different manners in which semantic and phonological information are encoded in these two orthographies. In the L2 priming study and the L2 repetition blindness study, the activation patterns of semantic and phonological information were also found to be different in native Chinese speakers and

Spanish speakers when they read English, demonstrating orthographic transfer.

5.2.1 Semantic Activation

The semantic activation was manifested by semantic priming in the L1 and L2 priming studies and by semantic RB in the L1 and L2 repetition blindness studies.

5.2.1.1 Semantic Priming

In the L1 priming study, semantic priming occurred only in the sentence-based paradigm in Chinese reading, but occurred only in the single-word paradigm in English reading. In the sentence-based paradigm, each prime was embedded in a sentence; in the single-word paradigm, each prime war presented alone. It is possible that due to the polysemous nature of Chinese characters, neighboring characters are required to help readers figure out the intended meaning of a prime which would later facilitate the access to the meaning of the matching target. In contrast, the intended meaning of an English prime word is usually specific enough for readers to access when the prime is presented alone. If presented in a sentence, the meaning of the prime is probably rapidly washed away by the following words, resulting in no facilitation for the access to the meaning of the matching target.

In the L2 priming study, semantic priming occurred in the native Chinese speakers, but not in the native Spanish speakers. Semantic information is encoded more reliably than phonological information in Chinese orthography, which encourages native Chinese speakers to rely more on semantic information than on phonological information for word recognition. It seems that the Chinese group brought this habit to English reading, which resulted in semantic priming. Therefore, this finding provides evidence for orthographic transfer.

5.2.1.2 Semantic RB

The semantic RB effects found in the native English speakers and the native Chinese speakers reading English is remarkable. It has been widely assumed that semantic RB does not occur between two semantically related words in the same language, even though it has been found between pictures representing associated items (Kanwisher, Yin, & Wojciulik, 1999), between a word and a picture referring to the same item (Bavelier, 1994), and between words denoting the same meaning in two different languages[28] (i.e., translated words) (McKay & Miller, 1994). My finding of semantic RB is by no means accidental, because it was observed in two different groups of participants with one read their native language and the other read their second language. With enough number of experimental trials and participants, semantic RB emerged in word pairs in English, a deep orthography.

5.2.2 Phonological Activation

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[28] It is controversial whether translation semantic RB existed. Several studies (Altarriba & Soltano, 1996; Coltheart & Ling, 1998; MacKay, James, & Abrams, 2002; Sanchez-Casas, Davis, Garcia-Albea, 1992) reported either semantic priming or no effect instead of semantic RB.

The phonological activation was manifested by phonological inhibition in the L1 and L2 priming studies and phonological RB in the L1 and L2 repetition blindness studies.

5.2.2.1 Phonological Inhibition

Phonological inhibition, instead of phonological priming, was found in the L1 and L2 priming studies because of the use of rhyming primes. Although no consensus is reached yet regarding the cause of phonological inhibition, researchers agreed that it is the phonological processing of rhyming primes that leads to inhibition effect for targets (Colombo, 1986; Lupker & Colombo, 1994; Segui & Grainger, 1990). It is thus legitimate to consider phonological inhibition an index of phonological activation like phonological priming.

In the L1 priming study, phonological inhibition occurred for only low frequency targets in the Chinese group, but for both high and low frequency targets in the English group. This finding suggests that phonology plays a more important role in English reading than in Chinese reading.

In the L2 priming study, phonological inhibition occurred only in the native Spanish speakers and was absent in the native Chinese speakers. This finding is an illustration of orthographic transfer. The consistent and transparent grapheme-phoneme correspondence in Spanish builds native Spanish speakers' heavy reliance on phonological information for word identification. When they brought this habit to English reading, phonological inhibition was observed.

5.2.2.2 Phonological RB

The phonological RB was robust across different language groups in both the L1 and L2 repetition blindness studies despite the use of rhyming primes. This finding indicates that phonological activation is obligatory across orthographies in first language reading and across L1 literacy backgrounds when reading an alphabetic orthography as a second language.

In both the L1 and L2 studies, the magnitudes of phonological RB were significantly smaller in native Chinese speakers than in their alphabetic counterparts (i.e., native English speakers and native Spanish speakers). This finding implies that the extent to which phonological information is activated is modulated by the manner in which phonology is encoded in the orthography that is read (first language reading) or encoded in the L1 orthography of the second language learners (second language reading).

5.3 Orthographic Depth and First Language Reading

The world's orthographies differ from each other in many respects, for example, the writing direction (left to right, right to left, or top to bottom), the graphemes (alphabets or characters), the use of diacritics, the inclusion of vowels, and so on. The Orthographic Depth Hypothesis attempts to capture one variation and the consequence of this variation: phonological information is encoded with different amounts of consistency and transparency in orthographies, which leads to different degrees of phonological activation in reading the orthographies. Due to its focus on the aspect of variation, the

Orthographic Depth Hypothesis is considered by some researchers the opposite of the universal hypothesis which advocates the universality of the reading process across orthographies (e.g., Baluch, 1993; Tzeng, 1994). Is the reading process only either language universal or language specific? In fact, there is a converging view that some components of the reading process are language universal and some are language specific (e.g., Koda, 2007; Perfetti, 2003).

Perfetti and his colleagues (Perfetti, 2003; Perfetti et al. 1992; Perfetti et al. 2005; Perfetti & Dunlap, 2008) argue that there are two reading universals. One is the Language Constraint on Writing Systems which states that all writing systems (including alphabetic orthographies, syllabic orthographies, and morphosyllabic orthographies) represent spoken languages instead of meaning. In addition to semantic information, phonological information is also encoded in orthographies. The other reading universal that Perfetti and his colleagues claim is the Universal Phonological Principle (UPP) which states that phonology is activated in reading every orthography, even when reading a very deep orthography like Chinese. The reading universals that they propose highlight the important role that phonology plays in the reading process. However, Perfetti and his colleagues (e.g., Liu, Wang, & Perfetti, 2007; Perfetti, 2003; Perfetti, Liu, & Tan, 2005) also admit that there are some differences in reading Chinese versus reading alphabetic orthographies. For example, when reading alphabetic orthographies, phonological information is processed in a cascade style in which "the word-level units do not wait for a complete specification of all letter units prior to activation of word-level phonology" (Liu, Wang, & Perfetti, 2007, p. 472). In contrast, when reading Chinese, phonological information is processed in a threshold style in which "the word-level phonology is not activated prior to a full orthographic specification of the character" (Liu, Wang, & Perfetti, 2007, p. 472).

