Different Phonographic L1 Effects in Processing L2 Chinese Characters: The Role of Phonology and Orthography in Lexical Entry

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DIFFERENT PHONOGRAPHIC L1 EFFECTS IN PROCESSING L2 CHINESE CHARACTERS: THE ROLE OF PHONOLOGY AND ORTHOGRAPHY IN LEXICAL ENTRY

A Dissertation presented in partial fulfillment of requirements for the degree of Doctor of Philosophy in the Department of Modern Languages The University of Mississippi

by

SHUANG CHENG

August 2023
ABSTRACT

Orthography-phonology mapping in world languages exhibits variations. Extensive research has investigated whether orthographic-phonological consistency impacts the cognitive processing of written words. A major body of work has focused on the recognition of phonographic first language (L1) written words. Results show that the more transparent the orthography, the more reliance on phonological processing, and vice versa (Katz & Frost, 1992). Another body of work has paid attention to the cognitive process of identifying Chinese characters because of their logographic nature. These studies have mostly focused on recognizing L1 Chinese words (including both simplified and traditional written words) (Perfetti & Zhang, 1995; Wong, Wu & Chen, 2014). However, both lines of research do not clarify whether the orthographic transparency of phonographic writing systems impacts the recognition of logographic L2 words. This study aims to address this gap by investigating how beginner Chinese learners, whose native writing systems were phonographic but with varying phonological-orthographic consistencies, process Chinese as a second language (L2) written words. Through online training sessions and a lexical decision task of beginner Chinese learners whose L1 writing systems have various levels of transparency (i.e., English, Arabic, and Italian), it investigated whether learners with different phonographic L1s were capable of processing Chinese characters orthographically, and the influences of different L1 phonological-orthographic consistencies on their processing patterns on recognizing L2 Chinese printed words. The results showed that all participants, regardless of their L1 orthographic transparency, used
both orthographic and phonological processing paths, but with different levels. They also showed that L1 orthographic transparency impacted the recognition of L2 Chinese written words. These findings have implications for L2 learning and pedagogy, suggesting that L1 orthographic transparency should be considered in learning or teaching L2 Chinese characters. It also indicates the need for further research on the impact of L1 orthographic transparency on the recognition of L2 logographic written words.
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>L1</td>
<td>First language</td>
</tr>
<tr>
<td>L2</td>
<td>Second language</td>
</tr>
<tr>
<td>ODH</td>
<td>Orthographic Depth Hypothesis</td>
</tr>
<tr>
<td>UDH</td>
<td>Universal Direct Access Hypothesis</td>
</tr>
<tr>
<td>UPP</td>
<td>Universal Phonological Principle</td>
</tr>
<tr>
<td>RT</td>
<td>Reaction time</td>
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ACKNOWLEDGMENTS

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TABLE OF CONTENTS

ABSTRACT ............................................................................................................................................ ii

LIST OF ABBREVIATIONS AND SYMBOLS .................................................................................. iv

ACKNOWLEDGMENTS ....................................................................................................................... v

LIST OF TABLES .................................................................................................................................. x

LIST OF FIGURES ............................................................................................................................. xi

LIST OF CHARTS ............................................................................................................................... xii

CHAPTER 1: INTRODUCTION ........................................................................................................... 1

  Background: Writing Systems, Word Decoding, and Word Recognition .................................... 1

  Exploring Orthographic Depth/Transparency: Examples from Chinese, English, Italian, and
  Arabic Writing Scripts ..................................................................................................................... 3

  Objectives of the current study ....................................................................................................... 6

CHAPTER 2: LITERATURE REVIEW .................................................................................................. 9

  Processing Patterns in L1 Written Word Recognition ................................................................. 9

  Hypotheses in L1 Written Word Recognition ................................................................................ 9

  Written Word Recognition for Chinese L1 Readers ................................................................. 12

  Phonological Activation and Facilitation in Chinese Word Recognition ................................ 13

  Chinese Character Features and L1 Word Recognition .......................................................... 18

  Contexts, Young Readers in Chinese L1 Word Recognition .................................................. 21

  Conclusion: Chinese Written Word Recognition by L1 Readers ........................................... 23
Written Word Recognition for L2 Readers: Cross-Orthographic Processing .................... 24
Cross-orthographic Reading: ESL Learners with Phonographic L1 Writing Systems ..... 25
Cross-orthographic Reading: ESL Learners with Logographic L1 Writing Systems .... 27
Cross-orthographic Reading: Japanese L2 Learners ............................................. 31
Cross-orthographic Reading: Chinese L2 Learners ............................................. 35
Conclusion: cross-orthographic word recognition ................................................. 40
Gaps and Research Questions ............................................................................... 41

CHAPTER 3: METHODOLOGY ............................................................................. 45
Participants ........................................................................................................... 45
Methods ................................................................................................................ 47
Survey .................................................................................................................... 47
Training Phase ...................................................................................................... 48
Testing Phase: Lexical decision Task ................................................................. 51
Stimuli ..................................................................................................................... 53
Testing materials .................................................................................................. 53
Training materials ................................................................................................ 56
Procedure .............................................................................................................. 57
Data Analysis ....................................................................................................... 58

CHAPTER 4: RESULTS ..................................................................................... 60
Accuracy ............................................................................................................... 60
Latency (Reaction Time)................................................................................................................. 64

CHAPTER 5: DISCUSSION................................................................................................................... 69
Orthographic Effects were Found in Processing Written Chinese Characters by all Participants,
the Beginner Learners with Varied Phonographic L1s ................................................................. 70
Differential Effects of Orthographic and Phonological Distractions on Chinese Character
Recognition Across Three Language Groups .................................................................................. 73
Highlights from the Present Study .................................................................................................... 75
Implications........................................................................................................................................ 81
Limitations and Recommendations for the Future Study ................................................................. 83
Conclusion........................................................................................................................................ 86
BIBLIOGRAPHY ................................................................................................................................. 89
APPENDICES...................................................................................................................................... 101
APPENDIX I: TRAINING MATERIALS .............................................................................................. 102
APPENDIX II: STIMULI USED IN THE LEXICAL DECISION TASK ............................................. 103
APPENDIX III: SURVEY ..................................................................................................................... 106
APPENDIX IV: SAMPLE OF TESTING QUESTIONS (GROUP 1) ...................................................... 108
APPENDIX V: SAMPLE OF TRAINING INTERFACE ........................................................................ 115
VITA.................................................................................................................................................... 118
LIST OF TABLES

1. Demographic Information of Participants................................................................. 46
2. Character Stimuli Used in the Experiment............................................................... 55
3. Means and Standard Deviations on Accuracy of Three Language Groups ................. 61
4. Pairwise Comparisons Between Four Answer Types in Three Language Groups (Accuracy).
   ............................................................................................................................. 63
5. Means and Standard Deviations on RT (in milliseconds) of Three Language groups....... 65
6. Pairwise Comparisons Between Four Answer Types in Three Language Groups (RT) ..... 66
7. Training materials ....................................................................................................... 101
8. Stimuli Used in the Lexical Decision Task.................................................................... 102
LIST OF FIGURES

1. Training Paradigms ........................................................................................................................................... 51

2. The Paradigm of Each Trial in the Experiment.................................................................................................. 53
LIST OF CHARTS

1. The Estimated Marginal Means of Accuracy Between Three Language Groups .................. 62
2. The Estimated Marginal Means of Reaction Time Between Three Language Groups .......... 66
CHAPTER 1
INTRODUCTION

1.1 Background: Writing Systems, Word Decoding, and Word Recognition

Writing scripts of world languages vary fundamentally in their visual forms. Based on the connection between their written forms and sounds/meanings, writing systems are typically divided into phonographic and logographic (or morphographic) systems (Dawson & Phelan, 2016; Grabe, 1991). Writing systems that use symbols to represent the sounds of language are considered phonographic, such as English, Russian, Korean, and Arabic, despite the use of different alphabets (e.g., Roman, Cyrillic, Hangul, abjad, etc.). Logographic writing systems, on the other hand, assign each symbol to a specific meaning of a morpheme or word, such as the ancient Egyptian hieroglyphic writing, the Mayan glyphs, and the Chinese characters.

The dramatic differences among writing scripts of world languages lie not only in their visual forms but also in different ways of orthography-phonology mapping. Word decoding, which involves identifying phonological information from visual words, is a crucial skill for reading (Hamada & Koda, 2010). According to Perfetti & Liu (2005), the initial step in learning to read is connecting sounds with graphemes through grapheme-phoneme decoding, which is universal across languages (Commissaire, Duncan & Casalis, 2011; Koda, 2007; Perfetti & Zhang, 1995). However, how these two elements are encoded is language specific, depending on the features of languages (Koda, 2005, 2007).
There are various methods of orthography-phonology correspondence within phonographic writing systems. In alphabetic writing systems (e.g., English, Russian, Korean), each written symbol represents a single sound - either vowel or consonant (e.g., English word, think [θɪŋk]); In syllabic writing systems (e.g., Japanese kana system), each symbol represents a syllable (e.g., こ れ [kore]); In abjads (e.g., Arabic, Persian), each symbol represents only consonants (e.g., Arabic word อำเภอ [fkr], [fakara]). Furthermore, the level of consistency between orthography-phonology mapping varies across languages and their respective writing systems. Some languages (e.g., Greek, Spanish) demonstrate a direct one-to-one correspondence between graphemes and phonemes, or with consistent spelling rules (i.e., Italian, German). In contrast, other languages (e.g., English, French) show a less direct grapheme-phoneme relationship. Their orthographies do not strictly represent the phonology on a one-to-one basis, and the connection between sounds and letters can be inconsistent. The orthography of the former group of languages is referred to as “shallow” or “transparent”, whereas the orthography of the latter is considered as “deep” or “untransparent” (Dawson & Phelan, 2016; Katz & Frost, 1992; Nassaji, 2014).

In contrast, orthography-phonology mapping appears more obscure in logographic writing systems. It has been traditionally believed that logographic scripts evolved from earlier pictographic systems that did not convey phonological information at all (Dawson & Phelan, 2016). In fact, in the later stages of development, a significant portion of logographs came to represent sounds, as is the case with ancient Egyptian hieroglyphs and Chinese characters (Dawson & Phelan, 2016; Katz & Frost, 1992). For example, the traditional Chinese character 馬 (simplified version 马) represents a word meaning “horse,” but it does not explicitly contain its syllabic sound ([ma3], the number 3 refers to the tone of the character) in the written symbol.
Different from orthographic-phonological decoding, word recognition (also referred to as word identification) is a more complicated process that includes many subcomponent processes such as recognizing and analyzing visual symbols, identifying letters or morphemes, decoding orthographic-phonological mapping, and eventually accessing lexical meanings (Grabe, 1991; Nassaji, 2014). Phonological processing and orthographic processing are two critical subcomponents of word recognition. Phonological processing refers to the process by which readers access word meanings by decoding the visual forms, primarily through manipulating phonological information or utilizing knowledge of sound structures. Conversely, orthographic processing pertains to the direct access of word meanings by readers, primarily through utilizing visual orthographic information. How these two components develop and interact has been considered fundamental in accurate and efficient word recognition (Grabe, 1991; Nassaji, 2014; Van Orden, 1987). Overall, there have been arguments for three different processing routes in word recognition, including (1) the phonological path, or phonological dominant and visual subsidiary route (Luo, Johnson, & Gallo, 1998; Perfetti & Tan, 1998; Tan & Perfetti, 1997; Van Orden, 1987), (2) the direct visual-to-semantic access (Akamatsu, 2002; Seidenberg, 1992; Wong, et al., 2014; Zhou & Marslen-Wilson, 1999, 2000), and (3) the dual-route, in which visual and phonological information was activated in parallel and both access semantic retrieval (Leck, Weekes & Chen, 1995; Xu, Pollatsek & Potter, 1999).

1.2 Exploring Orthographic Depth/Transparency: Examples from Chinese, English, Italian, and Arabic Writing Scripts

As previously introduced, writing systems can be categorized into phonographic systems, encompassing alphabetic, syllabic, and abjad systems, and logographic systems. Furthermore,
based on the degree of consistency in mapping between orthography and phonology, there are transparent (or shallow) and untransparent (or deep) orthographies. The current study takes English, Italian, Arabic, and Chinese writing systems as examples, to illustrate the characteristics of these orthographic types and depths.

The writing systems of English, Italian, and Arabic are all classified as phonographic. English and Italian are alphabetic systems, in which a written symbol corresponds to each sound, either a vowel or a consonant (e.g., *think* [θɪŋk]; *pensare* [peŋˈsare]). In contrast, the Arabic writing system is an abjad, where each symbol represents only a consonant or long vowel sound (e.g., ❮k❯ (fkr), [fakara]) in standard written forms. Moreover, apart from its inconsistency in grapheme-phoneme correspondence, the Arabic writing system is also featured with polyphony (where a single unit of written symbol may represent multiple pronunciations, Arab & Sénéchal, 2001). For instance, the sequence /ʕlm/ could be pronounced as /ʕilm/ meaning 'science,' or as [ʕaląm] meaning 'flag,' or even as [ʕalima] meaning 'he knew' (Boumaraf & Macoir, 2016).

These complex features lower the transparency of the Arabic writing system compared to alphabetic systems (e.g., English and Italian) (Boumaraf & Macoir, 2016; Katz & Frost, 1992; Juhani, 2015).

However, even within alphabetic writing systems, the orthographic depth varies between languages, such as English and Italian. Italian has a one-to-one correspondence between graphemes and phonemes (e.g., *pensare* [peŋˈsare]) and it maintains consistent spelling-to-sound connections (e.g., *gn* = [ɲ], *gl* = [ʎ], *schi* = [ski], *sci* = [ʃi]). Consequently, the Italian writing system is considered shallow or transparent. In contrast, the English writing system demonstrates a less direct one-to-one grapheme-phoneme mapping (e.g., *th* [θ]), and it also presents inconsistent sound-letter correspondence (e.g., *que* is pronounced as [k] in *critique* and as [kwe]...
in question). These characteristics render English orthography deeper or less transparent in comparison to Italian (Arab-Moghaddam & Sénéchal, 2001; Bates, Burani, D’Amico, & Barca, 2001; Dawson & Phelan, 2016; Ellis & Hooper, 2001; Katz & Frost, 1992).

Chinese characters are logographic, and each character connects directly to a syllable in speech. It seems that there is no direct link between components within a character and its sound or tone (Chen, 2019; Yum, et al., 2016), as illustrated by the character 马 ([ma3], horse). However, approximately 80%-90% of Chinese characters are phonograms (Dawson & Phelan, 2016; Katz & Frost, 1992; Wang, 2014), which contain both phonetic and semantic components. For example, the characters 妈 ([ma1], mother), 骂 ([ma4], to scold), 玛 ([ma3], jade/agate), and 码 ([ma3], number/code), share the same phonetic component 马 [ma3] and thus are pronounced very closely ([ma]). Meanwhile, their semantic components (i.e., 女, 口, 王, 石) denote different meanings of these characters. Yet, in most cases, semantic components do not indicate accurate meanings (e.g., the semantic component 石 meaning stone in the character 码 [ma3] has nothing to do with the meaning of the latter - number or code), and also, phonetic components no longer represent sounds nor are they pronounced identically with characters (Chen, Wang & Peng, 2006; Wang, 2014). According to Law, Weekes, Wong, & Chiu’s (2009) study, only 34–40 % of phonograms are pronounced segmentally identical to their phonetic components, and around 30 % of phonograms and their phonetic components are partially identical (i.e., share the same rimes).

In addition, the inconsistency of orthography-phonology mapping in the Chinese writing system is also reflected in the existence of massive homophones, which could be orthographically different (e.g., 大, 打, 答, 忍, 勖, 暗, 裳, 聊, all pronounced as [ta]) and a large
number of homographs which are orthographically similar but dramatically differ in sounds (e.g., 红 [hɔŋ], 江 [ɣian], 抗 [kaŋ]) (Koda, 2007; Perfetti & Tan, 1995; Wong et al., 2014). These inconsistent features of orthographic-phonologic mapping of Chinese characters increase complexities in direct visual-sound decoding for readers (Chen, Wang & Peng, 2006; Zhang & Wang, 2010).

In conclusion, for beginner learners of L2 Chinese, the logographic writing system, lacking direct orthography-phonology connections, alongside the irregular spelling-to-sound correspondence, renders the Chinese written forms deeper or less transparent orthographies in comparison to Arabic, English, and Italian.

1.3 Objectives of the current study

Various types of orthography-phonology correspondence of writing systems of world languages suggest varying processing patterns in the recognition of written scripts. According to the Orthographic Depth Hypothesis (ODH) theory, readers of shallow orthographies are more likely to rely on phonological processing when reading printed words, whereas readers of deep orthographies tend to rely more on the orthographic processing path to recognize written words (Katz & Frost, 1992). It's worth noting that the ODH theory is based on L1 phonographic orthographies and has been supported by numerous empirical studies that focus on phonographic L1 writing systems (e.g., English, Italian, Arabic, etc.) (Arab-Moghaddam & Sénéchal, 2001; Aro & Wimmer, 2003; Boumaraf & Macoir, 2016; Russak & Fragman, 2014). Therefore, it is worth exploring whether the ODH theory applies to the recognition of L2 written words. Specifically, whether and to what extent readers with different L1 orthographic transparency
levels demonstrate varying degrees of reliance on phonological or orthographic information when processing L2 words.

Meanwhile, the cognitive processing of the Chinese written word (i.e., character) has attracted researchers’ attention due to its logographic nature. Similar to the studies focusing on phonographic writing systems, this research has mostly focused on recognizing L1 Chinese characters. Its findings have shown that L1 Chinese speakers predominantly rely on orthographic processing accompanied by phonological processing, depending on various conditions such as tasks, types of characters, frequency, and developmental stages (Chen & Shu, 2001; Ren, Han & Liu, 2012; Zhou & Marslen-Wilson, 1999).

However, there are a limited number of studies focusing on L2 Chinese written word recognition, which mainly emphasize the different effects between logographic L1 readers (e.g., Japanese) and phonographic L1 readers (e.g., English), with the former predominantly relying on orthographic processing and the latter mainly on phonological processing (Jiang, 2003; Zhang & Wang, 2010). It remains unclear whether phonographic L1s with varying degrees of orthographic transparency impact L2 Chinese written word recognition. Furthermore, previous studies have mainly selected subjects from a limited number of L1 writing systems, such as English, Japanese, Korean, Indonesian, and Spanish (Wang, 2014; Zhang & Wang, 2010).