The results reported in this dissertation also support the view that the reading process is language universal as well as language specific. Semantic priming, phonological inhibition, semantic RB,[29] and phonological RB were found in both native Chinese speakers and native English speakers when they read in their first language. In other words, semantic information and phonological information were both activated in Chinese reading as well as in English reading even though they are encoded in different manners in Chinese and English orthographies. This implies a reading universal: any linguistic information encoded in an orthography will be activated in the reading process regardless of the manner in which it is encoded.

However, the patterns of semantic and phonological activation were not the same in reading Chinese and English. In the priming study, semantic priming was found in the sentence-based paradigm in Chinese reading, but in the single-word paradigm in English reading. This suggests that neighboring words facilitate access to the intended meaning of primes in Chinese, but wash away the activated semantic information of primes in English.

Phonological inhibition was found in the sentence-based naming task for both orthographies. However, it occurred only for low frequency targets in Chinese reading, but occurred for both high and low frequency targets in English reading. This shows that phonology played a more important

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[29] In Chinese L1 reading, semantic priming instead of semantic RB was found in the repetition blindness study, which still can be regarded as an index of semantic activation.

role in English reading than in Chinese reading.

In the repetition blindness study, semantic priming was found in the Chinese naming task, while semantic RB was found in the English naming task. Although phonological RB was found in both orthographies, the magnitudes in English were significantly larger than those in Chinese (in the naming task, 24% vs. 12.3% for high frequency trials, 17.7% vs. 10.5% for low frequency trials; in the confirmation task, 17.1% vs. 3.7% for low frequency trials). These differences demonstrate language-specific reading processes which result from the distinct manners in which semantic and phonological information are encoded in Chinese and English orthographies.

As these results show, the Orthographic Depth Hypothesis successfully predicts the different degrees of phonological activation in reading Chinese versus reading English. However, it does not prohibit the reveal of the common properties in reading these two orthographies. The Orthographic Depth Hypothesis, though emphasizes the variation in reading different orthographies, does not deny the universality of reading. Therefore, instead of arguing whether the reading process is language universal or language specific, we should try to identify what components of the reading process are language universal and what components are language specific. The results reported in this dissertation reveal that the occurrence of semantic and phonological activation, which was found for both Chinese and English reading, is a good candidate for a reading universal. The degree to which semantic and phonological information is activated, however, differed between Chinese and English reading. This suggests that the pattern of semantic and phonological activation during reading is a language specific property.

5.4 Orthographic Transfer in Second Language Reading

Transfer is a phenomenon that can be observed in second language learners who apply the lexical, morphological, phonological, syntactic, and pragmatic rules of their first language to their second language. The influence of first language on second language is found not only in speaking but also in reading. It has been reported that when reading the same second language, learners with different first languages performed differently. For example, Koda (1988, 1990) and Wade-Woolley (1999) found that when reading English, the native Japanese speakers in their studies demonstrated better graphic processing skills, whereas those whose first languages were alphabetic (Arabic, Russian, and Spanish) demonstrated better phonological processing skills. Although orthographic transfer has attracted increasing attention, the majority of studies investigate only the transfer of phonological awareness and decoding skills (Koda, 2008). This dissertation extends the understanding of orthographic transfer from the perspective of semantic and phonological activation with advanced English learners whose first language is either alphabetic (i.e., Spanish) or morphosyllabic (i.e., Chinese).

Spanish orthography and Chinese orthography encode phonology in different manners. Spanish is a shallow orthography in which the grapheme-phoneme correspondence is quite consistent and transparent. In contrast, Chinese is a very deep orthography in which only one third of the characters carry useful phonological information. According to the Orthographic Depth Hypothesis, Spanish should activate phonological information more strongly than Chinese. Most Chinese characters include a semantic radical which usually provides reliable clues to the character meaning, which might lead to prominent semantic activation. These predictions were confirmed by the L2 priming study and the L2 repetition blindness study even when the participants read in their second language, English, which is not as shallow as Spanish and not as deep as Chinese.

When performing priming tasks in their second language (i.e., English), native Chinese speakers showed only semantic priming, while native Spanish speakers showed only phonological inhibition. In the repetition blindness study, semantic RB was found in native Chinese speakers yet was absent in native Spanish speakers in the naming task. Although phonological RB was found in both groups in the naming task as well as in the confirmation task, the magnitudes were significantly larger in the native Spanish speakers than in the native Chinese speakers (in the naming task, 26.5% vs. 11.3% for high frequency trials, 17.1% vs. 12.2% for low frequency trials). These results clearly showed that the second language learners carried the distinctive patterns of semantic and phonological activation from their first language reading to their second language reading, demonstrating orthographic transfer.

These findings in second language reading have three important implications. Firstly, the patterns of linguistic activation can be transferred from first language reading to second language reading. How linguistic information is encoded in L1 orthography shapes readers' habits of information decoding. The more reliably the information is encoded, the more readers are accustomed to using it to decode written text and thus facilitate word identification. When reading a second language, this habit is carried over even when the L2 orthography does not encode linguistic information in the same manner as the L1 orthography.

Secondly, the transfer of activation patterns is not limited to phonological information. The activation of semantic information can also be transferred, which is a novel finding. Previous studies repeatedly reported the transfer of phonological and orthographic processing skills from L1 literacy experiences to L2 reading without mentioning semantic processing skills (e.g., Chikamatsu,1996; Wang, Koda, & Perfetti, 2003). The finding of semantic priming and semantic RB in Chinese learners of English showed that semantic information plays a role in reading a second language. Moreover, if the learners are used to relying on semantic information for L1 word recognition, they would bring the reliance to second language reading.

Thirdly, the influence of L1 orthography on the patterns of semantic and phonological activation is deep and long lasting, because these L1 transfer effects were found in advanced second language learners. Some previous studies show that the L1 orthographic transfer effects may diminish (Chikamatsu, 2006; Haynes & Carr, 1990; Miller, 2011) or completely disappear in advanced second language learners (Akamatsu, 2002; Jackson et al., 1999; Lemhöfer et al., 2008), suggesting that as second language proficiency increases, some reading skills can develop to such a high level that the learners do not need to resort to their L1 reading experiences. In this dissertation, however, orthographic transfer was clearly observed in advanced second language learners. This indicates that the patterns of semantic and phonological activation shaped by L1 orthography might not be easily modified for L2 orthography.

5.5 Limitation

The major limitation of this dissertation is that the English primes and targets did not have the same word length, although all the Chinese primes and targets were single-character words. The English phonological primes and targets were all one-syllable words. However, it was very difficult to find English semantic primes that are one-syllable words. In order not to make the semantic primes stand out, the English unrelated primes were not limited to one-syllable words, either. Therefore, the word length of the semantic and unrelated primes in this dissertation was not controlled.

5.6 Future Research Directions

"How is the reading process shaped by the manners in which linguistic information is encoded in orthographies?" is an intriguing research topic worth further exploration. One way to extend the current work is to adopt neuroimaging techniques such as Event Related Potential (ERP) and Functional Magnetic Resonance Imaging (fMRI). ERP will reveal a more precise time course of the activation of semantic and phonological information, while fMRI will manifest whether different brain regions are activated when reading different orthographies.

Another way to extend this present work is to investigate the development of the patterns of semantic and phonological activation in first language reading as well as in second language reading. If the patterns of semantic and phonological activation are indeed shaped by L1 orthography, the patterns are expected to be similar across orthographies in young readers and divergent as L1 reading experiences increase. This investigation will also provide insights in reading universals. It would be very useful to find out whether the influence of L1 orthography on the patterns of semantic and phonological activation in second language reading decreases as the L2 proficiency increases. This will inform us whether the patterns of semantic and phonological activation can be modified to adapt to language specific properties in the orthography of a second language.

APPENDICES

Appendix A – Sample Stimuli for the L1 and L2 Priming Studies[30]

A.1 Simplified Chinese

A.1.1 For naming tasks.

Target Frequency	Target	Prime type	Prime	Sentence for the Prime (only used in the sentence-based paradigm)
high	走	unrelated	脸	他们的脸上见不到一丝倦容。
high	走	semantic	步	新婚伉俪步入北京饭店宴会大厅。
high	走	phonological	抖	小姑娘们颤抖着钻进冰冷的被窝。
low	邸	unrelated	作	在华工作的外国专家逾四万。
low	邸	semantic	舍	错落的农舍在画面中各显风姿。
low	邸	phonological	启	代表团今日启程前往六国进行访问。

A.1.2 For semantic category judgment tasks.

Target Frequency	Target	Semantic Category Judgment Question	Prime type	Prime	Sentence for the Prime (only used in the sentence-based paradigm)
high	比	比是残留物吗?	unrelated	清	乡亲们在清除围墙边缘的杂木蔓草。
high	比	比是残留物吗?	semantic	竞	这幅《鱼跃图》竞价到四万元才成交。
high	比	比是残留物吗?	phonological	理	当事人仍无理纠缠，影响工作秩序。

30 A complete list of the stimuli may be downloaded at http://blogs.bu.edu/hwcheng or be requested by writing to BUreading@gmail.com.

low	酌	酌是用来描述频率的吗?	unrelated	投	乔丹投入了决定胜利的一球。
low	酌	酌是用来描述频率的吗?	semantic	喝	小廖只喝了三杯，人就不行了。
low	酌	酌是用来描述频率的吗?	phonological	挪	他挪用公款，终至锒铛入狱。

A.2 Traditional Chinese

A.2.1 For naming tasks.

Target Frequency	Target	Prime type	Prime	Sentence for the Prime (only used in the sentence-based paradigm)
high	走	unrelated	臉	他們的臉上見不到一絲倦容。
high	走	semantic	步	新婚伉儷步入北京飯店宴會大廳。
high	走	phonological	抖	小姑娘們顫抖著鑽進冰冷的被窩。
low	邸	unrelated	作	在華工作的外國專家逾四萬。
low	邸	semantic	舍	錯落的農舍在畫面中各顯風姿。
low	邸	phonological	啓	代表團今日啓程前往六國進行訪問。

A.2.2 For semantic category judgment tasks.

Target Frequency	Target	Semantic Category Judgment Question	Prime type	Prime	Sentence for the Prime (only used in the sentence-based paradigm)
high	比	比是殘留物嗎?	unrelated	清	鄉親們在清除圍墻邊緣的雜木蔓草。
high	比	比是殘留物嗎?	semantic	競	這幅《魚躍圖》競價到四萬元才成

					交。
high	比	比是殘留物嗎?	phonological	理	當事人仍無理糾纏，影響工作秩序。
low	酌	酌是用來描述頻率的嗎?	unrelated	投	喬丹投入了決定勝利的一球。
low	酌	酌是用來描述頻率的嗎?	semantic	喝	小廖只喝了三杯，人就不行了。
low	酌	酌是用來描述頻率的嗎?	phonological	挪	他挪用公款，終至鋃鐺入獄。

A.3 English

A.3.1 For naming tasks.

Target Frequency	Target	Prime type	Prime	Sentence for the Prime (only used in the sentence-based paradigm)
high	eye	unrelated	daughter	I'm my mother's oldest daughter, so I had a lot of cooking experience with her.
high	eye	semantic	look	Hey, look at what they are doing in the field.
high	eye	phonological	pie	There's also a pie for vegans, starring chopped olives, herbs and cashew.
low	nun	unrelated	kite	A kite flies in much the same way as an airplane does.
low	nun	semantic	church	Weekly church attendance had risen to 46 percent of the population.
low	nun	phonological	one	The suspects are all Americans. One is a man who

				looked after the elderly in Pennsylvania.

A.3.2 For semantic category judgment tasks.