This study aims to explore how beginner Chinese learners, whose native writing systems are phonographic but have different levels of phonological-orthographic consistency, process L2 Chinese written words. Two research questions are expected to be addressed: first, whether beginner Chinese learners whose L1 writing systems are English, Arabic, and Italian (representing three different levels of orthographic transparency) can process Chinese characters orthographically, and second, to what extent the different phonological-orthographic
consistencies of their L1 writing systems influence their processing patterns in identifying L2 Chinese printed words.

The research employed a behavioral study design, which involved a six-session training phase followed by a computer-based Lexical Decision Task. Participants with native languages in English, Italian, and Arabic were recruited from two universities in the US and Italy. During the main task of the experiment, the lexical decision task, four types of answers were provided, including a target character, an orthographic distractor, a phonological distractor, and a control character. The reaction time and accuracy rates of participants in responding to the questions were recorded and analyzed. The results showed that beginner Chinese learners whose phonographic L1 writing systems had varying orthographic-phonological consistency could process Chinese characters orthographically. Furthermore, learners’ L1 orthographic transparency impacted the recognition of L2 Chinese written words.
CHAPTER 2
LITERATURE REVIEW

2.1 Processing Patterns in L1 Written Word Recognition

2.1.1 Hypotheses in L1 Written Word Recognition

The majority of previous studies that investigated written word recognition have primarily focused on identifying L1 orthographies, particularly in phonographic L1 orthographies (Nassaji, 2014). Three hypotheses have been proposed to address the question of how readers process their native orthographies: the universal direct access hypothesis (UDH, Seidenberg, 1992), the universal phonological principle (UPP, Perfetti & Zhang, 1995; Tan & Perfetti, 1997), and the Orthographic Depth Hypothesis (ODH, Katz & Frost, 1992). According to the UDH, the direct orthographic-to-meaning route is efficient in processing both shallow and deep orthographies, and the role of the phonological route is conditional, depending on individual habits or word frequencies. This has been supported by Akamatsu's (2002) study, which compared the accuracy and latency of word recognition among ESL learners with different L1 writing systems (i.e., Chinese, Japanese, and Persian), and found no fundamental differences in processing high-frequency English words between the three groups, despite their typologically different native orthographies. However, focusing on visual word recognition of phonographic orthographies (e.g., English, Arabic), many studies found that phonological information is automatically activated rather than being conditional or supplementary in recognizing visual words (Bentin & Ibrahim, 1996; Luo et al, 1998; Van Orden, 1987), which rejects the UDH.
On the contrary, the UPP posits that phonological information is primarily activated in recognizing all visual words, including those in orthographically deep or opaque forms (i.e., logographic writing systems such as Chinese characters and Japanese kanji). Several behavioral studies have investigated participants' reactions to primed words/characters and found that phonological processing plays a significant role in predicting visual word recognition in logographic writing systems (Chikamatsu, 2006; Grainger et al., 2006; Hamada & Koda, 2010; Matsumoto, 2013; Perfetti & Tan, 1998; Perfetti, Liu & Tan, 2005; Perfetti & Zhang, 1995; Wong, Wu & Chen, 2014; Wu & Ma, 2017). However, many other studies focusing on the recognition of Chinese characters, have disputed the UPP and found that orthographic information plays a predominant role in retrieving word meanings (Chen & Shu, 2001; Wong, Wu & Chen, 2014; Zhou & Marslen-Wilson, 1999, 2000).

The ODH proposed that the depth of orthographies affects the processing routes used by readers. In shallow, or transparent, orthographies, readers rely more on phonological processing to access lexical entries, whereas in deep, or opaque, orthographies, readers rely more on orthographic routes to access word meanings as holistic visual symbols (Grabe, 1991; Katz & Frost, 1992). More specifically, the ODH posits that both phonological and visual-orthographic processes played a role in recognizing written words. The extent to which each of these processes are activated depends on the levels of orthographic transparency. Empirical studies have supported the ODH, particularly in alphabetic L1 reading (Landerl, Wimmer & Firth, 1997; Paulesu, McCrory, Fazio, Menoncello, Brunswick, Cappa, Cotelli, Cossu, Corte, Lorusso, & Pesenti, Gallagher, Perani, Price, Frith, & Frith, 2000; Rau, Moll, Moeller, Huber, Snowling & Landerl, 2016; Zeguers, van den Boer, Snellings, & de Jong, 2018). For instance, the study by Paulesu, et al. (2000) utilized brain imaging techniques to investigate the processing of printed
words among Italian and English native speakers. They found that when Italian children recognized L1 written words, the activated areas of their brains were associated with phonological processing. Conversely, English native readers demonstrated activation in brain regions linked to semantic or orthographic processing. Aro and Wimmer (2003) compared the reading performance of native speakers of various European languages in numeral reading, number word reading, and pseudoword reading tasks, and found that English children, by the end of first Grade, had lower accuracy rates in reading pseudowords compared to their peers whose native orthographies were more transparent than English (e.g., Dutch, Swedish, Spanish, and Finnish, etc.). The underperformance of English children was attributed to the difficulty of phonological decoding due to its more complex and opaque orthography. Landerl, et al. (1997) and Rau, et al. (2016) also found that English speakers were slower in reading speed and made more errors compared to German speakers due to differences in orthographic transparency. These empirical studies provide substantial evidence that the degree of orthographic transparency impacts the pattern and efficiency of processing written words, especially among L1 readers of alphabetic orthographies.

Additionally, written word recognition in L1 abjad orthographies (e.g., Arabic, Hebrew, Persian) also echoes the ODH theory. Abjad orthography, being a phonographic system, possesses unique features such as vowel omission, connectedness between consonants, non-linear agglutination of morphemes, variations in the shape of each letter, and gaps between oral language and written scripts (Katz & Frost, 1992; Juhani, 2015), which contribute to the orthography's deep and opaque nature. Studies have shown that native Arabic speakers spend a longer time processing written words than some alphabetic L1 readers (e.g., English, Serbo-Croatian) in reading their L1 scripts respectively (Russak, & Fragman, 2014). Both Arabic
(Boumaraf & Macoir, 2016) and Persian (Arab-Moghaddam & Sénéchal, 2001) native speakers rely heavily on orthographic processing when recognizing L1 orthographies; although phonological processing was also important (Bentin & Ibrahim, 1996), orthographic processing accounted for higher proportions in comparison to how English native speakers processing printed words (Arab-Moghaddam & Sénéchal, 2001; Boumaraf & Macoir, 2016). Obviously, compared to transparent (e.g., Serbo-Croatian) and even less transparent (e.g., English) phonographic orthographies, abjad readers relied more on orthographic process in recognizing their L1 written words, due to the complexity of orthographic-phonological consistency of the orthography.

In sum, there has been a discussion about whether different writing systems (i.e., phonographic versus logographic writing systems) or writing systems with different degrees of transparency (i.e., deep versus shallow writing systems) use different processing paths in recognizing written words. The Universal Direct Access Hypothesis, the Universal Phonological Principle, and The Orthographic Depth Hypothesis, are three typical hypotheses regarding the relationship between writing systems and word recognition.

2.1.2 Written Word Recognition for Chinese L1 Readers

The majority of research on Chinese character recognition focuses on native Chinese readers (Leck et al., 1995; Perfetti & Tan, 1998; Perfetti, Liu & Tan, 2005; Perfetti & Zhang, 1991; Wong, Wu & Chen, 2014; Zhou & Marslen-Wilson, 1999, 2000). These studies have revealed that Chinese L1 readers rely on different processing routes for recognizing printed words, depending on various factors such as research methods (Chen & Shu, 2001; Perfetti & Zhang, 1995; Tan & Perfetti, 1997; Wang, 2011; Wang, Mecklinger, Hofmann & Weng, 2010;
Wong, Wu & Chen, 2014; Xu, Pollatsek, & Potter, 1999; Zhang, Zhang & Kong, 2009), word frequencies (Chen & Peng, 2001; Chen, Liu, Wang, Peng & Perfetti, 2007; Chen, Wang & Peng, 2003, 2006; Zhang, Zhang & Kong, 2009), sub-orthographic features (Leck et al., 1995; Lee et al., 2007; Zhou & Marslen-Wilson, 1999), reading contexts (Ren, Han & Liu, 2012), and readers' developmental stages (Siok & Fletcher, 2001; Tan et al., 2005).

2.1.2.1 Phonological Activation and Facilitation in Chinese Word Recognition

Chinese characters, being a logographic writing system, do not explicitly represent phonological information (e.g., 马 [ma3], meaning horse). According to both the UDH and the ODH, the orthographic processing path to lexical entry should be applicable in recognizing Chinese written words. However, research on Chinese reading, which involves semantic retrieval, has shown that the activation of phonology (Chen, Zhong, Leng, & Mo, 2014; Perfetti & Zhang, 1995; Tan & Perfetti, 1997; Xu, Pollatsek, & Potter, 1999), and the phonological activation is also facilitative to meaning retrieval (Perfetti et al., 1995, 1997, 1998, 2013). These results seem to support the UPP, which hypothesizes that the phonological processing path occurs in all written systems.

First, phonology is found as part of the process of Chinese word identification. Perfetti and Zhang (1995) selected thirty-four core characters and each one was paired with three foils: a synonym, a homophone, and a control character in a semantic judgment task and a phonological judgment task, that were conducted on 48 Chinese native speakers. They found that participants had lower accuracy and took a longer time to reject homophone foils, indicating automatic activation of phonological information. Xu et al. (1999) conducted a task where participants were asked to judge the semantic relatedness of Chinese characters, and found that the
phonological activation occurred, particularly with orthographically similar homophones, and that phonological interference effect was also present in orthographically dissimilar characters with shared consonants, vowels, and tones. Through a series of sound-based semantic judgment tasks, Chen, Zhong, Leng, & Mo (2014) found that regardless of written or spoken Chinese word recognition, all components of a word (orthography, phonology, and meaning) are activated and share the same mental lexicon access. These findings suggest that, akin to alphabetic writing systems, Chinese printed word recognition involves the activation of phonological information (Luo et al., 1998; Van Orden, 1987).

Furthermore, research has investigated how phonological information contributes to Chinese word meaning retrieval, and whether it directly accesses word meanings or mediates orthography-to-meaning recoding. Xu et al. (1999) found that phonological activation occurs particularly with orthographically similar homophones, while orthographically similar non-homophones had a stronger interference effect. This suggests two parallel paths for accessing word meanings: the direct orthography-to-meaning path, and the orthography-to-phonology-to-meaning path. Tan and Perfetti (1997) also found the mediate role of phonology in Chinese character recognition. They conducted a primed naming task, with 45 characters as targets and primes paring with a synonym, a homophone of the synonym (tones were not counted), and unrelated characters. Results demonstrate a significant homophone interference effect at prime-target stimulus onset asynchronies (SOA, the measurement starts at the initiation of the prime and continues until the onset of the target) 129 millisecond (ms) and 243 ms, suggesting the phonological activation was in the early stage. Also, the semantic priming effect was found stronger than the phonological effect, indicating that the visual-to-meaning path was the stronger than sound-to-meaning path. In addition, the evidence that the number of homophones impacted
the semantic priming effect implied that semantic access in Chinese reading was mediated by phonological information. Perfetti and Tan (1998) further clarified the role of phonological information in Chinese word recognition, finding that orthographic, phonological, and semantic information is not activated synchronously, but in a clear-cut sequence: orthographic facilitation, phonological facilitation, and semantic activation, suggesting a facilitative rather than a mediative role of phonological information in meaning retrieval.

However, not all studies have agreed that phonological information plays a facilitative or mediating role in Chinese written word recognition, and the UPP hypothesis seemed to be challenged. First, several replication studies of Perfetti and colleagues (1997, 1998) failed to find evidence supporting the crucial role of phonological activation in accessing word meanings, indicating a different role of phonology in word recognition. Zhou and Marslen-Wilson (1999) and Zhou, Marslen-Wilson, Taft, and Shu (1999) conducted a series of experiments, including lexical/character decision tasks, primed naming tasks, and phonological and semantic judgment tasks, to investigate how phonological and orthographic constraints affected semantic activation. They used the same materials and procedures as in Tan and Perfetti’s (1997) study, but differently, their results indicated that phonological information did not necessarily facilitate or mediate semantic activation in Chinese character recognition, as orthographically dissimilar homophones did not significantly interfere with character recognition and there was no significant homophone density effect. Using the same stimuli and procedure as Perfetti and Tan’s (1998) study, Chen and Shu (2001) conducted primed-naming tasks on Chinese L1 readers and found that the sequencing order of activations was not necessarily orthography-phonology-semantics, as shown in Perfetti and Tan’s (1998) study. Moreover, they found a smaller effect size of homophonic priming, suggesting an optional role of phonology in accessing word
meanings. Taking these together, Zhou and Marslen-Wilson (1999) concluded that phonologically mediated access to meanings in reading Chinese was not a predominant nor default mechanism, and this was not in conflict with the early activation of phonology in reading Chinese characters.

Furthermore, several non-replicative studies have shown that phonology has a minimal or non-dominant role in written Chinese word recognition. Zhou and Marslen-Wilson (2000) investigated the time course of phonological and semantic activation in reading Chinese and found stronger semantic effects in both short and long SOAs, which contradicted Perfetti and Tan’s (1998) findings. Four experiments were conducted, covering both two-character (experiment 1) and one-character words (experiments 2, 3, 4). Strong semantic effects were consistently found across all four experiments at short and long SOAs, while phonological effects varied from absent to strong or were only found at long SOA, depending on the task. No evidence showed that phonological activation was earlier than semantic activation, which suggests that phonology does not have a privileged role in visual word recognition, as claimed by Perfetti and his colleagues (1995, 1997, 1998), and orthographic information plays an equally important or more important role than phonological information in accessing word meanings in Chinese reading. Leong, Tse, Loh, and Hau’s (2008) study involving a large number of Chinese-speaking children (Grades 3 to 5) also found that phonological skills, including phonological awareness and decoding, may play a far less prominent role in Chinese reading.

While some behavioral studies have found conflicting results (as shown above), brain imaging research has provided more evidence for the subsidiary role of phonology in L1 Chinese readers' word recognition (Wang, 2011; Wang, Mecklinger, Hofmann & Weng, 2010; Wong, Wu & Chen, 2014; Zhang, Zhang & Kong, 2009). These studies used event-related potentials
(ERP, minute electrical potentials produced within the brain structures in response to particular events or stimuli) to record readers' neural patterns in the brain during reading. For example, Wang et al. (2010) used the Stroop paradigm with ERP recordings to examine the time course of phonological and semantic activation in reading Chinese single characters. They found that semantic activation appeared earlier (400-500ms post target) than homophone activation (600-800ms), indicating that while phonological information can be activated, it does not facilitate meaning retrieval while reading Chinese single characters. In another study, Wong et al. (2014) investigated how Chinese Cantonese readers recognize two-character written words using a masked-priming paradigm with ERP recordings. They found significant facilitative effects in character-related and semantic-related primes, but no significant effect in syllable-related primes. ERP waves showed that in the 150-250ms-window (N250) in anterior-central regions, there was a significantly attenuated amplitude in character-related conditions, and there was a significant effect in the semantic-related conditions in the 250-500ms-window (N400) in a widespread scalp region, suggesting a possible facilitative role of orthographic information in accessing word meanings. However, unlike reading alphabetic scripts, no phonological N250 effect was found in reading Chinese two-character words, indicating that phonology alone was not sufficient to facilitate meaning retrieval in reading two-character Chinese words. The findings of Wong’s study suggest that the salient role of phonology is not universal but rather language dependent.

Brain imaging studies have provided additional evidence of the distinct neural mechanisms involved in reading alphabetic and logographic scripts. For instance, the N170 effect, which is associated with the early extraction of phonological information, has been found in the left-lateralized and posterior region in alphabetic reading (Lee et al., 2007), while the N200 effect, a negative-going ERP wave occurring in the centro-parietal region, has been uniquely identified in
processing Chinese characters, indicating a Chinese orthographic effect rather than phonological or semantic-related processing (Zhang, Fang, Du, Kong, Zhang, & Xing, 2012). Furthermore, reading Chinese and English has been linked to different neural circuits, with Broca’s area and Wernicke’s area being involved in Chinese and English reading, respectively (Tan et al., 2005).

In conclusion, previous studies have shown that phonological information is activated in reading Chinese characters, but the degree to which it plays a primary, intermediary, or subsidiary role in accessing meaning remains controversial. Earlier behavioral studies suggested that L1 Chinese readers are more likely to rely on the phonological pathway or the phonological-orthographic dual path. However, more recent studies that combined behavioral and brain imaging paradigms have shown that Chinese L1 readers tend to use the orthographic path or the orthographic-phonological dual pathway to recognize Chinese characters. Furthermore, brain imaging studies have demonstrated neural differences between reading Chinese (a logographic writing system) and English (an alphabetic writing system).

2.1.2.2 Chinese Character Features and L1 Word Recognition

In addition to the various methodologies used to investigate how Chinese L1 readers process written words, different features of characters have also been taken into consideration, such as word frequency and character structure (i.e., integrated characters, compound characters, phonograms). Consequently, different processing paths are observed based on these features.

Previous behavioral studies have shown an inconsistent time course of orthographic, phonological, and semantic activation in Chinese word recognition. Chen and Peng (2001) and Chen, Wang, and Peng (2003, 2006) claimed that characters’ frequencies used in those studies might be one of the causes. Chen and Peng (2001), Chen et al. (2003), and Chen et al. (2006)
conducted semantic judgment tasks, homophone judgment tasks, and orthographic judgment tasks on Chinese L1 speakers and found that for high-frequency characters, the time course of activation was orthography-.semantics-phonology, regardless of task type. For low-frequency characters, however, after orthographic information was activated, it was not clear whether phonology or semantics had been activated first. Chen, Liu, Wang, Peng, and Perfetti (2007) used the ERP paradigm, and a similar result was found in reading high-frequency characters. However, an earlier phonological activation than semantic activation was found in reading low-frequency characters. Clearly, in addition to their previous behavioral studies, this study provided a more detailed time course of activation between phonology and semantics, which implied that phonology would facilitate meaning access in reading low-frequency Chinese characters.