Target Frequency	Target	Semantic Category Judgment Question	Prime type	Prime	Sentence for the Prime (only used in the sentence-based paradigm)
high	case	Is a case a type of container?	unrelated	weather	When weather gets this bad, power systems fail, water lines break.
high	case	Is a case a type of container?	semantic	box	In a smashed box on the floor were several hundred brown eggs.
high	case	Is a case a type of container?	phonological	brace	I will wear a brace and stay away from all of the action.
low	weird	Is weird a part of a transportation network?	unrelated	future	Scientists expect that in the future patients will be tested routinely for a variety of genes.
low	weird	Is weird a part of a transportation network?	semantic	strange	This sounds strange, but I was just happy to have a job.
low	weird	Is weird a part of a transportation network?	phonological	feared	He still feared Duch and was unable to look him in the eye.

Appendix B – Instructions for the L1 and L2 Priming Studies

B.1 Single-word Naming Task

B.1.1 Simplified Chinese.

屏幕上会先出现一个黑字，接着会出现一个红字。请用最快的速度念出红字。念字时声音要大到足够启动计算机的语音接收软件。若是红字没有消失的话，表示您的声音不够大。请将麦克风拿近一点。我们准备了一些练习题让您熟悉这项实验的进行方式。请按下空格键开始练习。

B.1.2 Traditional Chinese.

螢幕上會先出現一個黑字，接著會出現一個紅字。請用最快的速度唸出紅字。唸字時聲音要大到足夠啓動電腦的語音接收軟體。若是紅字沒有消失的話，表示您的聲音不夠大。請將麥克風拿近一點。我們準備了一些練習題讓您熟悉這項實驗的進行方式。請按空白鍵開始練習。

B.1.3 English.

You will see a black word followed by a red word. Your task is to say the red word as quickly as possible. You will need to speak loudly in order to trigger our voice activation software. Note that if the red word does not disappear, it means you did not speak loudly enough. We prepared some examples for you to practice. Please press the space bar to go to the practice session.

B.2 Single-word Semantic Category Judgment Task

B.2.1 Simplified Chinese.

屏幕上会先出现一个字，接着会出现一道问题。请用最快的速度按下键盘上的 YES 键或 NO 键回答问题。为了使答题过程顺利，请现在先找好这两个键的位置。建议您将手指放在这两个键上，以方便答题。我们准备了一些练习题让您熟悉这项实验的进行方式。请按下空格键开始练习。

B.2.2 Simplified Chinese.

螢幕上會先出現一個字，接著會出現一道問題。請用最快的速度按下鍵盤上的 YES 鍵或 NO 鍵回答問題。爲了使答題過程順利，請現在先找好這兩個鍵的位置。建議您將手指放在這兩個鍵上，以方便答題。我們準備了一些練習題讓您熟悉這項實驗的進行方式。請按下空白鍵開始練習。

B.2.3 English.

You will see a single word followed by a question. Please answer the question that appears as quickly as possible by pressing the “yes” key or the “no” key on the keyboard. For the ease of response, please look for the two keys now, and feel free to put your fingers on them during the task. We prepared some examples for you to practice. Please press the space bar to go to the practice session.

B.3 Sentence-based Naming Task

B.3.1 Simplified Chinese.

屏幕上会有一些字闪现，请专心阅读这些字直到红字出现。。忽略这些字会严重影响您的实验结果。一旦红字出现，请用最快的速度念出声。念字时声音要大到足够启动计算机的语音接收软件。若是红字没有消失的话，表示您的声音不够大。请将麦克风拿近一点。我们准备了一些练习题让您熟悉这项实验的进行方式。请按下空格键开始练习。

B.3.2 Traditional Chinese.

螢幕上會有一些字閃現，請專心閱讀這些字直到紅字出現。。忽略這些字會嚴重影響您的實驗結果。一旦紅字出現，請用最快的速度唸出聲。唸字時聲音要大到足夠啓動電腦的語音接收軟體。若是紅字沒有消失的話，表示您的聲音不夠大。請將麥克風拿近一點。我們準備了一些練習題讓您熟悉這項實驗的進行方式。請按下空白鍵開始練習。

B.3.3 English.

You will see a sentence shown one word at a time, please FOCUS CAREFULLY on those words until a red word appears. Ignoring the running words will significantly affect your performance. Once the red word appears, please say it as quickly as possible. You will need to speak loudly in order to trigger our voice activation software. Note that if the red word does not disappear, it means you did not speak loudly enough. Please readjust the position of the microphone in that case. We prepared some examples for you to practice. Please press the space bar to go to the practice session.

B.4 Sentence-based Semantic Category Judgment Task

B.4.1 Simplified Chinese.

屏幕上会有一些字闪现，请专心阅读这些字直到一道问题出现。忽略这些字会严重影响您的实验结果。一旦问题出现，请用最快的速度按下键盘上的 YES 键或 NO 键回答问题。为了使答题过程顺利，请现在先找好这两个键的位置。建议您将手指放在这两个键上，以方便答题。我们准备了一些练习题让您熟悉这项实验的进行方式。请按下空格键开始练习。

B.4.2 Traditional Chinese.

螢幕上會有一些字閃現，請專心閱讀這些字直到一道問題出現。忽略這些字會嚴重影響您的實驗結果。一旦問題出現，請用最快的速度按下鍵盤上的 YES 鍵或 NO 鍵回答問題。為了使答題過程順利，請現在先找好這兩個鍵的位置。建議您將手指放在這兩個鍵上，以方便答題。我們準備了一些練習題讓您熟悉這項實驗的進行方式。請按下空白鍵開始練習。

B.4.3 English.

You will see a sentence shown one word at a time, please FOCUS CAREFULLY on those words until a question appears. Ignoring the running words will significantly affect your performance. Once the question appears, please answer it as quickly as possible by pressing the “yes” key or the “no” key on the keyboard. For the ease of response, please look for the two keys now, and feel free to put your fingers on them during the task. We prepared some examples for you to practice. Please press the space bar to go to the practice session.

Appendix C – Sample Stimuli for the L1 and L2 Repetition Blindness Studies[31]

C.1 Simplified Chinese

C.1.1 Repetition blindness naming task.

Target Frequency	Target	Prime type	Prime	Filler 1	Filler 2
high	红	unrelated	救	瑟	蛙
high	红	semantic	蓝	瞬	蜂
high	红	phonological	虫	瘦	淼
high	红	identical	红	巢	篷
low	奢	unrelated	日	叶	屋
low	奢	semantic	贵	宽	净
low	奢	phonological	遮	刊	忘
low	奢	identical	奢	耐	踏

C.1.2 Repetition blindness confirmation task.

Target Frequency	Target	Prime type	Prime	Filler 1	Filler 2	Confirmation word
high	海	unrelated	贴	塔	驻	海
high	海	semantic	船	腿	致	海
high	海	phonological	凯	鬼	棋	海
low	灶	unrelated	季	皱	晕	灶
low	灶	semantic	厨	瞪	慨	灶
low	灶	phonological	豹	羡	髓	灶

[31] A complete list of the stimuli may be downloaded at http://blogs.bu.edu/hwcheng or be requested by writing to BUreading@gmail.com.

n/a	平	foil	内	此	间	万

C.2 Traditional Chinese

C.2.1 Repetition blindness naming task.

Target Frequency	Target	Prime Type	Prime	Filler 1	Filler 2
high	紅	unrelated	救	瑟	蛙
high	紅	semantic	藍	瞬	蜂
high	紅	phonological	蟲	瘦	淼
high	紅	identical	紅	巢	篷
low	奢	unrelated	日	葉	屋
low	奢	semantic	貴	寬	淨
low	奢	phonological	遮	刊	忘
low	奢	identical	奢	耐	踏

C.2.2 Repetition blindness confirmation task.

Target Frequency	Target	Prime type	Prime	Filler 1	Filler 2	Confirmation word
high	海	unrelated	貼	塔	駐	海
high	海	semantic	船	腿	致	海
high	海	phonological	凱	鬼	棋	海
low	灶	unrelated	季	皺	暈	灶
low	灶	semantic	廚	瞪	慨	灶
low	灶	phonological	豹	羨	髓	灶

n/a	平	foil	內	此	間	萬

C.3 English

C.3.1 Repetition blindness naming task.

Target Frequency	Target	Prime type	Prime	Filler 1	Filler 2
high	clear	unrelated	shape	bomb	dive
high	clear	semantic	unambiguous	breakfast	minority
high	clear	phonological	mere	consensus	thesis
high	clear	identical	clear	tooth	direct
low	beard	unrelated	exciting	tablet	promotion
low	beard	semantic	mustache	diet	enormous
low	beard	phonological	cheered	ignore	powerful
low	beard	identical	beard	provided	significance

C.3.2 Repetition blindness confirmation task.

Target Frequency	Target	Prime type	Prime	Filler 1	Filler 2	Confirmation word
high	night	unrelated	guess	testament	synthesis	night
high	night	semantic	evening	grip	widow	night
high	night	phonological	site	giant	precious	night
low	jail	unrelated	horse	crash	super	jail
low	jail	semantic	prisoner	north	discount	jail
low	jail	phonological	scale	winner	vital	jail

Appendix D – Practice Trials for the L1 and L2 Repetition Blindness Studies

D.1 Simplified Chinese

D.1.1 Repetition blindness naming task.

First block: 136ms

	W1	W2	W3	W4
1	钧	干	帮	邱
2	云	叩	分	稚
3	总	汀	铸	宛
4	通	棒	倩	箱

Second block: 119ms

	W1	W2	W3	W4
1	肥	苗	信	残
2	柔	彬	头	蟹
3	事	淀	帖	斌
4	工	楚	峭	稳

Third block: 102ms

	W1	W2	W3	W4
1	色	丘	色	蠢
2	楼	砂	问	督
3	枣	眷	枣	趟
4	高	零	蚕	武

D.1.2 Repetition blindness confirmation task.

First block: 119ms

	W1	W2	W3	W4	Confirm Word	Correct Answer
1	墙	萤	不	拨	不	Yes
2	的	是	他	到	以	No
3	西	砖	没	兽	没	Yes
4	华	揽	疚	橘	疚	Yes
5	导	发	寨	竹	寨	Yes

Second block: 102ms

	W1	W2	W3	W4	Confirm Word	Correct Answer
1	妈	豆	行	伊	行	Yes
2	诚	岂	两	毯	两	Yes
3	期	掌	雏	纷	雏	Yes
4	议	袱	链	惹	链	Yes
5	家	着	进	全	产	No

Third block: 82ms

	W1	W2	W3	W4	Confirm Word	Correct Answer
1	及	膨	换	涡	换	Yes
2	婆	胶	边	撞	边	Yes
3	市	者	你	政	定	No

4	单	霉	趴	螃	趴	Yes
5	世	靠	徽	忆	徽	Yes

D.2 Traditional Chinese

D.2.1 Repetition blindness naming task.

First block: 136ms

	W1	W2	W3	W4
1	釣	干	幫	邱
2	雲	叩	分	稚
3	總	汀	鑄	宛
4	通	棒	倩	箱

Second block: 119ms

	W1	W2	W3	W4
1	肥	苗	信	殘
2	柔	彬	頭	蟹
3	事	澱	帖	斌
4	工	楚	峭	穩

Third block: 102ms

	W1	W2	W3	W4
1	色	丘	色	蠢
2	樓	砂	問	督
3	棗	眷	棗	趙

4	高	零	蠶	武

D.2.2 Repetition blindness confirmation task.

First block: 119ms

	W1	W2	W3	W4	Confirm Word	Correct Answer
1	牆	螢	不	撥	不	Yes
2	的	是	他	到	以	No
3	西	磚	沒	獸	沒	Yes
4	華	攬	疚	橘	疚	Yes
5	導	發	寨	竹	寨	Yes

Second block: 102ms

	W1	W2	W3	W4	Confirm Word	Correct Answer
1	媽	豆	行	伊	行	Yes
2	誠	豈	兩	毯	兩	Yes
3	期	掌	雛	紛	雛	Yes
4	議	袱	鏈	惹	鏈	Yes
5	家	著	進	全	產	No

Third block: 85ms

	W1	W2	W3	W4	Confirm Word	Correct Answer
1	及	膨	換	渦	換	Yes

2	婆	膠	邊	撞	邊	Yes
3	市	者	你	政	定	No
4	單	黴	趴	螃	趴	Yes
5	世	靠	徽	憶	徽	Yes

D.3 English

D.3.1 Repetition blindness naming task.