Zhang et al. (2009) also used the ERP paradigm and found slightly different results from Chen et al.’s (2007) study. They found the N400 effect in both semantic and phonological interferences while reading high-frequency characters, indicating similar activation times of phonology and semantics. While reading low-frequency characters, a large P200 effect (150 to 250ms after target) representing phonological activation was found, indicating an earlier activation of phonology than semantics.

Taken together, word frequency affects the time course of orthographic, semantic, and phonological activation in Chinese word recognition. Regardless of task types or study methods, orthographic information is first activated in Chinese character recognition. Phonological activation or facilitative effect was found depending on word frequency. Only in low-frequent word recognition may phonology facilitate meaning retrieval.
The structure of Chinese characters is an important factor that impacts written word recognition. There are two types of Chinese characters, integrated and compound characters. The former accounts for approximately 5% and the latter accounts for 95% (Zhou & Marslen-Wilson, 1999). Integrated characters consist of crisscross strokes and are inseparable, such as 马 ([ma3], horse), and their pronunciation is arbitrary, requiring learners to memorize them by rote. Compound characters, on the other hand, usually consist of two identifiable subcomponents. The most common compound characters are phonograms (Dawson & Phelan, 2016; Yum, 2016), which account for 80% of all Chinese characters (Li, 1977, as cited in Leck, Weekes & Chen, 1995; 85% in Wang, 2014). Phonograms contain phonetic and semantic subcomponents, such as 妈 ([ma1], mother), including the semantic component 女 (meaning “women”) and the phonetic component 马 (ma3, meaning “horse”). With the historical development of sounds and meanings of Chinese characters, very few modern characters’ meanings and sounds are consistent with their semantic and phonetic components respectively. According to previous studies, only 33% to 39% of phonograms have the same pronunciation as their phonetic components (Kim, et al., 2016; Law, et al., 2009; Xu, et al., 1999; Zhou & Marslen-Wilson, 1999) and 30% of phonograms are partially similar between phonetic component and the pronunciation of the character (i.e., sharing the same rime) (Law, et al., 2009).

Various studies have shown that phonological information is only activated in recognizing phonograms. Leck et al. (1995) used the semantic categorization paradigm to investigate the recognition of both integrated and compound characters. They found that Chinese L1 readers relied only on orthographic information in recognizing integrated characters. For compound character recognition, visually similar foils that were phonologically identical (with the same
phonetic or semantic components) were the most challenging to reject, indicating that both visual and phonological information were employed in processing compound characters. In Zhou and Marslen-Wilson’s (1999) experiments, no phonological effect was found in orthographically different homophones, for either integrated or compound characters. However, they found that phonological information facilitated semantic activation when the characters share the same pronunciations with their phonetic components (e.g., 马, [ma3], with the phonetic component 马, [ma3]), even if they are orthographically different from target characters. Using the ERP paradigm, Lee et al. (2007) used the ERP paradigm to show that the processing path was affected by whether the phonograms' neighborhood (characters sharing the same phonetic components with identical pronunciations) was identical or similar. The more phonograms that shared common phonetic components with identical or similar pronunciations, the more readers relied on the phonological process.

In conclusion, Chinese L1 readers use different paths in recognizing Chinese characters, depending on word frequency and character structures. Phonological information is only facilitative to semantic retrieval in reading low-frequency characters and compound characters with limited conditions.

2.1.2.3 Contexts, Young Readers in Chinese L1 Word Recognition

Rather than identifying isolated Chinese characters, word recognition has also been examined in context. Ren, Han, and Liu (2012) conducted a study using the ERP and eye-tracking detection paradigms to explore how Chinese L1 readers recognize characters within sentences. They found that in the high-constraint sentence context, where readers could infer word meanings based on context, orthographic information was crucial for lexical entry, while
phonological information played a role in the post-lexical stage (N400). On the contrary, in the condition of low contextual constraint, in which readers cannot infer word meanings based on context, phonology was active and effective throughout the whole process, including meaning access and post-lexical analysis. Furthermore, the authors observed that the word frequency effect was only evident in the low-constraint sentence context. Ren’s et al. (2012) study demonstrated the important role of context in determining processing paths in Chinese word recognition, showing that phonological information would be facilitative to word meaning retrieval only when word meanings could not be inferred from context. Moreover, context could even affect how word features, such as frequency, impact lexical access.

Researchers have also investigated how young Chinese L1 readers, who are still in the process of learning characters, recognize written words (Siok & Fletcher, 2001; Tan, Spinks, Eden, Perfetti, & Siok, 2005b). Siok and Fletcher (2001) conducted a series of tests on 154 Chinese elementary children in grades one, two, three, and five (ages 6 to 11) in Beijing. They found that visual skills, including visual memory and visual analysis performance, predicted reading abilities in the lower grades, whereas phonological awareness, homophone identification, and pinyin (a phonetic system using Roman alphabets to transcribe Chinese sounds) knowledge facilitated reading abilities at later stages. This suggests that Chinese word recognition is a developmental process, progressing from a visual phase to a visual-sound phase. By conducting a battery of tasks including measures of intelligence, writing, phonological awareness, rapid-naming, and copying tasks, Tan, et al. (2005a) found a stronger orthographic (i.e., skill and awareness) effect on reading abilities than phonological awareness for both beginning (age 7-8) and intermediate level (age 9-10) Chinese readers. In other words, for L1 readers aged between 7-10, phonological awareness played a minor or secondary role in Chinese reading. These
studies showed that orthographic skill plays a central role in the reading abilities of young Chinese children, which is opposite to the results found in young alphabetic script readers, whose reading abilities are strongly predicted by phonological awareness (Baddeley, 2003; Dufva, Niemi & Voeten, 2001).

2.1.2.4 Conclusion: Chinese Written Word Recognition by L1 Readers

Extensive empirical studies demonstrate that phonological information is activated during Chinese character recognition (Perfetti & Zhang, 1995; Tan & Perfetti, 1997; Xu, Pollatsek, & Potter, 1999; Zhou & Marslen-Wilson, 1999, 2000), indicating that phonology plays a role regardless of reading phonographic or logographic scripts. However, the varying methodologies/tasks, selected words, and reader ages across studies suggest that phonological and orthographic information may play different roles in Chinese word recognition. Consequently, Chinese L1 readers may rely on different paths to access word meanings in different conditions.

In fact, many studies have shown that relying solely on phonological processing is insufficient for accessing Chinese word meanings. Phonological information only facilitates meaning retrieval in the following conditions: 1) Orthographically similar homophones (Xu et al., 1999; Zhou & Marslen-Wilson 1999; Zhou, et al., 1999); 2) Low-frequency characters (Zhang et al, 2007; Chen, et al., 2007); 3) Phonograms with identical pronunciations to their phonetic components (Leck et al., 1995; Yum, et al., 2016; Zhou & Marslen-Wilson, 1999; Zhou, et al., 1999); 4). A small number of phonograms that share the same phonetic components and have the same pronunciations (Lee, et al, 2007); 5). In the condition of low contextual constraint (Ren, Han & Liu, 2012); and 6) children at a later developmental stage. It is worth
noting that some of these conditions can overlap, such as 2) and 4), 2) and 5), and 6) and the rest of the items, indicating that the phonological path to lexical entry is relatively limited in Chinese character recognition.

In conclusion, Chinese L1 readers predominantly process written words through two paths: the orthographic path and the orthographic-phonological dual path (Chen & Shu, 2001; Tan et al., 2005; Wang et al., 2010; Xu et al., 1999; Zhou & Marslen-Wilson, 1999). The findings of L1 Chinese character recognition are consistent with the ODH theory, which suggests that as a deep logographic orthography, L1 Chinese readers mainly rely on the orthographic processing path, with conditional phonological processing when recognizing Chinese characters. According to Chen et al. (2014), Chinese L1 readers rely heavily on the orthographic path in processing written words due to the extensive practice of character writing since childhood, which also contributes to their reading abilities (Tan, et al., 2005b). This large reservoir of character knowledge is crucial in choosing the process path of written words for Chinese L1 readers. It is worth investigating the processing path by Chinese L2 readers, who lack extensive character writing practice and knowledge, and what role their L1 orthographic processing strategies play in Chinese L2 word recognition.

2.2 Written Word Recognition for L2 Readers: Cross-Orthographic Processing

The process of recognizing written words in a second language (L2) is more complex than in L1 reading, as it involves more factors, such as prior reading experience, limited knowledge of the L2, and the influence of both L1 and L2 during reading (Grabe, 1991; Koda, 2005, 2007). Therefore, reading across different orthographic writing systems can add further difficulties (Grabe, 1991). Advanced-level L2 readers have been found to use L1 neural patterns for
processing L2 written words, resulting in a less efficient process compared to L1 monolinguals (Tan et al., 2003). According to Koda (2005, 2007), the two processing mechanisms corresponding to two different writing systems may interact with each other, requiring constant adjustments from L2 readers and increasing the processing burden.

2.2.1 Cross-orthographic reading: ESL learners with phonographic L1 writing systems

Most studies on cross-orthographic word recognition have focused on L2 English reading by learners with different phonographic L1 writing systems (i.e., French, Italian, Persian, Russian, and Korean, etc.) (Abu Rabia, 2001; Arab-Moghaddam & Sénéchal, 2001; Commissaire, Duncan and Casalis, 2011; D’Angiulli, Siegel & Serra, 2001; Deacon, Wade-Woolley & Kirby, 2009; Wang, Park, & Lee, 2006). Researchers have attempted to examine to what extent L1 reading skills facilitate L2 reading.

A substantial body of research has investigated the relationship between L1 and L2 reading skills among ESL learners whose L1 writing systems are phonographic (Abu Rabia, 2001; D’Angiulli, et, al., 2001; Deacon, et al., 2009; Wang, et al., 2006). Findings indicate a strong facilitative effect of L1 phonological processing skills on L2 word reading, regardless of whether the two alphabetic writing systems share the same alphabets (e.g., Italian, French) or have different alphabets (e.g., Russian, Korean) (Abu Rabia, 2001; D’Angiulli et al., 2001; Deacon et al., 2009; Wang et al., 2006). These results suggest that better L1 phonological skills predict more sophisticated L2 phonological processing and that the phonological processing path is predominantly used in cross-orthographic word recognition among phonographic L1-L2 writing systems.
It is worth noting that English L2 learners whose L1 is Persian (abjad) have been found to apply both orthographic and phonological paths in reading English and Persian, with a slightly greater reliance on the orthographic path in reading L1 Persian compared to L2 English (Arab-Moghaddam & Sénéchal, 2001). The authors suggest that the different grapheme-phoneme correspondences (i.e., polyphony and polygraphy) between English and Persian may explain the differences in processing paths in written word recognition.

However, orthographic processing skills among ESL learners whose L1 writing systems are phonographic have demonstrated different outcomes (Arab-Moghaddam & Sénéchal, 2001; Abu Rabia, 2001; Commissaire, et al., 2011; D’Angiulli, et al., 2001; Deacon, et al., 2009; Wang, et al., 2006). Studies focusing on French-, Italian-, and Persian-speaking ESL learners have shown that orthographic processing skills transfer between L1 and L2 (Arab-Moghaddam & Sénéchal, 2001; Commissaire, et al., 2011; D’Angiulli, et al., 2001; Deacon, et al., 2009), when orthographic processing skill is conceptualized as the ability to distinguish alternative spellings in a language (e.g., brain and brane in English). For example, Deacon, et al. (2009) found English orthographic processing skills would predict French reading skills and vice versa. However, studies have shown that L1 orthographic skills do not contribute to L2 English word processing when orthographic processing skill is alternatively defined as the reader's sensitivity to orthographic regularities in both languages, such as the position of doublet consonants or vowels (e.g., saff vs saf) or the onset or coda context surrounding the letters (e.g., leck vs leque) (Commissaire, et al., 2011). Focusing on L2 English learners of L1 French speakers, Commissaire, et al. (2011) has found that traditionally defined orthographic processing skill, the ability to discriminate correct spelling from a spelling with pseudohomophone (e.g., clean-cleen; low-loe; key-kee;), are transferred between French and English, similar to Deacon et al.’s (2009)
findings. However, readers' sensitivity to orthographic regularities did not transfer between L1 and L2, even if both writing systems were alphabetic (i.e., English and French). Similar results have been found among English L2 learners whose L1 are Russian (Abu Rabia, 2001) and Korean (Wang, et al., 2006). Wang et al. (2006) have discovered that L1 Korean orthographic processing skills do not contribute to L2 English word/nonword reading, indicating that different alphabets may result in different orthographic processing skills.

Taken together, for readers whose L1 and L2 orthographies are both phonographic, there is evidence of phonological transfer across orthographies in reading, suggesting a predominant use of phonological processing in written word recognition. However, orthographic processing skills appear to be more language-specific, with different orthographic regularities or alphabets resulting in distinct orthographic processing skills. Furthermore, varying grapheme-phoneme consistency between L1 and L2 orthographies may lead to different levels of reliance on orthographic or phonological processing in word recognition.

2.2.2 Cross-Orthographic Reading: ESL Learners with Logographic L1 Writing Systems

Studies investigating cross-orthographic word recognition between phonographic and logographic orthographies have primarily focused on English as a second language (ESL) learners whose L1 writing systems include both phonographic (e.g., Arabic, Korean, Persian, Turkish) and logographic (e.g., Chinese, Japanese) systems. These studies have generally found that L1 processing patterns transfer to the identification of L2 written words, such that logographic L1 readers rely more on orthographic information, whereas phonographic L1 readers rely more on phonological information in alphabetic L2 lexical entry (Abbott, 2006; Akamatsu,
Research has shown that among ESL learners, those with phonographic L1 tend to outperform their logographic L1 counterparts in recognizing L2 English words, indicating that phonographic L1 can facilitate word recognition in phonographic L2. For example, Wang et al. (2003) conducted a semantic category judgment task and phoneme deletion task on advanced-level ESL learners with L1s in Korean and Chinese. The results showed that Korean speakers overall performed better in both tasks in terms of accuracy and responding time, and were more distracted by homophone foils. Conversely, Chinese speakers were more confused by orthographic similar distractions. This suggests that Korean L1 readers use the phonological path in word recognition, while Chinese L1 readers rely more on the orthographic path in processing written words, resulting in differences in performance in recognizing alphabetic L2 words. Similarly, by conducting a lexical decision task, Muljani et al. (1998) found that L1 readers of Indonesian, which uses the Roman alphabetic writing system, responded faster than their Chinese counterparts in a lexical decision task, regardless of word frequency or spelling patterns.

From a neurological perspective, Tan’s et al. (2003) study provided compelling evidence for why logographic L1 readers cannot perform as well as alphabetic L1 readers when recognizing L2 English words. Using functional magnetic resonance imaging (fMRI), Tan et al. (2003) observed brain activity in Chinese bilingual speakers when they were processing phonological information in both Chinese and English. They found that the regions of the brain that had been activated while processing Chinese phonological information were related to spatial information representation, which was also activated during processing English phonological information. However, the same areas were not or were weakly activated by English monolingual speakers.
when they were processing English phonological information. These findings suggest that Chinese L1 speakers use a spatial-related or holistic approach to process both Chinese and English phonology, which may result in lower efficiency of visual-to-sound decoding in L2 English.

Although logographic L1 readers primarily rely on an orthographic or holistic path to process alphabetic L2 words, phonological information has also been used in alphabetic L2 word recognition, and the extent to which readers rely on phonological processing depends on their L2 proficiency. In Wang’s, et al. (2003) study, although Chinese L1 speakers were less distracted by homophone foils compared to their L1 Korean counterparts, the homophone effect weakly existed, suggesting a phonological activation in L2 English word recognition. The authors suggested that the reliance of logographic L1 readers on phonological processing in L2 word reading would increase as their L2 proficiency improved. Some studies have investigated how Chinese-English bilingual children recognize English words in the US (Wang, Perfetti, & Liu, 2005) and Canada (Gottardo, Yan, Siegel, & Wade-Woolley, 2001). The participants they selected were young Chinese-speaking children aged 7-12 who were either born and lived in North America or young immigrants who came to North America at an early age and went to local English-speaking schools. Through conducting a battery of tests including Reading, Phonological Processing, and Orthographic Legality tests in both English and Chinese, results showed that phonological processing skills of both L1 and L2 contributed to L2 English word reading, however, orthographic processing skills of both languages did not facilitate each other’s word recognition. These results indicate that for Chinese-English bilingual children, whose English proficiency is similar to English monolingual speakers, their phonological rather than orthographic processing skills are predictive of alphabetic L2 word reading.
It is worth noting that some ESL learners with abjad L1 orthographies do not experience facilitative L1 phonological effect on L2 word recognition, even if their L1 and L2 orthographies are typologically similar (i.e., phonographic). For instance, in a word recognition task, Fender (2003) found that Arabic ESL learners made more errors and had slower reaction times than Japanese ESL learners when identifying English words. Similarly, Abbott (2006) found that Mandarin speakers were more accurate in orthographic-phonological decoding of English words than Arabic ESL learners. The author attributes the underperformance of Arabic speakers to their unique processing strategies, with more reliance on sentence context and prior knowledge cues for recognizing L2 alphabetic words, rather than bottom-up decoding. Akamatsu (2002) found that there were no significant differences in visual-sound decoding between phonographic L1 and logographic L1 readers. In a naming task involving 40 high-frequency and 40 low-frequency monosyllabic English words, 48 fluent ESL learners whose native languages were Chinese, Japanese, and Persian showed similar processing patterns: direct orthography-to-lexis access while reading high-frequency words and phonological mediation for reading low-frequency words. The reaction time did not differ significantly among the three groups, suggesting that the nature of L1 orthography did not affect L2 word processing patterns.

In sum, studies of L2 word recognition by ESL learners demonstrate that readers’ strategies in L1 word recognition transfer to L2 word recognition. Specifically, phonographic L1 readers tend to rely on phonological processing for lexical entry, and this can facilitate recognizing phonographic L2 words (e.g., Korean and Indonesian readers). In contrast, logographic L1 readers tend to rely more on orthographic or holistic processing for recognizing phonographic L2 words (e.g., Chinese readers). Brain imaging studies have confirmed the transfer of processing strategies from L1 to L2, as evidenced by the observation of the same activated regions in the
brain. However, the research suggests that cross-orthographic interference declines with increasing L2 proficiency. It is noteworthy that abjad L1 readers (e.g., Arabic, Persian) have demonstrated exceptions to this pattern, with phonographic L1 not facilitating phonographic L2 reading, indicating a different processing pattern in written word recognition.