First block: 136ms

	W1	W2	W3	W4
1	bakery	loss	sure	model
2	autumn	rise	get	date
3	parent	award	leak	better
4	magic	nature	prone	news

Second block: 119ms

	W1	W2	W3	W4
1	friend	glove	time	wit
2	national	rear	buy	optimistic
3	beach	ancestor	swift	overnight
4	morning	bull	heap	erosion

Third block: 102ms

	W1	W2	W3	W4
1	world	sense	world	black

2	salt	boxing	lie	neatly
3	spy	neither	spy	instrument
4	join	wear	arc	series

D.3.2 Repetition blindness confirmation task.

First block: L1-119ms/L2-136ms

	W1	W2	W3	W4	Confirm Word	Correct Answer
1	quiet	support	full	window	full	Yes
2	money	week	before	room	both	No
3	agree	melt	home	cleaner	home	Yes
4	west	economy	choke	significant	choke	Yes
5	picture	inclusion	sweat	this	sweat	Yes

Second block: L1-102ms/L2-119ms

	W1	W2	W3	W4	Confirm Word	Correct Answer
1	green	explain	old	yesterday	old	Yes
2	mouth	belly	run	fame	run	Yes
3	water	made	mother	after	head	No
4	bridge	gut	trunk	praise	trunk	Yes
5	movie	customer	bin	outside	bin	Yes

Third block: L1-85ms/L2-102ms

	W1	W2	W3	W4	Confirm Word	Correct Answer
1	woman	number	often	how	ever	No
2	pull	mammal	ask	chemist	ask	Yes
3	December	everything	land	relationship	land	Yes
4	garbage	culture	monk	blood	monk	Yes
5	milk	loyal	boast	calendar	boast	Yes

Appendix E – Instructions for the L1 and L2 Repetition Blindness Studies

E.1 Repetition Blindness Naming Task

E.1.1 Simplified Chinese.

你会看到连续几个字快速地闪现。请依照这些字出现的顺序大声读出来。有些字会出现两次。若你看到同一个字出现两次，请说两次这个字。我们准备了几道练习题让您熟悉这项实验的进行方式。请按下空格键开始练习。

E.1.2 Traditional Chinese.

你會看到連續幾個字快速地閃現。請依照這些字出現的順序大聲讀出來。有些字會出現兩次。若你看到同一個字出現兩次，請說兩次這個字。我們準備了幾道練習題讓您熟悉這項實驗的進行方式。請按下空白鍵開始練習。

E.1.3 English.

You will see a series of words displayed at about twice normal reading speed. Please say out loud all the words in the order that you see them. Some words may appear twice. If you see a word twice, please say it twice. We prepared some examples for you to practice. Please press the space bar to go to the practice session.

E.2 Repetition Blindness Confirmation Task

E.2.1 Simplified Chinese.

你会看到连续几个字快速地闪现。接着有一个字停留在屏幕上。请判断这个字是否为快速闪

现字之一。请用最快的速度按下键盘上的 YES 键或 NO 键回答。在回答每道练习题之前，请先告知实验管理员你的答案，再按下键盘作答。请按下空格键开始练习。

E.2.2 Traditional Chinese.

你會看到連續幾個字快速地閃現。接著有一個字停留在螢幕上。請判斷這個字是否爲快速閃現字之一。請用最快的速度按下鍵盤上的 YES 鍵或 NO 鍵回答。在回答每道練習題之前，請先告知實驗管理員你的答案，再按下鍵盤作答。請按下空白鍵開始練習。

E.2.3 English.

You will see a series of words displayed at about twice normal reading speed. Then a single target word will appear and remain on the screen. Your job is to decide whether that target word was in the previously displayed rapid sequence. Please press the “yes” key or the “no” key on the keyboard as quickly as possible to indicate your decision. For practice trials, tell your experimenter your response to each trial before your press the keyboard. Please press the space bar to go to the practice session.

Appendix F – Determining Exposure Duration in the L1 and L2 Repetition Blindness Studies

F.1 Repetition Blindness Naming Task

1. During the 102ms trials, how many repeated words did the participant perceive?

   2 → set the speed setting to 85ms

   1 → set the speed setting to 102ms

   none → did the participant get 7 or 8 words in trial 2 and 4 correctly?

   Yes, 7 words →set the duration at 102ms

   Yes, 8 words → set the duration at 85ms

   No → check the performance in 119ms trials

2. During the 119ms trials, how many words in total did the participant get right?

   More than 14 → set the duration at 102ms

   14→ set the duration at 119ms

   Less than 14 → set the duration at 136ms

3. During the 136ms trials, how many words in total did the participant get right?

   More than 14 → set the duration at 119ms

   14→ set the duration at 136ms

   Less than 14 → set the duration at 153ms

F.2 Repetition Blindness Confirmation Task

F.2.1 For the first language study.

1. During the 85ms trials (the third block), how many trials did the participant get right?

   5 → set the duration at 68ms

   4 → set the duration at 85ms

   3 → check the performance in 102ms trials

2. During the 102 ms trials (the second block), how many trials did the participant get right?

   5 → set the duration at 85ms

   4 → set the duration at 102ms

   3 → check the performance in 119ms trials

3. During the 119 ms trials (the first block), how many trials did the participant get right?

   5 → set the duration at 102ms

   4 → set the duration at 119ms

   3 → set the duration at 136ms

F.2.2 For the second language study.

1. During the 102ms trials (the third block), how many trails did the participant get right?

   5 → set the duration at 85ms

   4 → set the duration at 102ms

3 → check the performance in 119ms trials

2. During the 119ms trials (the second block), how many trails did the participant get right?

    5 → set the duration at 102ms

    4 → set the duration at 119ms

    3 → check the performance in 136ms trials

3. During the 136ms trials (the first block), how many trails did the participant get right?

    5 → set the duration at 119ms

    4 → set the duration at 136ms

    3 → set the duration at 153ms

Appendix G: Online Survey for Native Chinese Speakers and Native Spanish Speakers

Greeting page

Thank you for your interest in participating in my reading research. This study is conducted for my dissertation, and aims to investigate the effect of writing systems on the reading process.