2.2.3 Cross-Orthographic Reading: Japanese L2 Learners

Among the logographic writing systems that remain in current world languages, Chinese character, also known as “hànzì” (汉字) and Japanese kanji (漢字) are the two most extensively studied scripts in the field of written word recognition. Chinese characters are the only written form used in Chinese (i.e., Pinyin, which uses Roman alphabets to represent sounds of characters, is only used to assist character learning, but it is not used in almost any daily and official documents). In contrast, kanji is not the only writing system used in Japanese, as both logographic (kanji) and syllabic systems (hiragana and katakana) are used in Japanese (Leong & Tamaoka, 1998; etc.).

Despite the differences in writing systems employed by Chinese and Japanese, the relationship between Chinese characters and Japanese kanji may give rise to potential analogical patterns in the recognition of written words. Kanji, meaning Chinese character in Japanese, was originally borrowed from Chinese characters since the 5th century. Phonologically, 60% of kanji has two pronunciations: On-reading (of Chinese origin) and Kun-reading (of Japanese origin) (Tamaoka, Kirschner, Yanase, Miyaoka, & Kawakami, 2002). Due to the different historical periods of borrowing and Chinese phonetic development, Japanese kanji and Chinese hànzì are not pronounced in exactly the same manner, and On-reading may be close to some Chinese
dialects (Leong & Tamaoka, 1998). However, Chinese hànzì usually have single pronunciations. Orthographically, both Japanese kanji and Chinese hànzì have developed in their own way. Traditional Chinese hànzì are mostly used in Japanese kanji, whereas simplified characters were used in mainland China since 1955 (Li, 2005) (but traditional characters continue to be employed in Hong Kong, Macau, and Taiwan). On the other hand, there was a movement for simplifying Japanese kanji since 1946. Some of these simplifications overlapped with Chinese simplified hànzì; most are simplified in a slightly different way (e.g., traditional hànzì 驅, modern simplified hànzì 驅, modern simplified kanji 驅, with the meaning of drive or ride).

Semantically, a small portion of kanji words have different meanings from their Chinese counterparts (e.g., 手紙 means “toilet paper” in Chinese, but “letter” in Japanese), but in most cases, Chinese hànzì and Japanese kanji readers are intelligible to both forms (Zhang, 1982).

Studies focusing on L2 Japanese learners have compared processing paths applied by readers with logographic and alphabetic L1 writing systems. Consistent results across these studies show that Chinese L1 speakers used orthographic processing skills to recognize kanji, leading to superior accuracy and latency performance compared to their alphabetic L1 counterparts (Chikamatsu, 2006; Matsumoto, 2013; Mori, 1998; Tamaoka, 1997). Additionally, Tamaoka (1997) found that Chinese L1 readers performed faster and more accurately in processing kanji compared to English L1 readers, but no differences were observed in processing kana (the phonographic writing systems in Japanese) between the two groups. Mori (1998) compared L2 Japanese learners whose L1s were Chinese, Korean, and English, and found that both Chinese and Korean readers could recognize phonologically inaccessible pseudo-kanji words, but English L1 speakers had difficulties identifying those words. It is worth noting that
the author categorized Korean scripts as morphographic due to the massive use of loaned Chinese characters (hanja) in the Korean written system at the time of data collection (1990-1991).

Other than examining the differences between Chinese and English L1 speakers in recognizing L2 Japanese kanji words, Chikamatsu (2006) and Matsumoto (2013) investigated whether English L1 speakers change the pattern of word recognition as their L2 proficiency develops. Matsumoto (2013) conducted a kanji lexical judgment on three groups of participants: beginning-level and intermediate-level Japanese L2 learners whose L1 was English, and beginning-level Japanese L2 learners whose L1 was Chinese. Testing materials contained 60 primes, consisting of 15 pseudo-homophones, 15 pseudo-homographs, and 30 correct kanji. Results showed that Chinese native speakers outperformed the other two English native groups in accuracy and latency. The intermediate-level English group responded much faster to pseudo-homographs than the beginning-level English group. Furthermore, both the Chinese native group and the intermediate-level English group were most distracted by homograph primes among all three types of primes, indicating orthographic processing in identifying kanji words. Matsumoto’s (2013) study suggested a strong influence of L1 orthography on L2 reading strategy, and L2 experience might change learners’ processing patterns in recognizing L2 words.

In Chikamatsu's (2006) study, lexical judgment tests of Katakana Block and Hiragana Block were administered to novice and intermediate-level L2 Japanese learners whose L1 was English. The results showed that learners with higher proficiency in L2 Japanese relied more on visual cues than on phonological cues, suggesting the development of reading strategies or processing paths with increased L2 exposure.
To sum up, the findings on how Japanese L2 learners recognize written words are in line with results on ESL learners: L1 readers transfer their L1 processing strategies to L2 word processing, and L2 written word recognition is facilitated if L1 and L2 writing systems are close (e.g., Chinese - Japanese), and, vice versa, reading L2 words can be more challenging when L1 and L2 writing systems are different (e.g., English – Japanese Kanji). In addition, L2 reading experiences can affect processing patterns, even when L1 and L2 writing systems differ. However, studies focusing on Japanese L2 learners have limitations, for example, most studies mainly recruited participants whose L1s were Chinese or English, and limited varieties of other phonological L1 writing systems were included.

It is worth noting that the finding that L1 Chinese orthographic knowledge facilitates L2 Japanese kanji reading may raise questions about the association between Chinese characters (i.e., hànzì) and Japanese kanji. The choice of kanji in the aforementioned studies may introduce a distinction between recognizing words within the same logographic writing system and recognizing words that share similarities with one's native orthography. In the case of the latter, comparing Chinese L1 readers to English L1 readers in their recognition of L2 Japanese kanji appears untenable.

In fact, regardless the similarities between kanji and hànzì, the cognitive processes involved in reading Japanese kanji and Chinese hànzì by native speakers may differ. This underscores the importance of exploring the distinct ways in which L2 Chinese readers recognize logographic written words. Although different processing patterns were found in reading hiragana and kanji (Yamada, Imai, & Ikebe, 1990), L1 Japanese readers recognize one-word kanji and two-word kanji using both phonological and orthographic information to retrieve meaning. Either phonology-mediated meaning access or both phonological and orthographic information are
activated, and lexical entry occurs simultaneously (Kess & Miyamoto, 1999; Morita & Tamaoka, 2002; Verdonschot, La Heij, & Schiller, 2010; Wang, 1988; Yu, 2016). However, these results are slightly different from how Chinese L1 readers process written words: the orthographic path is primarily adopted, and the orthographic-phonological dual path is also used in certain situations (Chen & Shu, 2001; Tan, et al., 2005; Wang, et al, 2010). Verdonschot, et. al., (2010) found that the semantic facilitative effect significantly occurred in Japanese L1 readers but did not significantly facilitate Chinese L1 readers. The authors explained that multiple pronunciations of kanji might delay the process of orthographic-to-meaning connection, and the provided semantic hints facilitated the process of the lexical entry. These results suggest that phonological mediation generally occurs in Japanese kanji recognition. Therefore, although Chinese and Japanese characters have the same origin, their respective development in pronunciations, orthographic shapes, and meanings have resulted in complex relationships between reading Chinese hànzì and Japanese kanji. Studies focusing on L2 learners of Japanese kanji have shown that the logographic L1 writing system contributes to logographic L2 reading. Meanwhile, the differences between the two writing systems cause the different processing paths by native speakers in reading kanji and hànzì respectively. Hence, research on L2 Japanese kanji recognition alone is inadequate for exploring logographic word recognition. It is necessary to investigate the uniqueness of how L2 Chinese readers recognize logographic written words.

2.2.4 Cross-orthographic Reading: Chinese L2 Learners

In the past fifteen years, research on how L2 learners recognize Chinese written words has gained attention (Kong, 2018). Despite the limited number of studies, researchers have explored various dimensions, including methodological approaches (e.g., offline paper-based tests, behavioral studies, and ERP-based studies), materials (e.g., single characters versus double-
character words, and phonograms), and target participants (e.g., different language background and proficiency levels).

Chinese word or character recognition by bilinguals who have extensive exposure to L2 Chinese has demonstrated a similar processing pattern to Chinese L1 speakers. However, bilingual speakers have also shown different processing features based on the types of two languages, either due to fewer orthographic representations or the effect of two simultaneously activated language processing modes. Wu and Ma (2017) investigated semantic access in reading Chinese two-character compounds by early Hakka-Mandarin bilinguals. Hakka is a regional "dialect" which is pronounced dramatically differently from Mandarin, but both Hakka speakers and Mandarin speakers use the same writing system, hànzì, which is based on Mandarin pronunciations. They conducted a semantic-relatedness decision task on Hakka-Mandarin bilinguals and monolingual Mandarin speakers as a control group, with materials including sound stimulus, visual control, and semantically related words for each experimental item. Results showed that for both groups, synonyms of homophones were more difficult to reject and slower to respond to (e.g., 直行-实施), compared to visual controls (e.g., 真切-实施), indicating phonological interference in two-character word recognition. This pattern was shared by both monolingual Mandarin speakers and Hakka-Mandarin bilingual speakers. Yum et al. (2016) used the ERP paradigm to investigate how phonetic components in characters influence word recognition by English-Chinese bilinguals. They selected 160 real phonograms and 160 pseudo-phonograms and conducted a lexical decision task and a naming task. Brain imaging patterns showed that in the early stage, English-Chinese bilinguals' phonological information was activated by the regular phonetic components (in which the phonetic component and the character were pronounced the same), and characters sharing the same phonetic components
were also activated. This processing pattern resembled L1 Chinese speakers, but a delayed effect was found among English-Chinese bilinguals. In addition, both English (N 400) and Chinese (N170) processing modes were activated during the process. However, the processing patterns demonstrated in bilinguals whose Chinese proficiencies were near-native speakers might not be extended to late L2 Chinese learners.

Adult L2 Chinese learners with classroom-based learning experiences demonstrate a similar pattern to that of Japanese L2 and ESL learners in terms of recognizing characters. Among L2 Chinese learners whose L1 writing system is logographic (e.g., Japanese kanji, Korean hanja), findings show a strong L1 influence and a dominant orthographic processing pattern (Jiang, 2003; Lin & Collins, 2012; Zhang & Wang, 2010). In contrast, Chinese learners whose L1 writing system is alphabetic (e.g., English, Indonesian), findings show a predominant phonological processing pattern (Wang, 2014), and tend to underperform their logographic peers in processing Chinese characters (Jiang, 2003; Zhang & Wang, 2010).

For instance, Zhang and Wang (2010) conducted two primed lexical judgment tasks at SOA 57ms, 157ms, and 314ms. The study selected 90 intermediate-level Chinese L2 learners whose L1s were Korean and Indonesian, and used fillers that were orthographically similar pairs, homophone pairs, semantic-related pairs, and non-relevant control pairs. The results showed that the Korean group followed the time course of activation as orthography-semantics-phonology, whereas the Indonesian speakers followed the pattern of orthography-phonology-semantics. These findings suggest that L2 Chinese learners with logographic L1 knowledge utilize orthographic information to access meanings, whereas learners with phonographic L1s access meaning through phonological processing, indicating a strong L1 transfer of written word processing strategies. Wang (2014) compared how Spanish L1 speakers process three languages
with five types of written forms to access word meanings. Eight college students who were learning Chinese in Mexico were selected and asked to judge whether or not the pictures and words were consistent. The five written forms with corresponding pictures were: Spanish words, English words, Chinese characters, Chinese pinyin, and both Chinese characters and pinyin. Two different processing paths were found based on different task conditions. When the pictures and words were matching, Chinese characters did not contribute to meaning access. Instead, both pinyin and characters combined with pinyin had a facilitative effect, indicating a phonological processing path. When the pictures and words were not matched, Chinese characters, pinyin, and characters combined with pinyin had the same effect, which might suggest an orthographic path to word meanings.

Intermediate to advanced level L2 Chinese learners who have had classroom-based learning experiences also demonstrate orthographic awareness in processing Chinese characters. As previously mentioned, 95% of Chinese characters are compounds with two or more components and are structured in various types (e.g., left-right, up-down, enclosure, etc.). Studies using paper-based tests have shown that English L1 speakers who learned Chinese for five months exhibited an awareness of character structure (only for up-down type) (Jiang, 2003), while intermediate-level learners with knowledge of 543 characters had an awareness of component position, and the awareness of component forms was formed later, in the advanced level (Hao, 2007). Brain-imaging studies have supported these findings, as Yum, Law, Lee, and Shum (2018) used an ERP paradigm to compare how L1 and L2 Chinese (English L1) speakers process character components. Both L1 and L2 speakers detected component position violations at the early stage (P100), but the regions activated in the brain were distinct between L1 and L2 speakers, indicating different neural patterns used in processing compound characters.
Furthermore, unlike L1 speakers, L2 Chinese learners did not identify component violations in the later stage (N270), suggesting that L2 learners may use fuzzy identification of Chinese characters when their proficiency is relatively low. The orthographic awareness observed in L2 Chinese learners with a certain level of character knowledge is similar to the developmental effect seen in L2 Japanese kanji recognition (Chikamatsu, 2006; Matsumoto, 2013). As L2 Chinese learners' character knowledge increase, they may utilize either an orthographic-to-semantic activation or a phonetic component-to-lexical entry processing pattern, depending on the character structure and word frequency, as seen in L1 Chinese word recognition (Leck et al., 1995; Lee et al., 2007; Yum et al., 2016).

To summarize, in a very limited number of studies focusing on L2 Chinese written word recognition, learners of Chinese demonstrate some similar processing patterns as found in ESL and L2 Japanese kanji learners. Specifically, learners with logographic L1s show facilitation in L2 Chinese word recognition while those with phonographic L1s use phonological processing and perform more slowly and less accurately. However, very few types of L1 writing systems have been involved in L2 Chinese written word recognition (also in studies on L2 Japanese kanji recognition), the complexities arising from various types of L1 writing systems (e.g., diverse processing patterns resulting from varying orthographic regularities, alphabets, and orthographic-phonological consistency, etc.) observed among ESL learners, have not been found in L2 logographic word recognition. Additionally, advanced-level L2 Chinese learners (i.e., bilingual) exhibit similar processing features to L1 Chinese readers in word recognition, which might not be the case for classroom-based L2 Chinese learners. Finally, novice to intermediate-level L2 Chinese learners have shown orthographic awareness, particularly in the componential positions of compound characters.
2.2.5 Conclusion: cross-orthographic word recognition

Cross-orthographic word recognition within phonographic writing systems indicates that phonological processing is prevalent across orthographies in reading. However, orthographic processing skills may not always transfer between phonographic writing systems, depending on the orthographic regularities (e.g., French, Commissaire, et al., 2011) or alphabets used (e.g., Korean, Wang, et al., 2006).

Cross-orthographic word recognition between phonographic and logographic writing systems demonstrate that L1 processing strategies transfer to L2 word processing. Phonographic L1 readers majorly rely on phonological processing for lexical entry, which then facilitates recognizing phonographic L2 words (e.g., L1 Korean-L2 English) but impedes recognizing logographic L2 words (e.g., L1 English- L2 Japanese kanji). In contrast, logographic L1 readers tend to rely on orthographic processing for recognizing L2 words, facilitating L2 logographic word recognition (e.g., L1 Chinese-L2 Japanese) but hindering L2 phonographic word recognition (e.g., L1 Chinese-L2 English). Furthermore, as L2 proficiency increases, cross-orthographic interference tends to decrease. L2 learners may employ increasing portions of L2 word processing patterns.

However, there are exceptions to the facilitative effect of L1 orthographies on recognizing typologically similar orthographies, particularly for L2 learners with abjad L1 writing systems. Studies have shown that Arabic speakers underperform Chinese and Japanese native speakers in reading L2 English written words (Abbot, 2006; Fender, 2003), while Persian, Chinese, and Japanese readers show similar processing patterns in recognizing English words (Akamatsu, 2002). For abjad L1 readers, their phonographic L1 does not appear to facilitate phonographic L2 reading, indicating different processing patterns in identifying phonographic L1 and L2 written
words, which may be due to the varying orthographic-phonological correspondence (Arab-Moghaddam & Sénéchal, 2001).

2.3 Gaps and Research Questions

Firstly, it is important to investigate whether the ODH theory is applicable to L2 word recognition. The writing systems of world languages are divided into phonographic systems and logographic systems, based on the symbolic representation of the written form and its corresponding sound/meaning of the language. The patterns of written word recognition vary among different writing systems, not only across orthographies between phonological and orthographic writing systems (Chikamatsu, 2006; Jiang, 2003; Matsumoto, 2013; Tamaoka, 1997; Wang, et al., 2003; Zhang & Wang, 2010;), but also within phonographic writing systems, depending on the sub-category features, such as orthographic regularities (Commissaire, et al., 2011) and alphabets (Wang, et al., 2006). Furthermore, the exceptional features exhibited by abjad (e.g., Arabic, Persian) L1 readers in recognizing L2 English words (Abbott, 2006; Akamatsu, 2002; Fender, 2003) have raised the concern of whether orthographic-phonological consistency also impacts the processing patterns of L2 written words.

As previously mentioned, the Orthographic Depth Hypothesis (ODH, Katz & Frost, 1992) describes the relationship between orthographic-phonological consistency and written word processing patterns, suggesting that the depth of orthographies influences processing paths in the recognition of written words, with more transparent orthographies leading readers to rely more on phonological processing, and deeper orthographies requiring more orthographic processing. The ODH has been supported by numerous empirical studies focusing on L1 written word recognition, including studies that focused on English, Italian, Arabic, and Chinese (Arab-
Moghaddam & Sénéchal, 2001; Aro & Wimmer, 2003; Bentin & Ibrahim, 1996; Landerl et al., 1997; Paulesu et al., 2000; Perfetti & Zhang, 1995; Tan & Perfetti, 1997; Xu, et al., 1999). However, it remains unclear whether the orthographic transparency effect on L1 reading, as stated in the ODH theory, is also applicable to L2 written word recognition.

Another aspect worth investigating is the extent to which each of phonological and orthographic processing paths contribute to the recognition of L2 words by phonographic L1 readers. Previous studies have shown that phonographic L1 readers predominantly rely on the phonological processing path in both L1 (Bentin & Ibrahim, 1996; Luo, et al, 1998; Paulesu et al., 2000; Van Orden, 1987) and phonographic L2 word recognition (Arab-Moghaddam & Sénéchal, 2001; Abu Rabia, 2001; Commissaire et al., 2011; D’Angiulli, et al., 2001; Deacon, et al., 2009; Wang, et al., 2006). The ODH theory posits that both orthographic and phonological processing are used during L1 word recognition but in varying proportions, depending on the depth of the orthographies. It is unclear whether the orthographic depth of L1 writing systems impacts the proportion of using phonological and orthographic processing in recognizing L2 written words, particularly logographic L2 words.