You will first provide some information about yourself and your language/schooling experiences to help me determine if you have the right background for this study. You will then take an English proficiency test that will determine which participant group you will be in for the experiment. If you complete both of these parts, you will be paid $10. We will then contact you about providing payment and the following steps for being in the actual experiment.

If you have any questions about the survey or the experiment, please contact me at hwcheng@bu.edu.

Sincerely,

Hui-wen Cheng

Ph.D. Candidate

Program in Applied Linguistics, Boston University

Contact information

Please provide your contact information, so that I can contact you later for payment and experiment schedule.

1. Full name
2. E-mail address
3. Phone number

Language background and schooling experiences

Please answer the following questions about your language background and schooling experiences.

1. How old are you? 35 or below/above 35
2. Did you start to learn Mandarin Chinese/ Spanish at birth? Yes/No
3. Is Mandarin Chinese/ Spanish your dominant language? Yes/No
4. Did you attend elementary, middle, and high school in Mainland China or Taiwan/ a Spanish speaking country? Yes/No
5. Were the majority of your courses in elementary, middle, and high school taught in Mandarin Chinese/ Spanish? Yes/No
6. Have you ever attended any English-only school for your elementary, middle, or high school education? Yes/No
7. Is either of your parents or grandparents a native English speaker? Yes/No

8. Did you frequently talk to one or more of your family members in English before you came to the States? Yes/No

9. When did you come to the United States for your current stay?

   Before graduating from high school

   After graduating from high school

10. What scores did you get for TOEFL or IELTS last time?

    Below 550 (paper-based TOEFL)/ 213 (CBT)/ 79(iBT)/ 6.5 (IELTS)

    550 (paper-based TOEFL)/ 213 (CBT)/ 79(iBT)/ 6.5 (IELTS) or above

Appendix H: Language Background Questionnaire

Please provide us your personal and language background information by answering the following questions. We will only use your information for statistical analysis.

Personal information

1. Participant ID
2. E-mail address
3. Phone number
4. Age
5. Sex Male/Female
6. Nationality (e.g., US, Taiwan, Mexico)

Language background

7. How many languages have you learned?
8. Please write down all the languages that you have learned in order of reading proficiency level (most proficient language comes first), and indicate the proficiency level for each language in parentheses.
9. What is/are your native language(s)?

English learning experience

10. At what age did you start to learn English?

11. At what age did you come to the United States for your current stay?

English proficiency

12. In what year did you take TOEFL or IELTS last time?

13. Did you take TOEFL or IELTS?

14. For the TOEFL, please specify whether it was a paper-based test, CBT, or iBT.

Please report your latest TOEFL or IELTS scores.

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CURRICULUM VITAE

HUI-WEN CHENG
Program in Applied Linguistics, Boston University
96 Cummington Street, Room 246
Boston, Massachusetts 02215
USA

EDUCATION

Doctor of Philosophy
Program in Applied Linguistics, Boston University, USA, May 2012.
Dissertation: Semantic and Phonological Activation in First and Second Language Reading

Master of Arts
Graduate Institute of Linguistics, National Chengchi University, Taiwan, July 2004.
Thesis: The Syntax and Semantics of Post-verbal "*Diao*"

Bachelor of Arts
Department of English, National Central University, Taiwan, June 1999.

RESEARCH INTERESTS

Psycholinguistics

Chinese reading, the representation and processing of words and phrases

Second language acquisition

L2 mental lexicon, language and orthographic transfer

HONOR and AWARDS

2011. Linguistic Society of America Summer Institute Fellowship.
2010. Boston University Graduate Student Organization Travel Grant.
2009; 2010. Taiwan Ministry of Education Travel Grant.
2007; 2009; 2010, 2011, 2012. Program in Applied Linguistics (at Boston University) Travel Grant.
2005~2012. Boston University GSU scholarship.
2001~2002. Graduate Institute of Linguistics (at National Chengchi University) Travel Grant.
1999. Member of the Phi Tau Phi Scholastic Honor Society of the Republic of China.

GRANTS

2010/05-2012/04. National Science Foundation Linguistics Doctoral Dissertation Research Improvement Grant. Semantic and phonological activation in first and second language reading. (Advisor: Dr. Catherine Caldwell-Harris).

2007/07~2008/06. Chiang Ching-kuo Foundation for International Scholarly Exchange. Advantages and disadvantages of processing simplified and traditional Chinese scripts. (Co-Investigator with PI: Dr. Catherine Caldwell-Harris).

1998/11~1999/06. National Science Council Undergraduate Research Grant (in Taiwan). The politeness of the entertainers in TV shows: The usage of titles. (Advisor: Dr. Jen-i Li).

PUBLICATIONS

(a) Conference Proceedings

Hui-wen Cheng and Catherine Caldwell-Harris. To appear. Orthography shapes semantic and phonological activation in reading. Proceedings of the 36th Annual Meeting of the Berkeley Linguistics Society. University of California, Berkeley, USA.

Hui-wen Cheng and Catherine Caldwell-Harris. To appear. The representation of polysemy in the monolingual and bilingual mental lexicon. Proceedings of the 30th Annual Winter Applied Linguistics Conference. Columbia University, USA.

Hui-wen Cheng. 2002. A study of complement diao. Proceedings of the 2002 National Conference on Linguistics. Providence University, Taiwan.

Hui-wen Cheng. 2001. The subordinates' usage of address toward the superiors in Chinese. In S. Burusphat (Ed.), Papers from the Eleventh Annual Meeting of the Southeast Asian Linguistics Society, Tempe, Arizona, (pp. 121-136). Arizona State University, Program for Southeast Asian Studies.

(b) Book Review

Hui-wen Cheng. 2012. (Book Review for) K. Koda and A. M. Zehler (Eds.): Learning to read across languages: cross-linguistic relationships in first- and second-language literacy development. Routledge, London, 2008. Reading and Writing: An Interdisciplinary Journal, 25 (2), 611-617.

(c) Others

Hui-wen Cheng and Catherine Caldwell-Harris. Under review. When semantics overrides phonology: Semantic substitution during oral Chinese reading. Journal of Experimental Psychology: General.