Moreover, while cross-orthographic studies have examined logographic L2 word recognition, such as L2 Japanese kanji and L2 Chinese characters, the emphasis has been on L2 learners with typologically different L1 orthographies (Chikamatsu, 2006; Jiang, 2003; Matsumoto, 2013; Tamaoka, 1997; Wang, 2014; Zhang & Wang, 2010, etc.). The impact caused by different sub-category features among phonographic L1 writing systems has rarely been noticed. In fact, few studies have investigated L2 logographic word recognition involving various types of L1 writing systems, and the impact of sub-category level features of L1 writing systems on logographic L2 reading remains unclear.
Finally, there have been very few studies on L2 Chinese word recognition that focus on early beginning learners. The developmental effect has been found in processing L2 written words; namely, the more L2 written word knowledge the learners have, the more L2 processing strategies the learners use in identifying L2 written words (Hao, 2007; Matsumoto, 2013; Wang, et al., 2002). Novice to intermediate L2 learners already demonstrate L2 Chinese orthographic awareness (Hao, 2007; Jiang, 2003), and advanced learners or bilinguals exhibit similar processing features to Chinese L1 speakers from a behavioral perspective. Hence, it is necessary to examine the word processing patterns of beginner learners of Chinese.

Therefore, the current study aims to investigate how beginner Chinese learners, whose native writing systems are phonographic but with varying phonological-orthographic consistency, process L2 written Chinese words. The study addresses two main research questions:

1) To what extent do the phonological and orthographic processes of beginning learners of L2 Chinese contribute to L2 meaning retrieval? In other words, are beginning Chinese L2 learners with phonographic L1 able to process Chinese characters orthographically, or are they distracted by homographs in the experiment?

2) How do beginning learners of L2 Chinese whose L1 writing systems are phonographic but with different orthography-phonology correspondence (i.e., English, Italian, Arabic) compare in their performance of L2 Chinese character recognition? To be specific,

   a) Do all learners perform less accurately and more slowly when presented with homophones than with homographs?

   b) Compared to L1 Italian speakers, do L1 English and L1 Arabic speakers perform less accurately or less quickly when presented with homographs?
Based on prior research (Chikamatsu, 2006; Hao, 2007; Matsumoto, 2013; Wang et al., 2002), lower L2 proficiency learners tend to rely more on their L1 processing strategies for written word recognition. Thus, in this study, with all participants being beginner learners of L2 Chinese, it is assumed that they would primarily rely on their phonographic L1 processing strategies for recognizing logographic L2 Chinese words, meaning a predominant use of phonological processes, regardless of the logographic features of L2 written words.

Moreover, if the ODH theory applies to L2 learners in recognizing written words, then it can be predicted that learners with more transparent L1 orthographies would rely more on the phonological processing path, whereas those with more opaque L1 orthographies would rely more on the orthographic processing path when identifying L2 Chinese words. Therefore, in the current study, the proportion or amount of orthographic or phonological processes used by beginner L2 Chinese learners is assumed to be influenced by their L1 orthographic depth: learners with the most transparent L1 orthographies (e.g., Italian) would use more phonological processing compared to their English and Arabic counterparts, while learners with the least transparent L1 orthographies (e.g., Arabic) would use more orthographic processing than their Italian and English counterparts.
CHAPTER 3

METHODOLOGY

The objective of this study is to examine how novice Chinese learners, whose L1 writing systems are phonographic but with differing levels of phonological-orthographic consistencies, process L2 Chinese written words. To achieve this goal, English (alphabetic, deep), Italian (alphabetic, shallow), and Arabic (Abjad, deep) were selected as representative phonographic systems with different degrees of orthographic-phonological consistency: from most transparent to least transparent (Bates et al., 2001; Boumaraf & Macoir, 2016; Ellis & Hooper, 2001; Juhani, 2015; Katz & Frost, 1992; Paulesu et al., 2000; Russak & Fragman, 2014). Native speakers of these languages were recruited to participate in the study as trainees and testees. The current experiment consists of a survey, a six-session training phase, and a judgment decision task, all of which are computerized.

3.1 Participants

The study involved three groups of adult participants whose native languages were English, Italian, and Arabic, respectively (see Table 1). English and Arabic speakers were recruited from a college town in the southern United States, while Italian speakers were recruited from a college in southern Italy. The participants included thirteen English native speakers (F = 11, M = 2) with undergraduate or graduate degrees in various majors, thirteen Italian native speakers (F = 9, M = 4) who were mostly undergraduate students in various majors, and fourteen Arabic native
speakers (F = 9, M = 5) who were undergraduate or graduate students studying in the US and were from different Arabic-speaking countries, with varying majors. All Arabic speakers had at least beginner-level proficiency in English, and the majority of Italian speakers (92%) had basic or higher proficiency in English.

Table 1
Demographic Information of Participants

<table>
<thead>
<tr>
<th>Language</th>
<th>Age</th>
<th>Gender</th>
<th>Degrees</th>
<th>L2 / L3 experience</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>English</td>
<td>18-25</td>
<td>26-35</td>
<td>36-45</td>
<td>46-55</td>
</tr>
<tr>
<td>Arabic</td>
<td>15.4%</td>
<td>38.5%</td>
<td>46.2%</td>
<td>0</td>
</tr>
<tr>
<td>Italian</td>
<td>76.9%</td>
<td>15.4%</td>
<td>0</td>
<td>7.7%</td>
</tr>
</tbody>
</table>

Since L2 proficiency including vocabulary size and written word knowledge would influence L2 written word recognition (Chikamatsu, 2006; Jiang, 2003; Matsumoto, 2013; Wang, et al., 2003), the current study recruited individuals who had never learned Chinese characters nor Japanese kanji before to minimize the impact of differences in participants’ pre-knowledge. Additionally, the selected participants had similar individual backgrounds (i.e., education levels, multi-majors, L2 experiences, gender, age, etc.), which may maximize synchrony among participants during the Chinese character training phase and ensure that they had roughly the same level of knowledge of Chinese characters when taking the lexical decision.
task, thus avoiding experimental bias due to variations in pre-existing knowledge of Chinese characters.

3.2 Methods

The experiment consisted of several stages, including a survey to collect data on participants' language experience and their knowledge of Chinese characters, a six-session training phase that focused on teaching participants to comprehend the meaning, pronunciation, and shape of Chinese characters, and a lexical decision task, which aimed to determine whether the phonological distractors (i.e., homographs) or the orthographic distractors (i.e., homophones) were more prominent for L2 learners of Chinese, depending on the manner of phonology-orthography mapping of their L1 orthographic system.

3.2.1 Survey

At the beginning of the experiment, participants completed a questionnaire to provide basic demographic information such as age, gender, educational level, language background, and any visual, hearing, or neural conditions. To ensure that none of the participants had any prior experience with Chinese characters (including all dialects) or Japanese (due to the similarity between kanji and hànzì), a pre-experiment test was included in the survey, containing 20 Chinese characters. Participants were asked to indicate with a YES or NO whether they knew each target character. If the answer was YES, they were also asked to write down the pronunciation and the meaning of the character (see Appendix III). Additionally, Italian and Arabic participants were asked to indicate with a YES or NO whether they were familiar with a list of English words used to represent the meanings of Chinese characters in the training and
testing phases of the experiment, to ensure they understood the meanings of Chinese characters in the study.

The survey results revealed that none of the participants reported having any visual, hearing, or memory impairments, nor neurological or linguistic disorders. Moreover, none of the participants had any prior experience with the Chinese language nor Chinese characters, and all Italian and Arabic-speaking participants confirmed that they were familiar with the list of English words used in the study to represent the meanings of Chinese characters.

3.2.2 Training Phase

The training phase consisted of two types: four study-exercise sessions and two summative testing sessions. Participants completed all six training sessions within 11-14 days, completing roughly three sessions per week (see Figure. 1). Each study-exercise trial consisted of two parts: the introduction of new characters and exercises using those characters. In the introduction part, participants learned the meanings, pronunciations, and ways of writing five new characters, along with corresponding pictures that denoted meanings in English. The introduction of new characters was presented in a self-paced video format. In the exercise part, participants practiced the newly learned characters and old ones from previous training trials (starting from the second training session). The proportion of new and old characters in an exercise trial was five to three. The first study-exercise session was slightly different from the other three: it introduced and practiced only new characters (because there were no previously learned characters), and a video providing an overview of the training program and basic features of Chinese characters was presented at the beginning of the first training session.
The exercises in the training phase were selected based on teaching and learning theories (Celce-Murcia & McIntosh, 2014; Ellis & Shintani, 2013), specifically tailored for Chinese character learning (Chen et al., 2014; Jiang, 2003). The training sessions mainly consisted of task-based activities, such as ordering character-pinyin pairs using pictures, matching pictures and character-pinyin pairs, and games. These exercises were intentionally kept light-loaded to maintain the interest and motivation of novice learners and avoid the intense learning and rote memorization. Also, the experimental judgment task did not require participants to be expert character learners, so exercises were designed as multiple-choice, matching pairs, and true or false questions with animated pictures and games. However, to cater to different individual learning strategies, an optional "Draw it" question allowed participants to try writing the Chinese characters. While most exercises relied on visual and aural stimulus, this question accommodated learners who preferred learning through writing. To ensure fairness, participants were given only one entry for the writing practice to minimize any potential bias in learning results.

The first four study-exercise sessions included the following practices: "Matching Pairs," where participants paired pictures with the characters together with pinyin (a Roman alphabet system denoting pronunciations of Chinese characters); "Listening and Choosing," where participants selected the correct English meanings based on the pronunciation of the characters; "Choosing Correct Characters" based on pictures and English meanings; and "Filling in the Blanks," with provided options for either pinyin (i.e., pronunciations), meanings, or characters; "Drag and Drop," in which they rank pictures based on the listed order of character-pronunciation pairs; the game "Time to climb," where participants chose the correct character-pronunciation pairs based on picture-meaning pairs within 30 seconds. Participants could optionally participate in the "Draw it" practice, where they attempted to “draw” the Chinese
characters. Each character was presented an equal number of times in each type of practice to maintain balance. To ensure an equal amount of exposure to both orthographic and phonological information, characters and pinyin were typically displayed together (except for in the exercise “listening and choosing”). Finally, to emphasize the meaning of each character, pictures, and English meanings were always presented alongside the characters. For a more detailed overview, please see Appendix V.

Two summative testing sessions were incorporated into the study to assist participants in reviewing and recalling all the characters they had learned, given that they were all true novice learners. The summative tests were comprised of two question types: 1) similar to the practice questions used in the study-exercise trials but with all 20 characters, such as “Matching Pairs” and “Time to Climb”; and 2) akin to the experimental lexical decision task, where participants evaluated whether the characters (along with their pronunciations) and pictures (with their meanings in English) matched, but with longer display durations and without filler/distractor content as seen in the lexical decision task. In the last two training sessions, all elements, including characters, pronunciations, pictures, and meanings in English, were displayed together.

Each training session's duration ranged between 15-25 minutes, depending on the participants' learning pace. After completing the questions in each training session, participants received immediate corrective feedback. Additionally, the researcher monitored the participants' training progress, completion rates, accuracy, and progress via a web-based platform accessible on the teacher-end.
3.2.3 Testing Phase: Lexical Decision Task

A character lexical decision task as the main experiment was employed after the training phase. Participants were asked to judge whether the character-pronunciation pairs matched the picture-meaning pairs on the screen. The experimental stimuli included twenty target characters corresponding to twenty pictures. Meanwhile, each target character was paired with three fillers/distractors: homophone, homograph, and non-relevant character. Therefore, there were twenty pictures and eighty characters (i.e., 20 targets, 20 homophones, 20 homographs, and 20 non-relevant characters) altogether. Each question displayed one picture corresponding to one of four conditions: the target character, the homophone, the homograph, or the non-relevant character. Consequently, there were eighty questions in total, with twenty of them correctly matched between the characters and the pictures and the other sixty were unmatched (see
Appendix IV). Participants were presumed to predominantly rely on the phonological processing path if they were more distracted by the homophones. In contrast, if participants were more distracted by the homographs, then the orthographic processing path was assumed to be utilized (Perfetti & Zhang, 1995; Tan & Perfetti, 1997; Van Orden, 1987; Zhou & Marslen-Wilson, 1999, 2000).

In this computerized lexical decision task, the participants first saw instructions on the screen before the experiment started. They were asked to judge whether each picture-character pair that appeared on the screen matched, as fast and accurately as possible, by pressing either the left-arrow or the right-arrow keys on the keyboard. The left-arrow key indicated NO and the right arrow indicated YES. All stimuli were presented in white text on a dark grey background in the center of a 14-inch laptop screen, using Arial font size 20. Each trial started with a blank grey screen for 500 ms, followed by a picture-meaning pair displayed for 1000 ms, and then by a character, either the target or a foil character, with pinyin displayed on its right for 2000 ms (Chen et al., 2014, Matsumoto, 2013, Wang, 2014). To remind the participants of the direction of the negative and positive keys on the keyboard, one box with the word “NO” was displayed on the bottom left of the screen, and one box with the word “YES” on the bottom right) on the right once the character appeared on the screen. These boxes remained on the screen for an additional 1000 ms after the character disappeared, in case participants had a delayed reaction. Following each trial, there was another 500 ms of a blank grey screen before the next trial began (see Figure 2.). Altogether, each question remained on the screen for 5000ms, which was half of the time that Matsumoto (2013) set for her participants. This is because it was two or three-character word recognition in her experiment and one-character recognition in the current study.
The lexical decision task consisted of 80 questions, which were divided into four groups, with each group containing 20 questions. In each group, twenty pictures were shown once, each paired with one of four types of characters - target, homophone, homograph, and non-relevant characters. Each group contained five target characters and fifteen filler characters. This meant that each character, whether target or filler, appeared only once among the 80 questions, but each of the twenty pictures was repeatedly shown four times across the four groups. The order of questions in each group was not randomized to ensure that targets and fillers were evenly distributed. To help participants adjust to the pace of the task, they were given six practice trials with target character stimuli before the actual experiment started.

Figure 2.

*The Paradigm of Each Trial in the Experiment*

3.3 Stimuli

3.3.1 Testing materials

The stimuli for the lexical decision task consisted of 20 Chinese single characters as targets, and each character was paired with a homophone filler as phonological interference, a homograph filler as orthographic interference, an irrelevant character as control, and a corresponding picture that denoted the meaning (Leck, et al., 1995; Hao, 2007; Perfetti & Zhang,
1995; Matsumoto, 2013). Both integrated and compounding characters were included, but the structures of characters (e.g., integrated; left-right compound; top-down compound) in each pair were kept the same. The stroke numbers of characters in each pair were similar as well (see Appendix II).

Homophone pairs shared the same consonants, vowels, and tones, since the phonological interference effect was only found in the exact homophones (Xu et al., 1999; Zhou & Marslen-Wilson, 1999, 2000). Homographs either shared the same component (for compounding characters) or had a similar structure and stroke (for integrated characters) with the target character. Meanwhile, the pronunciations between the targets and the homographs were different, i.e., no shared onsets (consonants) nor rimes (vowels). The irrelevant characters were different from the target characters in pronunciation, shape, and meaning (please see samples in Table 2). The study did not place significant emphasis on the frequency of characters. While previous research has found that both word frequency and character structure can influence the processing of characters for both native Chinese Mandarin speakers and experienced non-native learners (Chen et al., 2003, 2006, 2007; Law, et al., 2009; Leck et al., 1995; Xu, et al., 1999; Yum, et al., 2016; Zhou & Marslen-Wilson, 1999), it was believed that for beginning learners who lacked sufficient knowledge of Chinese characters, such as identifying subcomponents (e.g., phonetic and semantic components) or pre-knowledge of high-frequency characters, neither frequency nor structure would interfere with their judgment (Wang, 2016). All of the characters used as stimuli were real characters sourced from the Contemporary Chinese Dictionary (现代汉语词典, Jiang, Tan, & Cheng, 2016). Furthermore, none of the 20 target characters were orthographically or phonologically similar to one another.
Table 2

(Character Stimuli Used in the Experiment)

<table>
<thead>
<tr>
<th></th>
<th>Target character</th>
<th>Homophone</th>
<th>Homograph</th>
<th>Non-relevant character</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Integrated</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>characters</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meanings</td>
<td>丰 (fēng /fəŋ1/)</td>
<td>风 (fēng /fəŋ1/)</td>
<td>干 (gān /gan1/)</td>
<td>云 (yún /yn2/)</td>
</tr>
<tr>
<td>Strokes</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>Compounding</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>characters</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meanings</td>
<td>纪 (jì /ʨi4/)</td>
<td>技 (jì /ʨi4/)</td>
<td>红 (hóng /hoŋ2/)</td>
<td>许 (xŭ /ɕy3/)</td>
</tr>
<tr>
<td>Strokes</td>
<td>6</td>
<td>7</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

To avoid obscure distractions between orthographic-related and phonological-related foils (Leck et al., 1995; Van Orden, 1987), 15 native Chinese speakers (ages 32-42) were asked to rate the orthographic similarities between the targets and homophones, homographs, and control characters on a 5-point Likert scale (5 = very similar; 1 = very different). The mean scores of the orthographic similarities between targets and each of the three other conditions of homophones, homographs, and control characters were 3.84 ($SD = 0.79$), 1.34 ($SD = 0.38$), and 1.32 ($SD = 0.29$) respectively. Pairs rated above 3 were deemed orthographically similar (Chen et al., 2014; Matsumoto, 2013). Additionally, a one-way ANOVA was conducted with foil type (homograph, homophone, and control character) as the independent variable and the rated scores as the dependent variable. The results demonstrated a significant difference in similarities between the targets and the homographs, homophones, and irrelevant characters [$F (2, 34.51) = 88.79, p < .001$]. A Tukey post hoc test further revealed that the orthographic similarities between the targets and the homographs were significantly higher than those between the targets and the
homophones ($d = 6.25, p < .001$) and irrelevant characters ($d = 8.3, p < .001$), with large effect sizes.

3.3.2 Training materials

The 20 target characters used in the character lexical decision task were also included in the training sessions along with their corresponding pictures and meanings. During the training sessions, participants were instructed to learn the pronunciations, written forms, and meanings of all 20 characters. However, the three types of fillers used in the task (homophones, homographs, and irrelevant characters) were excluded from the training materials to prevent any familiarity effects during the lexical judgment task.

Twenty target characters were divided into four groups, with each group containing five characters (see Appendix I). The orthographic structures, such as left-right, top-down, enclosure, and integrated structures, were equally distributed among each group. The average number of strokes of characters in each group was the same, 7.6 strokes. The right side of the characters displayed their pinyin symbols, representing their pronunciations. Additionally, an audio recording of each character's pronunciation was played three times while the character was displayed on the screen. Furthermore, an animated process of writing each character stroke by stroke in order was also shown to reinforce the participants' impression of the features of Chinese characters. Corresponding pictures of the characters were displayed on the same page, along with English meanings (one or two simple words) to help participants to better understand the characters. Participants from Arabic-speaking and Italian-speaking backgrounds were asked to recognize the English words in a pre-experiment survey to ensure they knew them and were not confused with the meanings of the target characters, but the instructions for the training sessions,
such as "please tell if the pictures and the characters match", were translated into Arabic and Italian respectively.

### 3.4 Procedure

The participants were recruited via email through the daily newsletter from a university in a southern state of the US, as well as through snowball sampling by asking friends, colleagues, and participants to participate. The recruitment letter provided basic information about the experimental procedures, time commitments, language qualifications, and rewards. Once potential participants expressed their interest in the experiment via email, the researcher provided more detailed instructions and a survey via email. Individuals who did not meet the eligibility criteria (e.g., who had previously learned Chinese or Japanese; whose ages significantly differ from the other participants, etc.), were not selected.

The training phase lasted around two weeks for each participant, spanning from October 2022 to February 2023. The training sessions were conducted through an online learning platform called Nearpod. The participants were able to access instructional videos, presentation slides, and exercises through their personal laptops or cellphones. The participants were instructed to set aside enough time to complete the two-week training and were recommended to begin the training sessions every other day. The training links of each session along with the corresponding instructions of the session were sent via email one day after the participants completed the previous session. If a participant had not completed a training session for more than two days, email reminders were sent as a prompt. Participants who did not do the training sessions for more than three consecutive days were excluded from the experiment.
Participants were individually presented with a lexical decision task via a laptop in a quiet lab room or study room in the university library, one or two days after the completion of all training sessions. To minimize potential distractions, participants were advised to mute their cellphones during the experiment. The PsychoPy (version 2022.2.4) program was used to conduct the experiment, which is designed for neuroscience, psychology, and linguistics research to accurately record participants' reaction times and accuracy rates to the millisecond. The lexical decision task consisted of 80 questions, divided into four groups, and participants were given a 30-second break after each group of questions, with three breaks in total. Prior to the actual experiment, participants were given six practice trials to become accustomed to the speed of the task, followed by a one-minute break. All participants who completed the whole experiment were debriefed, thanked, and given a 20-dollar Amazon gift card for their participation.

3.5 Data Analysis

During the lexical decision task, participants' reaction times (RT) in milliseconds and their accuracy rates (0=wrong, 1=correct) were recorded. The mean response times and accuracy rates for each answer type (i.e., targets, homographs, homophones, and nonrelevant characters) were analyzed for each participant. The assumption was that participants would utilize the orthographic path to process L2 Chinese written words if they took longer time or were less accurate in responding to the homographs, and would use the phonological path to process written Chinese words if they took longer time or were less accurate in responding to the homophones. Additionally, participants were expected to respond to the non-relevant characters more accurately and quickly, as they were neither orthographically nor phonologically familiar to them. Also, participants might respond to the target characters more accurately and quickly
because these characters were expected to be orthographically and phonologically familiar to them after two-week-long training.

Any missing items were coded as 0 for accuracy and 3000 ms for reaction time (which is the total screen duration for feedback). Participants with an answer rate below 75% (i.e., with 20 or more missing answers) were excluded from the data analysis. In this case, one Arabic-speaking participant's data were excluded, resulting in a total of thirteen participants in each language group included in the data analysis.

The data analysis was performed using SPSS 29.0. A two-way mixed Analysis of variance (ANOVA) was conducted to analyze participants' mean response times and accuracy rates, with one between-group factor (language group, 3 groups) and one within-group factor (answer type, 4 types). Follow-up post hoc tests with multiple pairwise comparisons were conducted to examine the results in greater details.
CHAPTER 4

RESULTS

4.1 Accuracy

To ensure the reliability of the data, the accuracy rate data were transformed using the square root arcsine to improve the normality of the data at each level. Prior to conducting the mixed ANOVA, the data were checked for outliers, normality, homogeneity, and sphericity across the twelve levels of data (3 language groups x 4 answer types) to ensure the validity of the statistical analysis. Overall, no extreme outliers were identified based on the Boxplot. The accuracy rates for homophones and homographs in all three language groups were normally distributed \((p > .05)\), but the mean accuracy rates for both targets and non-relevant characters in all three language groups were not normally distributed as assessed by Shapiro-Wilk's test of normality \((p < .05)\). This deviation from normality could be due to the familiarity effect of targets that participants were trained and the unfamiliar phonological and orthographic features of the non-relevant characters that they were never exposed to, which could have resulted in high scores for these types of answers. Levene's test showed that the data of accuracy for all three groups did not violate the assumption of homogeneity of variances \((p > .05)\). However, Mauchly's test indicated that the assumption of sphericity was violated \((\chi^2(5) = 43.67, p < .001)\), so the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity \((\varepsilon = .61)\).
The results showed that beginning Chinese learners from all three L1 language groups achieved the lowest accuracy rates in responding to the phonological distractors (i.e., homophones). Specifically, the English group had an accuracy rate of 51.92\% \ (SD = .33), the Arabic group had an accuracy rate of 50.38\% \ (SD = .30), and the Italian group had an accuracy rate of 52.69\% \ (SD = .32). The second lowest scores were obtained in responding to the orthographic distractors (i.e., homographs) with the English group achieving an accuracy rate of 81.15\% \ (SD = .14), the Arabic group achieving an accuracy rate of 73.08\% \ (SD = .27), and the Italian group achieving an accuracy rate of 86.15\% \ (SD = .14). However, all participants achieved high accuracy rates (> 90\%) in responding to the targets and the non-relevant characters (see Table 3 and Chart 1).

Table 3

*Means and Standard Deviations on Accuracy of Three Language Groups*

<table>
<thead>
<tr>
<th>Language groups</th>
<th>Targets Mean</th>
<th>SD</th>
<th>Homographs Mean</th>
<th>SD</th>
<th>homophones Mean</th>
<th>SD</th>
<th>Non-relevant characters Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td>93.85%</td>
<td>0.11</td>
<td>81.15%</td>
<td>0.14</td>
<td>51.92%</td>
<td>0.33</td>
<td>93.85%</td>
<td>0.07</td>
</tr>
<tr>
<td>Arabic</td>
<td>93.85%</td>
<td>0.06</td>
<td>73.08%</td>
<td>0.27</td>
<td>50.38%</td>
<td>0.30</td>
<td>90%</td>
<td>0.16</td>
</tr>
<tr>
<td>Italian</td>
<td>94.62%</td>
<td>0.06</td>
<td>86.15%</td>
<td>0.14</td>
<td>52.69%</td>
<td>0.32</td>
<td>96.92%</td>
<td>0.04</td>
</tr>
</tbody>
</table>
The mixed ANOVA revealed a significant main effect of answer types (i.e., the targets, the homophones, the homographs, and the non-relevant characters) in mean accuracy rates within each language group, $F (1.83, 65.81) = 52.37, p < .001, \eta^2 = .593, \varepsilon = .61$ (see Chart 2). Post hoc tests (see Table 4) showed that among English native speakers, the accuracy rate for homographs was significantly different from the targets ($M = .138, SE = .042, p < .05$), but not significantly different from the non-relevant characters ($M = -.134, SE = .043, p > .05$). The accuracy rates of homophones were significantly different from both the targets ($M = .417, SE = .068, p < .001$) and non-relevant characters ($M = -.413, SE = .072, p < .001$). Moreover, English native speakers had significantly different accuracy rates between homographs and homophones ($M = .279, SE = .076, p = .019$) in recognizing written Chinese characters.
The Arabic native-speaking group had significantly lower accuracy rates when responding to homographs compared to non-relevant characters ($M = .185, SE = .04, p < .01$). In addition, their accuracy rates for responding to homophones were significantly lower than both the targets ($M = .449, SE = .10, p < .01$) and the non-relevant characters ($M = .419, SE = .075, p < .01$). There was no significant difference between responding to homophones and homographs ($M = .235, SE = .097 p = .191$).

Among Italian native speakers, participants’ responses to homographs were not significantly different from both the targets ($M = .093, SE = .047, p = .417$) and the non-relevant characters ($M = .131, SE = .042, p = .057$). However, their accuracy rates of homophones were significantly lower than both the targets ($M = .422, SE = .086, p < .01$) and the non-relevant characters ($M = .46, SE = .083, p < .001$). Furthermore, there was a statistically significant difference in accuracy rates between the homophones and the homographs ($M = .329, SE = .10, p < .05$).

### Table 4

**Pairwise Comparisons Between Four Answer Types in Three Language Groups (Accuracy)**

<table>
<thead>
<tr>
<th></th>
<th>English</th>
<th>Arabic</th>
<th>Italian</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T</td>
<td>HG</td>
<td>HP</td>
</tr>
<tr>
<td>Targets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$*p &lt; .001$</td>
<td>$SE = .068$</td>
<td>$M = .417$</td>
</tr>
<tr>
<td>Homophones</td>
<td>$*p = .019$</td>
<td>$SE = .076$</td>
<td>$M = .279$</td>
</tr>
<tr>
<td></td>
<td>$SE = .032$</td>
<td>$SE = .064$</td>
<td>$M = .134$</td>
</tr>
<tr>
<td>Non-relevant characters</td>
<td>$p = 1.00$</td>
<td>$SE = .032$</td>
<td>$M = -.134$</td>
</tr>
<tr>
<td></td>
<td>$*p &lt; .001$</td>
<td>$SE = .072$</td>
<td>$M = .029$</td>
</tr>
</tbody>
</table>

**Notes:**
1. T=targets; HG=homographs; HP=homophones; N=non-relevant characters
2. Adjustment for multiple comparisons: Bonferroni
However, the main effect between language groups (i.e., English, Arabic, Italian) showed that there was no statistically significant difference in mean accuracy rates between the language groups, $F (2, 36) = .75, p = .48$, partial $\eta^2 = .04$. Additionally, there was no statistically significant interaction between the answer types and language groups in terms of accuracy rates, $F (3.66, 65.81) = .316, p = .85$, partial $\eta^2 = 0.02$, with an epsilon correction of 0.61 (see Chart 1 and Chart 2). This indicates that the overall accuracy rates for the four types of answers were statistically non-different among the three language groups.

4.2 Latency (Reaction Time)

Similarly, twelve levels of data (3 language groups × 4 answer types) were pre-checked for the outliers, normality, homogeneity, and sphericity before running the mixed ANOVA. The boxplots showed that there were no extreme outliers (i.e., more than 3 box-lengths away from the edge of their box) in each of the language groups. The reaction time to four types of answers in all three language groups was normally distributed ($p > .05$), as assessed by Shapiro-Wilk’s test. Levene’s test showed that the means of reaction time in responding to the targets, the homographs, and the homophones of three language groups did not violate the assumption of homogeneity of variances ($p > .05$), and the median of the reaction time in responding to the non-relevant characters of the three language groups did not violate the assumption of homogeneity of variances ($p > .05$). Moreover, Mauchly’s test of sphericity indicated that the assumption of sphericity was met for the two-way interaction, $\chi^2(5) = 7.67, p = .175$, indicating that the covariance matrices were equal for the different groups and conditions.

Overall means and standard deviations of reaction time on the lexical decision task were presented in Table 5 and Chart 3. Across all three language groups, beginning Chinese learners
took the longest time to reject phonological distractors (i.e., homophones) when recognizing written Chinese words: 1400 ms ($SD = 226$) for English native speakers, 1631 ms ($SD = 349$) for Arabic native speakers, and 1607ms ($SD = 349$) for Italian native speakers. English and Arabic native speakers took the second longest time in rejecting the orthographic distractors (i.e., homographs): 1235 ms ($SD = 180$) and 1472 (418), respectively. However, Italian native speakers took a longer time in rejecting targets (1450 ms, $SD = 391$) than the homographs (1413 ms, $SD = 377$). Almost all participants spent the least amount of time rejecting the controls (i.e., non-relevant characters): 1181 ms ($SD = 149$) for English speakers, 1282 ms ($SD = 387$) for Italian speakers, and 1475 ms ($SD = 408$) for Arabic speakers, which was a slightly longer time than the time taken to respond to targets (1472ms, $SD = 418$).

**Table 5**

**Means and Standard Deviations on RT (in milliseconds) of Three Language groups.**

<table>
<thead>
<tr>
<th>Language groups</th>
<th>Targets</th>
<th>Homographs</th>
<th>Homophones</th>
<th>Non-relevant characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td>1235 180</td>
<td>1321 175</td>
<td>1400 226</td>
<td>1181 149</td>
</tr>
<tr>
<td>Arabic</td>
<td>1472 418</td>
<td>1622 468</td>
<td>1631 349</td>
<td>1475 408</td>
</tr>
<tr>
<td>Italian</td>
<td>1450 391</td>
<td>1413 377</td>
<td>1607 349</td>
<td>1282 387</td>
</tr>
</tbody>
</table>

The main effect of the four answer types (the targets, the homophones, the homographs, and the non-relevant characters) revealed a significant difference in mean reaction time within each language group, $F [3, 108] = 18.90, p < .001, \eta^2 = .34$. Further post hoc tests (see Table 6) showed that for participants in the English native-speaking group, the reaction times to non-relevant characters were statistically significantly different from both the homophones ($M = 219$, $SE = 55, p < .01$) and the homographs ($M = 140, SE = 31, p < .001$). However, the reaction time between the homographs and the targets was not statistically significant ($M = 85.39, SE =$
41.41, \( p = .06 \), in contrast to the significant differences observed between homophones and the targets (\( M = -164.62, SE = 61.7, p = .02 \)).

**Chart 2**

*The Estimated Marginal Means of Reaction Time Between Three Language Groups*

![Chart showing estimated marginal means of reaction time between three language groups](chart.png)

**Table 6**

*Pairwise Comparisons Between Four Answer Types in Three Language Groups (RT)*

<table>
<thead>
<tr>
<th>Answer types</th>
<th>English</th>
<th>Arabic</th>
<th>Italian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Targets</td>
<td>T</td>
<td>HG</td>
<td>HP</td>
</tr>
<tr>
<td>Homographs</td>
<td>( p = .06 )</td>
<td>SE = 41</td>
<td>SE = 62</td>
</tr>
<tr>
<td>Homophones</td>
<td>( p = .02 )</td>
<td>SE = 62</td>
<td>SE = 64</td>
</tr>
<tr>
<td>Non-relevant characters</td>
<td>( p = .16 )</td>
<td>SE = 55</td>
<td>SE = 49</td>
</tr>
<tr>
<td></td>
<td>( p &lt; .001 )</td>
<td>SE = 31</td>
<td>SE = 168</td>
</tr>
</tbody>
</table>

Notes: 1. T=targets; HG=homographs; HP=homophones; N=non-relevant characters
2. Adjustment for multiple comparisons: Bonferroni
The reaction time of Arabic native speakers showed that their response to the orthographic distractors (i.e., homographs) was statistically significantly longer than both the targets ($M = -151$, $SE = 62$, $p < .05$) and the non-relevant characters ($M = 147$, $SE = 47$, $p < .01$). Similarly, the reaction time of Arabic speakers to the phonological distractors (i.e., homophones) was also significantly longer than both the targets ($M = -159$, $SE = 57$, $p < .01$) and the non-relevant characters ($M = 155$, $SE = 56$, $p < .01$).

For Italian native speakers, their reaction time to the homographs was significantly longer than that to the non-relevant characters ($M = -132$, $SE = 33$, $p < .01$), but not significantly longer than that to the targets ($M = 36$, $SE = 58$, $p = .55$). However, their reaction time to the homophones was significantly longer than both the targets ($M = -157$, $SE = 60$, $p < .05$) and the non-relevant characters ($M = -325$, $SE = 37$, $p < .001$). Unlike English and Arabic native speakers, Italian L1 speakers spent a significantly different amount of time reacting to homographs and homophones ($M = 193$, $SE = 35$, $p < .001$) and between targets and non-relevant characters ($M = -168$, $SE = 49$, $p < .01$).

However, the main effect of the language group showed no statistically significant difference in mean reaction time between groups, $F (1, 36) = 2.31$, $p = .114$, partial $\eta^2 = .114$ (see Chart 3 & 4), although the post hoc test revealed that English native speakers spent significantly less reaction time in the lexical decision task than the Arabic native speakers, $p = .039$, $SE = 124.09$, with a 95% confidence interval for the difference of [-517.46, -14.12]. Furthermore, there was no statistically significant interaction between the answer types and language groups in terms of reaction time, $F (6, 108) = 1.75$, $p = .12$, partial $\eta^2 = .09$. These results indicated that the patterns of the reaction time in response to the four answer types were
statistically non-different among English, Arabic, and Italian L1 speakers in recognizing written Chinese characters.
CHAPTER 5
DISCUSSION

The present study aims to investigate how beginning learners of Chinese, whose native writing systems are phonographic but with varying phonological-orthographic consistencies, process written Chinese words. To this end, six online training sessions and a lexical decision task were conducted for 39 participants whose native languages are English, Arabic, and Italian. The study sought to address two main research questions: first, whether beginner Chinese learners with different phonographic L1s are capable of processing Chinese characters orthographically, and second, to what extent the different phonological-orthographic consistencies of their L1 writing systems influence their ability to identify L2 printed words. More specifically, the study examined whether all learners perform less accurately and more slowly when presented with homophones than with homographs, and compared to L1 Italian speakers, whether L1 English and L1 Arabic speakers perform less accurately or less quickly when presented with homographs?