Hui-wen Cheng and Catherine Caldwell-Harris. In preparation. Reading Chinese simplified and traditional scripts.

Hui-wen Cheng. 2004. The syntax and semantics of post-verbal diao. Unpublished Master's thesis.

CONFERENCE PRESENTATIONS

Hui-wen Cheng and Catherine Caldwell-Harris. 2012. Phonological activation in Chinese reading: A repetition blindness study. Paper presented at the 86th Annual Meeting of the Linguistic Society of America. Portland, USA.

Hui-wen Cheng and Catherine Caldwell-Harris. 2011. When semantics overrides phonology: Semantic substitution errors in reading Chinese aloud. Paper presented at the 85th Annual Meeting of the Linguistic Society of America. Pittsburgh, USA. The abstract was designated as media-worthy.

Hui-wen Cheng and Catherine Caldwell-Harris. 2010. The representation of polysemy in L1 and L2 mental lexicon. Paper presented at the 7th International Conference on the Mental Lexicon. University of Windsor, Canada.

Hui-wen Cheng and Catherine Caldwell-Harris. 2010. Orthography shapes semantic and phonological activation in reading. Paper presented at the 36th Annual Meeting of the Berkeley Linguistics Society. University of California, Berkeley, USA.

Hui-wen Cheng, Jen-i Li, Hua Shu, Su-Ling Yeh, and Catherine Caldwell-Harris. 2009. Simplified and traditional scripts confer different advantages in reading. Paper presented at the 21st North American Conference on Chinese Linguistics. Bryant University, USA.

Hui-wen Cheng and Catherine Caldwell-Harris. 2009. The representation of polysemy in the monolingual and bilingual mental lexicon. Paper presented at the 30th Annual Winter Applied Linguistics Conference. Columbia University, USA.

Hui-wen Cheng. 2007. A study of post-verbal diao in Mandarin Chinese. Paper presented at the 15th Annual Conference of the International Association of Chinese Linguistics & the 19th North American Conference on Chinese Linguistics Joint Meeting. Columbia University, USA.

Hui-wen Cheng. 2004. The comprehension of L2 figurative language: A contrastive study of Chinese and English. Paper presented at the 2004 International Language and Cognition Conference. Coffs Harbour, Australia.

Hui-wen Cheng. 2002. A study of complement diao. Paper presented at the 2002 National Conference on Linguistics. Providence University, Taiwan.

Hui-wen Cheng. 2002. Chinese children's use of the mutual exclusivity constraint. Paper presented at the 47th Annual Conference of the International Linguistic Association. York University, Canada.

Hui-wen Cheng. 2001. The subordinates' usage of address toward the superiors in Chinese. Paper presented at the 11th Annual Meeting of the Southeast Asian Linguistics Society. Bangkok, Thailand.

Hui-wen Cheng. 1999. The politeness of the entertainers in TV shows: The usage of titles. Paper presented at the 8th Annual Conference of International Association of Chinese Linguistics. Melbourne, Australia.

POSTER PRESENTATIONS

Catherine Caldwell-Harris, Hui-wen Cheng, Tingyan Li, and Alison Morris. 2011. Testing the "activation reflects encoding transparency" principle in writing systems using repetition blindness. Paper presented at the 33rd Annual Meeting of the Cognitive Science Society. Boston, USA.

Hui-wen Cheng, Hua Shu, Su-Ling Yeh, Jen-i Li, and Catherine Caldwell-Harris. 2010. Reading Chinese simplified and traditional scripts. Paper presented at the Research in Reading Chinese and Related Asian Languages Conference. University of Toronto, Canada.

Hui-wen Cheng, Su-Ling Yeh, Jen-i Li, Hua Shu, and Catherine Caldwell-Harris. 2009. Readers of different Chinese scripts use different strategies to recognize Chinese characters. Paper presented at the 13th International Conference on Cognitive and Neural Systems. Boston University, USA.

INVITED TALKS

April, 2011. The effect of script on reading: A study of Chinese simplified and traditional scripts. Literacy and Language Program, Graduate School of Education at Harvard University. Cambridge, MA, USA.

May, 2009. The processing of Chinese simplified and traditional scripts: A psycholinguistic study. The 36th Annual Conference of the Association of Chinese Schools. Boston, MA, USA.

TEACHING EXPERIENCE

2007/10~present. Supervising more than 20 undergraduate and Master's students at the Psycholinguistics Lab, Boston University.

2006/09~2006/12. Grader, Introduction to Language and Linguistics, Boston University.

2005/03~2005/07. Adjunct lecturer, Freshman English, Chungguo Institute of Technology, Taiwan.

2001/09~2005/06. Private tutor, Elementary School English, Junior High School English, and Senior High School English, Taiwan.

2002/07~2002/08. Teaching assistant, English Writing, Teacher In-service Education Center, National Chengchi University, Taiwan.

1999/07~2000/06. Intern teacher, Junior High School English and Senior High School English, St. Francis Xavier High School, Taiwan.

ACADEMIC SERVICE

2010/09~2012/05. Organizer, Research Sharing Forum, Program in Applied Linguistics, Boston University.

2012/01. Volunteer, the 86th Annual Meeting of the Linguistic Society of America.

2005/11~2011/11. Volunteer, Boston University Conference on Language Development (BUCLD).

2011/01. Volunteer, the 85th Annual Meeting of the Linguistic Society of America.

2006/03~2007/02. Financial chair, the 31st Boston University Conference on Language Development.

WORKING EXPERIENCE

(a) Linguistics Related Jobs

2006/12~present. Chinese annotator lead, BBN Technologies, Cambridge, MA, USA.

2000/09~2002/07. Research assistant, Grammaticalization of body-part terms in Mandarin, PI: Dr. Jen-i Li, funded by National Science Council (of Taiwan).

(b) Other Jobs

2009/09~present. Program assistant, Program in Applied Linguistics, Boston University.

2006/09~2010/01. Librarian, Applied Linguistics Program Library, Boston University.

2000/09~2003/08. Administration assistant, Graduate Institute of Linguistics, National Chengchi University, Taiwan.

CERTIFICATION

The High School English Teacher Certificate, issued by the Ministry of Education, Taiwan.