To answer these questions, the lexical decision task with the simultaneous presentation of orthographic forms (i.e., Chinese characters), phonological forms (i.e., pinyin), and semantic information (i.e., the pictures and the meanings in English) was designed to ensure that participants utilized their preferred information, either orthographic or phonological, to access the lexical entry. In the lexical decision task, four types of stimuli were presented in the task, one target character, and three fillers: homophones, homographs, and non-relevant characters.
Based on previous studies (Commissaire, et al., 2011; Chikamatsu, 2006; Deacon, et al., 2009; Hao, 2007; Matsumoto, 2013; Wang et al., 2002), it is assumed that in the current study, beginner Chinese learners with phonographic L1s (i.e., all participants in this study) primarily rely on phonological processing. According to the ODH theory and the features of three orthographies (i.e., Italian, English, Arabic) (Bates, et al., 2001; Dawson & Phelan, 2016; Ellis & Hooper, 2001; Katz & Frost, 1992), Italian participants, with the most transparent L1 orthography, are predicted to use more phonological processing than English and Arabic participants when recognizing L2 Chinese written words. In contrast, Arabic-speaking participants, with the least transparent L1 orthographies, are expected to use more orthographic processing compared to their Italian and English counterparts. English-speaking participants' use of orthographic or phonological processing is proposed to fall in between Italian and Arabic speakers in recognizing L2 Chinese written words.

5.1 Orthographic Effects were found in Processing Written Chinese Characters by All Participants, the Beginner Learners with Varied Phonographic L1s

Regarding the first research question, “Are beginning Chinese L2 learners with phonographic L1 able to process Chinese characters orthographically, or are they distracted by homographs in the experiment?”, the results revealed that participants from all three language groups exhibited significantly longer reaction times when responding to homographs compared to non-relevant characters. Moreover, Arabic L1 speakers displayed significantly longer reaction times when responding to homographs compared to both the targets and the non-relevant characters. In terms of accuracy rates, English native speakers were less accurate in responding to homographs than targets. Similarly, Arabic-speaking participants were less accurate in
responding to homographs than the non-relevant characters. However, no significant differences were observed between homographs and the targets or the non-relevant characters among Italian speakers. Meanwhile, Italian speakers achieved the highest mean accuracy rate (86.15%, compared to English 81.15% and Arabic 73.08%) in responding to homographs among the three language groups, indicating the least distraction by orthographic information - although the difference between three language groups was not statistically significant ($p > 0.05$). These findings suggested that all participants, despite having phonographic L1 writing systems with varying degrees of orthographic-phonological consistency, were somewhat distracted by the orthographically-similar filler, indicating a visual-orthographic process, at possibly different levels, in recognizing logographic Chinese written words.

The results of the present study suggested that even very early Chinese learners, who have only received two weeks of character training, demonstrated orthographic processing when identifying typologically different L2 logographic printed words, despite having phonographic L1 writing systems. Previous research also identified early orthographic awareness in L2 learners of Chinese whose L1s were alphabetic. For instance, Jiang (2003) utilized a paper-based test and discovered that English speakers who studied Chinese for 5 months already possessed an awareness of character structure (e.g., up-down type). Similarly, in a cross-sectional study employing paper-based assessments, Hao (2007) found that elementary-level Chinese learners (who had knowledge of 543 characters) had already developed an awareness of component position within a Chinese character. Although the short duration of training in the present study suggests that participants may not yet have acquired awareness of character structures or component positions, their distraction by orthographic information when presented
simultaneously with phonological information in the lexical decision task could be explained by a salient orthographic process.

The orthographic distraction observed in early Chinese L2 learners might also be attributed to a learning pattern similar to that of Chinese L1 children when learning Chinese characters (Siok & Fletcher, 2001; Tan et al., 2005). Specifically, in the early stages of learning, younger Chinese children tend to rely more on orthographic processing when reading because they tend to remember characters one by one, with phonological processing being developed later when an adequate reservoir of characters has been acquired. The unique features of Chinese characters render early learners either to know the character or not to know it at all, leaving them unable to infer phonological information using sublexical information (Perfetti & Harris, 2013). Consequently, orthographic processing becomes the primary strategy for Chinese native speakers during the early stages of learning. Similarly, early Chinese L2 learners may also learn characters one by one, and once they remember the shape of characters, they process them through the orthographic path.

It is noteworthy that, despite lacking statistical significance, minor differences did exist between participants from the three groups in their responses to homographs. Specifically, only Arabic native speakers took a significantly longer time to reject the homographs than both the targets and the non-relevant characters, meanwhile, they had the longest mean reaction time among the three language groups [1622 ms, compared to English (1321 ms) and Italian (1413 ms) groups]. This outcome might suggest that Arabic native speakers relied more on the orthographic process than English and Italian native speakers. Moreover, only Italian native speakers did not show a significant difference in their accuracy rate of homographs compared to both the non-relevant characters and targets, which indicated that Italian native speakers relied
the least on the orthographic process. According to the orthographic depth hypothesis (ODH) (Katz & Frost, 1992), readers of shallow orthographies were more prone to phonological processing of printed words. Conversely, readers of deep orthographies relied more on the visual-orthographic processing path for recognizing written words. Studies focusing on phonographic L1 reading supported the ODH theory (Aro & Wimmer, 2003; Landerl et al., 1997; Paulesu et al., 2000). However, the current study provided insight into the recognition of logographic L2 written words and how this aligns with the ODH theory. Among the three phonographic writing systems, Arabic had the most opaque orthography (i.e., omitting vowels in most cases, Katz & Frost, 1992), and its L1 speakers relied the most on the orthographic process when recognizing L2 logographic words, shown in the current study. On the other hand, Italian had the most transparent orthography, and its L1 speakers relied the least on the orthographic process in recognizing logographic L2 written words.

5.2 Differential Effects of Orthographic and Phonological Distractions on Chinese Character Recognition Across Three Language Groups

The current study also examined to what extent orthographic and phonological information impact participants with different phonographic L1s on processing L2 Chinese written words. The results revealed that participants from all three language groups showed significant distractions by homophones, indicating that L2 Chinese learners whose L1s were phonographic writing systems with varying phonological-orthographic consistencies tended to rely heavily on phonological processing. Specifically, participants across all three groups displayed significantly longer reaction times when responding to the homophones than to both the targets and the non-relevant characters. In terms of accuracy rates, all three groups demonstrated lower accuracy
rates in responding to homophones than to both the targets and the non-relevant characters. The strong effects on homophones to both the targets and the non-relevant characters on the latency and the accuracy were not equally found on homographs (see section 5.1).

The strong phonological effects found in recognizing logographic L2 written words among participants with phonographic L1 writing systems, but differing orthography-phonology correspondence, aligned with previous research on cross-orthographic reading. Phonographic L1 readers tended to transfer their L1 written word processing strategies to different types of L2 reading, regardless of typological similarities between L1 and L2. For example, English native speakers used phonological processing in recognizing logographic L2 Japanese kanji (Chikamatsu, 2006; Matsumoto, 2013). Spanish native speakers performed significantly better in recognizing alphabetic L2 (English) compared to logographic L2 (Chinese) written words (Wang, 2014). Korean native speakers outperformed their Chinese L1 counterparts in identifying L2 English printed words due to their L1 phonological processing skills (Wang, et al., 2003). Dutch native speakers also benefited more from their L1 reading skills and phonological awareness when reading transparent L2 orthography Spanish than less transparent L2 orthographies, French and Chinese, due to the orthographic distance between L1 and L2 orthographies (Zeguers, et al., 2018). Therefore, the present study's finding that phonographic L1 readers from all three language groups primarily used their L1 reading strategies, specifically the phonological processing path, when recognizing L2 Chinese written words, also aligns with the earlier predictions.

Although no statistical significance between the three language groups in answering four types of answers was found in both the latency ($p = .12$) and accuracy ($p = .85$), distinctions were observed in the participants' responses to homographs and homophones. Not all participants
were more distracted by phonological information than orthographic information, or in other words, not all participants perform significantly less accurately and more slowly when presented with homophones than with homographs. Specifically, Italian native speakers showed longer reaction times and lower accuracy rates in responding to homophone than to homographs, indicating a stronger reliance on the phonological process. In contrast, Arabic speakers demonstrated no significant difference in accuracy rate or reaction time when responding to homophones and homographs, suggesting a balanced phonological-orthographic processing approach. Finally, English native speakers showed results that fell in between: less accurate in homophones but no difference in reaction times between homophones and homographs.

Regarding the responses to homophones and homographs among all three language groups, Italian native speakers, in comparison to English and Arabic speakers, demonstrated less distraction from orthographic information and greater distraction from phonological information. Interestingly, it is worth noting that Italian native speakers were the only group to reject the homographs (1413 ms) faster than the targets (1450 ms). It may be attributed to the absence of familiar or distracting phonological information in the homographs, making them easier to rule out in comparison to targets, which required the processing of at least familiar pronunciations. Taken together, these findings suggested that Italian speakers predominantly relied on phonological processing, with a limited or subsidiary orthographic process, when recognizing logographic L2 Chinese words.

5.3. Highlights from the Present Study

The findings of the current study demonstrated that participants from all three language groups were distracted by both the orthographic and phonological information to lexical entry,
albeit to varying degrees. Considering these differences in reliance on orthographic or phonological cues were found among participants with phonographic L1s of varying degrees of orthographic transparency, the weak Orthographic Depth Hypothesis (ODH) (Katz & Frost, 1992) might best explain the phenomenon. According to the weak ODH, both phonological and visual-orthographic processes were involved in written word recognition. The degree of activation of these two paths was dependent on the orthographic depth: the more transparent the orthography, the more readers relied on the phonological path, and the more opaque the orthography, the more readers relied on the orthographic path.

The ODH is supported by numerous studies on L1 reading, including alphabetic, abjad, and logographic writing systems. For instance, Italian and English native speakers were found activated different brain areas during L1 reading, with Italians relying on phonological processing and English speakers on semantic or orthographic processing (Paulesu et al., 2000). Also, English-speaking children were found less accurate in pseudoword reading compared to peers with more transparent native writing systems (e.g., Dutch, Swedish, Spanish, and Finnish) (Aro & Wimmer, 2003; Landerl et al., 1997; Rau et al., 2016). Studies on L1 abjad orthographies (e.g., Arabic, Hebrew, Persian) demonstrated that their deep and opaque nature, resulting from complex orthographic-phonological consistency, requires heavy reliance on orthographic processing (Russak & Fragman, 2014; Arab-Moghaddam & Sénéchal, 2001; Boumaraf & Macoir, 2016; Bentin & Ibrahim, 1996). Research on deep and logographic Chinese written word recognition indicated that L1 Chinese readers utilize both orthographic and phonological processing, with orthographic processing being predominant (Perfetti & Zhang, 1995; Tan & Perfetti, 1997; Xu, et al., 1999; Wang, et al., 2010; Wong, et al., 2014; Zhang et al., 2009; Zhou & Marslen-Wilson, 1999). Overall, these studies provide substantial evidence that the degree of
orthographic transparency impacts how readers process written words: more transparent orthographies lead to increased reliance on phonological processing, while deeper orthographies lead to greater reliance on orthographic processing.

The current study shed light on the recognition of logographic L2 written words and its alignment with the ODH theory. Specifically, the findings revealed that the transparency of L1 orthographies influences the processing patterns of recognizing logographic L2 printed words. According to the results found in the present study, Arabic speakers were most distracted by orthographic fillers, whereas Italian speakers were least distracted by orthographic information. Meanwhile, Italian speakers were found to be more distracted by phonological information compared to English and Arabic speakers. The order of transparency of the three involved orthographies, from highest to lowest, was Italian, English, and Arabic (Katz & Frost, 1992), and consequently, the reliance on orthographic processing, from highest to lowest in order, was found to be Arabic, English, and Italian, which was in line with the ODH theory that addressed L1 reading patterns.

Furthermore, it is possible to argue that the distance between the L1 and L2 orthographies in terms of orthographic transparency may account for the extent to which reliance was placed on orthographic or phonological processing paths. Previous studies showed that typological differences between L1 and L2 orthographies impacted L2 word recognition (Chikamatsu, 2006; Matsumoto, 2013; Wang, et al., 2003). The current study further demonstrated that the degree of transparency distance between L1 and L2 orthographies also affected the processing patterns of L2 words. Chinese is an opaque orthography – no phonological information in integrated characters and inconsistent phonological components in compound characters or phonograms (Leck, et al., 1995; Zhou & Marslen-Wilson, 1999). Prior studies showed that Chinese L1
speakers relied majorly on the orthographic path (Chen & Shu, 2001; Tan, et al., 2005a; Wang, et al, 2010). Of the three phonographic writing systems involved in the current study, Arabic written forms were the most opaque and thus the closest to Chinese in terms of orthographic transparency. Therefore, Arabic speakers showed the strongest reliance on the orthographic process when recognizing L2 Chinese, whereas Italian exhibited the greatest dissimilarity to Chinese scripts in orthographic transparency, and, thus, Italian speakers demonstrated the weakest reliance on the orthographic process in identifying L2 Chinese written words.

The present study extended previous research by revealing that even among L2 learners of Chinese with different phonographic L1s, distinct ways of processing logographic Chinese L2 words were evident. Previous investigations of L2 Chinese written word recognition primarily focused on differences in processing patterns between learners with phonographic L1s (e.g., English, Indonesian, Spanish) and those with logographic L1s (e.g., Japanese kanji, Korean hanja) (Hao, 2007; Jiang, 2003; Wang, 2014; Zhang & Wang, 2010). For example, Jiang (2003) utilized paper-based sound-meaning and sound-character tests to compare the effects on novice L2 Chinese learners whose native languages were Japanese, Korean, English, and Indonesian. His findings indicated identical results between English and Indonesian speakers due to their shared phonographic L1 writing systems, which lacked the distinctions between native readers of these two phonographic L1s. The current study provided a broader perspective on how L2 Chinese learners recognize written words. Given that the majority of world languages utilize phonographic orthographies, most Chinese learners' first writing systems are phonographic. Consequently, understanding how learners' native writing systems, with their different orthographic transparencies, affect the processing of L2 Chinese words is particularly valuable in guiding the teaching of writing in Chinese.
In addition to the results aligning with predictions, the study also uncovered unexpected findings. Despite exhibiting the highest degree of reliance on orthographic processing in recognizing Chinese characters, Arabic native speakers did not outperform Italian and English native speakers in terms of accuracy or speed when recognizing Chinese written words. In fact, longer processing times by Arabic native speakers when identifying their L1 orthographies in comparison to readers with more transparent L1 orthographies (e.g., English and Serbo-Croatian) (Russak, & Fragman, 2014), were also observed in recognizing L2 written words in the current study. Overall, Arabic speakers spent a longer time responding to all types of answers than English speakers \( (p = .039) \) and Italian speakers \( (p = .373) \). This result might be attributed to the reading strategies employed in their native orthography. The abjad feature within the Arabic writing system restricted the use of written symbols to consonants and long vowels. Moreover, a single consonant unit might correspond to multiple words with different pronunciations and meanings, necessitating substantial reliance on consonants and contextual cues for native readers (Juhani, 2015). However, this reading strategy (i.e., high reliance on consonants and context) might not be applicable when reading logographic L2 (i.e., Chinese) words. Additionally, the distinction between spoken language and written forms among most Arabic native speakers could contribute to challenges in their reading habits and strategies (Bentin, & Ibrahim, 1996), especially when compared to native readers of orthographies found in other languages. It was also possible that the differences in sample selections, such as age, gender, motivation, and educational background, might also contribute to the relative underperformance of Arabic-speaking participants. It is worth noting that the current study has provided a rare insight into how Arabic native speakers process L2 Chinese characters.
Furthermore, the unexpected outperformance of English-speaking participants in reaction times during the Lexical Decision Task merits attention. According to the ODH theory and the ranking of orthographic transparency among the three languages, it was anticipated that English-speaking participants' utilization of orthographic or phonological processing would fall between that of Italian and Arabic speakers when recognizing L2 Chinese written words. However, contrary to predictions, the current study revealed that English native speakers, albeit not significantly, exhibited shorter mean reaction times than both Arabic native speakers and Italian native speakers. This contradicted the expected outcome, which suggested that they would spend less time than Arabic speakers but more time than Italian speakers in rejecting homographs, and longer time than Arabic speakers but less time than Italian speakers in rejecting homophones.

Although the involvement of only a few basic English words was limited, and non-English-speaking participants underwent pre-testing on their knowledge of these words, it might still have caused interference for non-native speakers when processing the picture-English word pairs rapidly in the Lexical Decision Task. Conversely, native English speakers might have benefitted from the English explanations accompanying the pictures. Furthermore, the unevenness of language learning experiences among all participants could have influenced the current results. Notably, among the three participant groups, Arabic-speaking participants had the highest proportion of bilinguals (100%), while English-speaking participants had the lowest (84.6%) - although the proficiency levels of their L2s remained unclear. The previously learned languages (i.e., L1, L2) can either facilitate or hinder L3 acquisition depending on their typologies (Ellis & Shintani, 2013). It is plausible that the higher proportion of bilinguals (across all three groups) processing L3 Chinese written words within the limited time of training and testing phases might have led to more interference, while the smaller proportion of bilinguals in
the English-speaking group potentially contributed to their improved performance in recognizing logographic L3 words. Further investigation into the role of bilingualism and its impact on L3 Chinese word recognition could offer additional insights into these unexpected findings.

5.4 Implications

The results of the lexical decision task employed in the current study indicated that beginner learners of Chinese, whose L1 writing systems were photographic with different degrees of transparencies, demonstrated levels of reliance on orthographic and phonological processing in recognizing L2 Chinese written words. These findings have important implications for educators and researchers who work with Chinese as second language learners.

First, regardless of the transparency of their L1 orthographies, early Chinese learners exhibited the tendency of orthographic processing when identifying Chinese characters. Based on this finding, it is recommended that Chinese characters should be introduced naturally from the early stage of learning. The observed orthographic effects in the current study may have been due to the participant's character-by-character memorization, given their limited knowledge of Chinese characters. A similar pattern of orthographic processing was observed in L1 young Chinese learners, whereas phonological processing emerged in later stages with a larger reservoir of characters stored in their lexicon (Siok & Fletcher, 2001; Tan et al., 2005). Elementary school-aged L1 learners need to master 2500 characters, and their orthographic awareness and reading performance are enhanced by extensive writing practice (Chen et al., 2014). In the context of L2 Chinese learning, learners should be exposed to natural Chinese texts and learn characters either within vocabulary units or independently with adequate time allotted for
learning (Matsumoto, 2013), rather than avoiding presenting Chinese characters or relying solely on pinyin texts (Zhang, 2006).

Second, the finding that different levels of orthographic transparency in learners' L1 writing systems impact their cognitive processing of L2 Chinese characters suggests that character teaching should be tailored to the features of learners' L1 orthographies, particularly at the beginner level. For instance, Jiang (2003) found a high correlation between phonological information and semantic information in phonographic L1 speakers when recognizing Chinese characters, indicating that learners with phonographic L1s highly relied on phonological information to mediate meaning retrieval. Thus, he recommended that phonological information, such as pinyin, should serve as the primary auxiliary means for beginner learners in acquiring Chinese written forms. Moreover, the present study offers insight into the extent to which phonological and orthographic information should be applied to Chinese learners with different levels of orthographic transparency in their L1s. For instance, Italian has a more transparent orthography, and its native speakers may need more scaffoldings than English native speakers in recognizing logographic L2 written words. Bates, Burani, D’Amico, & Barca’s (2001) study demonstrated a pronounced phonological effect among Italian native speakers, with semantic effects disappearing during a word reading task but activating semantic information during a picture-naming task. Therefore, it is crucial to present visual information (i.e., Chinese characters, ways of writing characters, and related pictures) accompanied with sound information, including both the pinyin and audio-recorded pronunciation, while learning Chinese characters. In addition, both incidental (e.g., in tasks) and intentional (e.g., exercise, games, flashcards, etc.) exposure are necessary to deepen the impression of orthographic forms of Chinese characters (Matsumoto, 2013). Although these strategies are applicable to all
phonographic L1 speakers, the amount and duration may vary depending on their L1’s orthographic transparency.

Finally, the current study provides educational insights into the cognitive processes involved in the recognition of L2 Chinese characters among Arabic native speakers. Arabic is an opaque orthography, and its native speakers rely heavily on both the orthographic and phonological paths in processing L1 Arabic written scripts (Bentin & Ibrahim, 1996; Boumaraf & Macoir, 2016). Although their strong reliance on orthographic processing did not yield superior performance to their peers in identifying Chinese characters, they did exhibit a keen sensitivity to both orthographic and phonological distractions in Chinese characters. Hence, for novice Chinese learners whose L1 writing systems are Arabic or other abjad orthographies, it is important to provide both the sound (i.e., pinyin and audio) and the visual (i.e., characters and pictures) information throughout the beginning learning phases. Specifically, any visual means that may facilitate orthographic-semantic activation are recommended when learning Chinese characters. Additionally, the study received anecdotal feedback from Arabic-speaking participants who were enthusiastic about learning Chinese characters with the aid of pictures, sounds, games, and task-based exercises during the training session.

5.5. Limitations and Recommendations for the Future Study

The present study might be affected by statistical bias due to the small sample size of participants and the relatively wide range of individual differences among subjects. The recruitment of subjects faced a large challenge, particularly in the case of recruiting Arabic- and Italian-speaking participants in the US. To address this issue, Italian native speakers were recruited from the same department in a university in Italy, which resulted in a sample with a
highly homogeneous background of individuals aged between 18 and 25, undergraduates majoring in humanities-related fields, highly motivated, and academically well-performing. In contrast, the English and Arabic speakers exhibited greater diversity in terms of age, educational background, second language experiences, and individual learning strategies. Furthermore, Arabic native speakers who were willing to participate in the current study also generated diverse outcomes, due to variations in academic capabilities, cultural differences, and personal preferences (Juhani, 2015). One of the consequences of the relatively small sample size and the individual variability was that Italian native speakers might overperform, whereas Arabic speakers underperformed in comparison to English-speaking participants, thereby the direct comparison between the three language groups were not significantly different.

Therefore, to acquire more robust data and to increase the reliability and validity in future studies, a larger sample size of participants with more balanced backgrounds are recommended to be recruited. Hence, the effect of individual differences will be minimized, and the sample of the population will be more representative. In addition, to ensure greater control over the subject characteristics, participants should be more carefully screened and selected based on specific and strict inclusion and exclusion criteria. In doing so, a salient significance may be found among L2 Chinese beginner learners who have phonographic L1s with varying degrees of transparency.

Furthermore, the presence of English words used to explain the meanings of words and pictures in the training sessions and the Lexical Decision Task might cause interference for non-native speakers (i.e., Italian and Arabic speakers) when processing the picture-English word pairs. On the contrary, native English speakers might benefit from the English explanations accompanying the pictures, which could potentially contribute to their superior performance in reaction times compared to the other two language groups. Therefore, to ensure balanced
conditions for all participating language groups in future studies, it is recommended to utilize
different languages to explain word meanings and match corresponding pictures. Specifically,
Italian written words should be employed for Italian-speaking participants, and Arabic written
words should be used for Arabic-speaking participants in both the training and testing phases.

Lastly, the exercises employed during the training session might have influenced the
results with bias. The task-based and light-loaded activities might not be the most effective
approach for all participants within the limited training period. Despite the consideration of
diverse individual learning preferences (e.g., visual, aural, and writing modalities) in designing
the exercises, individual differences in learning abilities, strategies, and short-term memory
effects should still be duly acknowledged. To address these concerns, future studies should
incorporate a wider range of modalities and offer more options, including the inclusion of
mandatory writing exercises, to better cater to the diverse needs of individual learners.

The current study investigated how beginner learners with phonographic L1 writing systems
but varying degrees of orthographic transparency recognize L2 Chinese characters. To further
extend this research, future studies are necessary to examine how orthographic transparency of
L1 writing systems impacts the recognition of Chinese characters among learners with
intermediate or advanced proficiency levels. Research has found that phonographic L1 readers
rely on different processing patterns as their L2 proficiency increases while identifying
logographic L2 written forms (Chikamatsu, 2006; Kim, 2016; Lin & Collins, 2012; Matsumoto,
2013). Specifically, they transfer from relying on phonological processing patterns to relying
more on orthographic processing patterns. It remains unclear whether the feature of L1
orthographic transparency contributes to the recognition of logographic L2 words. In the case of
beginner learners, their knowledge of Chinese characters is limited, and they are unable to detect
or utilize phonological information (i.e., from phonograms) to process Chinese characters (Yum et al., 2016). However, it is worth examining whether L1 phonological processing patterns, based on different phonographic transparencies, play a role in recognizing Chinese characters among intermediate or advanced learners of Chinese who have sufficient storage of Chinese character knowledge and are able to use phonological cues in logographic written forms.

In addition, it is worthwhile to investigate teaching and learning methods tailored to Chinese character instruction for learners with specific types of L1 orthographies. For instance, it may be helpful to determine the extent to which Chinese learners with transparent L1 writing systems need support from sound and visual cues to facilitate learning. Such research will be particularly valuable for Chinese as a foreign language teaching in a single language context, such as teaching Chinese in Italy or Saudi Arabia.

5.6. Conclusion

The present study aimed to investigate the impact of L1 orthographic transparency on the recognition of L2 Chinese written words. The very beginning Chinese learners whose native languages were English, Arabic, and Italian that were recruited in this study demonstrated both orthographic and phonological effects, in varying levels, when identifying Chinese characters. The study also compared the responses of these three language groups to target characters, orthographic fillers, phonological fillers, and control characters. The results showed that there were no statistically significant differences between English, Arabic, and Italian native speakers in responding to these four types of answers. However, significant variations emerged within each group's responses to homophones and homographs, highlighting the degree to which
learners' reliance on orthographic or phonological processing depended on their L1 orthographic transparency.

The rationale for the comparison of participants from three types of L1 phonographic writing systems to recognize L2 Chinese characters is grounded in prior research suggesting that readers of different writing systems may rely on distinct processing patterns when recognizing L1 written words. Three hypotheses have been proposed to explain the relationship between writing systems and written word processing paths, namely, the Universal Direct Access Hypothesis (Seidenberg, 1992), the Universal Phonological Principle (Perfetti & Zhang, 1995; Tan & Perfetti, 1997), and the Orthographic Depth Hypothesis (ODH) (Katz & Frost, 1992). While only ODH provides a detailed account of the relationship between orthographic transparency and processing patterns in identifying written words, and many empirical studies focusing on reading phonographic L1 orthographies have supported this hypothesis (Aro & Wimmer, 2003; Paulesu et al., 2000; Boumaraf & Macoir, 2016), the findings from the present study extend the ODH theory by demonstrating that L1 orthographic transparency also impacts the recognition of logographic L2 written words. Specifically, the results indicate that readers with more transparent L1 writing systems (e.g., Italian) rely more on the phonological processing path when recognizing written Chinese words, whereas those with more opaque L1 writing systems (e.g., Arabic) rely more on the orthographic processing path.

The current study may contribute to the general research on Chinese as second language learning, particularly in the area of recognizing and processing Chinese characters. The results of this study indicate that Chinese as L2 learners’ L1 writing systems, especially L1 orthographic transparency, influence their processing patterns of Chinese characters. Therefore, scaffolding strategies for learning Chinese characters, which are logographic in nature, may need to be
tailored to learners based on their specific L1 writing systems. For instance, learners with more transparent L1 orthographies may require various sound aids to facilitate lexical entry while reading Chinese characters (Jiang, 2003). Additionally, the duration of this stage with sound aids may need to be extended compared to learners whose L1 orthographies are less transparent. Furthermore, it is also essential to introduce Chinese characters at the beginner level, using authentic texts, because novice learners of Chinese already begin to process characters orthographically. Appropriate exposure to Chinese characters may cultivate and strengthen learners' orthographic awareness of Chinese characters (Chen et al., 2014; Hao, 2007).

This study is expected to stimulate further research with more rigorous data, including larger sample sizes and better-controlled backgrounds of participants, to explore the impact of L1 orthographic transparency on the recognition of L2 logographic written words. Moreover, to test whether the effects of L1 orthographic transparency on processing logographic L2 words will disappear, and to what extent such effects will vanish, additional investigations are necessary. Specifically, future research should focus on intermediate or advanced-level Chinese L2 learners whose L1 writing systems with varying degrees of orthographic transparency in the recognition of Chinese Characters.
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Recognition by Learners from Korea and Indonesia. [Hanguo, Yinni liuxuesheng hanzi shibiezhong xing yin yi de jihuo]. Psychological Exploration, 30(6), 36-44


## APPENDIX I: TRAINING MATERIALS

Table 7

<table>
<thead>
<tr>
<th>Groups</th>
<th>Training characters</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>寺 园 货 助 损</td>
</tr>
<tr>
<td>2</td>
<td>曳 纪 赌 迟 芯</td>
</tr>
<tr>
<td>3</td>
<td>丰 笋 冻 挥 岛</td>
</tr>
<tr>
<td>4</td>
<td>未 玩 照 地 邪</td>
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</tbody>
</table>
### APPENDIX II: STIMULI USED IN THE LEXICAL DECISION TASK

**Table 8**

<table>
<thead>
<tr>
<th></th>
<th>Target character</th>
<th>Homophone</th>
<th>Homograph</th>
<th>Non-relevant character</th>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>玩</td>
<td>wán [wan2]</td>
<td>to play</td>
<td>8</td>
</tr>
<tr>
<td>11</td>
<td>电</td>
<td>diàn [dian4]</td>
<td>electricity</td>
<td>7</td>
</tr>
<tr>
<td>12</td>
<td>助</td>
<td>zhù / tsu4/</td>
<td>to help</td>
<td>6</td>
</tr>
<tr>
<td>13</td>
<td>页</td>
<td>yè [iɛ4]</td>
<td>page</td>
<td>6</td>
</tr>
<tr>
<td>14</td>
<td>赌</td>
<td>dǔ [du3]</td>
<td>gamble</td>
<td>7</td>
</tr>
<tr>
<td>15</td>
<td>损</td>
<td>sǔn [suan3]</td>
<td>damage</td>
<td>10</td>
</tr>
<tr>
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<td>赌</td>
<td>dǔ [du3]</td>
<td>stomach</td>
<td>7</td>
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<tr>
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<td>玩</td>
<td>wán [wan2]</td>
<td>fine silk</td>
<td>6</td>
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<tr>
<td>18</td>
<td>恢</td>
<td>huī [xuei1]</td>
<td>to wave</td>
<td>9</td>
</tr>
<tr>
<td>19</td>
<td>名</td>
<td>méi [mei2]</td>
<td>rose</td>
<td>8</td>
</tr>
<tr>
<td>20</td>
<td>赌</td>
<td>zhào [tʂau4]</td>
<td>to drag</td>
<td>6</td>
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<tr>
<td>photograph</td>
<td>cover</td>
<td>Breeze</td>
<td>to think</td>
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</table>
APPENDIX III: SURVEY

Demographic information

☐ By checking this box I certify that I am 18 years of age or older.

<table>
<thead>
<tr>
<th>Name</th>
<th>Nationality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Your email &amp; phone</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ 18-25</td>
<td>☐ Male</td>
</tr>
<tr>
<td>☐ 26-35</td>
<td>☐ Female</td>
</tr>
<tr>
<td>☐ 36-45</td>
<td></td>
</tr>
<tr>
<td>☐ 46-55</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>The highest degree you have received</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ High school or less than high school degree</td>
<td></td>
</tr>
<tr>
<td>☐ Associate degree</td>
<td></td>
</tr>
<tr>
<td>☐ Bachelor degree</td>
<td></td>
</tr>
<tr>
<td>☐ Master degree</td>
<td></td>
</tr>
<tr>
<td>☐ Doctorate degree</td>
<td></td>
</tr>
</tbody>
</table>

| Your major or/and minor | |
|-------------------------| |

| Your native/first language | |
|-----------------------------| |

| Other Languages you have learned | |
|----------------------------------| |

| How long have learned your second or third language(s)? (Please list all languages) | |
|--------------------------------------------------------------------------------| |

| How well is(are) your second/third language(s)? (Please describe the proficiency in all languages that you know) | |
|-------------------------------------------------------------------------------------------------------------| |
| ☐ A. native level in speaking and reading | |
| ☐ B. advanced; academic use in speaking and reading | |
| ☐ C. fluent in daily speaking and reading | |
| ☐ D. basic level in speaking and reading | |
| ☐ E. fluent in speaking, but cannot or basic in reading | |
| ☐ F. fluent in reading, but cannot or basic in speaking | |

Please use A to F to describe all your L2/L3 proficiency:

| Have you ever had the following conditions | |
|--------------------------------------------| |

☐ Visual impairment ☐ Hearing impairment ☐ Neurological disorder

☐ Memory impairment ☐ Language disorder
Knowledge of Chinese characters

If you know any of the characters below, please check YES, and write down their meanings and pronunciations. If you don’t know the character, then check NO.

<table>
<thead>
<tr>
<th>Characters</th>
<th>YES</th>
<th>NO</th>
<th>Meaning &amp; sound</th>
</tr>
</thead>
<tbody>
<tr>
<td>丰</td>
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<td></td>
<td></td>
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<tr>
<td>纪</td>
<td></td>
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<td></td>
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<tr>
<td>寺</td>
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<td>迟</td>
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<td></td>
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<tr>
<td>笠</td>
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<td></td>
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<td>园</td>
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<td>货</td>
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<td>芯</td>
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<td>冻</td>
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<td>玩</td>
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<td>曳</td>
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<td></td>
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<td>助</td>
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<td>岛</td>
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<td>挥</td>
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<td>赌</td>
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<td>地</td>
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<td>未</td>
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<td></td>
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<tr>
<td>邪</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>照</td>
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<td></td>
</tr>
</tbody>
</table>
APPENDIX IV: SAMPLE OF TESTING QUESTIONS (GROUP 1)

1. 助 (zhù)
   NO                      YES

2. 坟 (xūn)
   NO                      YES

3. 去 (qù)
   NO                      YES
4. 帛 (bó)  
| NO | YES |

5. 或 (huò)  
| NO | YES |

6. 曳 (yè)  
| NO | YES |
7. 红 (hóng)
   NO  YES

8. 肚 (dǔ)
   NO  YES

9. 报 (bào)
   NO  YES
10. **芯** (xīn)
   
   NO  YES

11. **干** (gān)
   
   NO  YES

12. **哥** (gē)
   
   NO  YES
13. 冻（dòng）
NO  YES

14. 恢（huī）
NO  YES

15. 爷（yé）
NO  YES
16. 古（gǔ）
   NO                             YES

17. 玩（wán）
   NO                             YES

18. 罩（zhào）
   NO                             YES
19. 他 (tā)
   NO  YES

20. 划 (huá)
   NO  YES
APPENDIX V: SAMPLE OF TRAINING INTERFACE

Character training

Matching pairs
Listen and choose correct words.

Question 1 / 5
Listen to the sound of the character, and choose the correct meaning of the character.

- A. core of the watch
- B. disciplined
- C. be late

Choose correct characters based on the provided meanings.

Question 1 / 20
Please choose the correct character according to the meaning (Scegliere i caratteri corrispondenti al significato).

abundant

- A. 翁
- B. 丰
- C. 鬼

True or False

Question 2 / 40
邪 xié

- A. true
- B. false
Drag & Drop

Please arrange the pictures on the left in the order of the characters below (you can drag the boxes on the left down below).

Sistemate le immagini a sinistra nell'ordine dei caratteri sottostanti (potete trascinare le caselle a sinistra in basso).

1. 园 yuán
2. 助 zhù
3. 冻 dòng

Game: Time to climb
VITA

EDUCATION

2018-2023 Ph.D. in Applied Linguistics, Department of Modern Languages, University of Mississippi, Oxford, MS, U.S.A

2016-2018 M.A. in TESOL, Department of Modern Languages, University of Mississippi, Oxford, MS, U.S.A

2005-2008 M.A. in Teaching Chinese as a Second Language, College of International Education, Shandong University, Jinan, China

2001-2005 B.A. in Chinese Language & Literature, School of literature & Journalism, Shandong University, Jinan, China

PROFESSIONAL APPOINTMENTS

2018-2023 Graduate Instructor/assistant at the Department of Modern Languages, University of Mississippi, USA

2016-2018 Graduate assistant/instructor at Intensive English Program, University of Mississippi, USA

2008-2016 Faculty Lecturer, teaching Chinese as a Second Language, Chinese University of Petroleum (East China), Shandong, China

2011-2013 Visiting scholar, teaching Chinese Language, Heartland Community College, Illinois, USA

2007-2008 Volunteer teacher, teaching Chinese as a foreign language, Tantiwatra School, Nakhon Si Thammarat, Thailand