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I, Xiao Luo, hereby submit this original work as part of the requirements for the degree of Doctor of Philosophy in Educational Studies.

It is entitled:

The Effect of Orthographic Neighborhood Size and Consistency on Character and Word Recognition by Learners of Chinese as a Second Language and Native Chinese Speakers

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The Effect of Orthographic Neighborhood Size and Consistency on Character and Word Recognition by Learners of Chinese as a Second Language and Native Chinese Speakers

A dissertation submitted to the
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by

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Abstract

Among contemporary Chinese characters, approximately 80% are semantic-phonetic compound characters, which consist of a phonetic radical that signals pronunciations and a semantic radical that suggests meanings. A cluster of such characters sharing the same phonetic radicals are referred to as an orthographic neighborhood. Previous research suggested that neighboring characters, if they have consistent pronunciations, could produce facilitatory consistency effects on characters' naming by both native (L1) Chinese speakers and learners of Chinese as a second language (L2). However, the larger number of characters in an orthographic neighborhood, more errors and slower responses were observed in naming tasks among L1 Chinese speakers, suggesting an inhibitory neighborhood size (NS) effect. However, this NS effect has not been investigated in L2 Chinese learners' reading of single characters and two-character words.

This dissertation aimed to fill this research gap by inviting 17 L2 Chinese learners and 35 L1 Chinese speakers (control group) to complete two studies. Study 1 focused on participants' reading of single semantic-phonetic compound characters. Experiment 1(a) used regular characters (i.e., a character's pronunciation is the same as that of its phonetic radical) whereas Experiment 1(b) used irregular characters. Both experiments adopted a 2 (NS) x 2 (consistency) x 2 (L1/L2 groups) repeated-measures design. Participants completed lexical decision tasks, and their reaction times (RTs) and accuracy data were collected and analyzed. ANOVA results of Experiment 1(a) showed significant main effects of NS and consistency as well as their interactions. A facilitatory consistency effect was found when L2 learners read small-NS characters. Results of Experiment 1(b) suggested a significant main effect of NS and that of consistency, but no significant interactions were found.

Study 2 examined the effects of a semantic-phonetic compound character's NS and consistency on reading two-character words. Each stimulus comprised a semantic-phonetic compound character and a non-semantic-phonetic compound character. Participants completed a lexical decision task. A 2 (NS) x 2 (consistency) x 2 (L1/L2 groups) repeated-measures design was adopted. ANOVA Results of participants' RT and accuracy indicated a significant main effect of NS and its interaction with the consistency effect. In particular, a facilitatory NS effect was detected when L2 leaners read words containing high-consistency characters.

This dissertation concluded that the effects of a semantic-phonetic compound character' NS and consistency played important roles in L2 Chinese learners' reading of single characters and two-character words. Theoretical and pedagogical implications were discussed.

Keywords: Orthographic neighborhood size, consistency, semantic-phonetic compound characters, Chinese as a second language

To my mother and father

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Chapter 1

General Introduction

Reading is a multifaceted process that involves a variety of perceptual and cognitive activities, such as bottom-up hierarchical recognition of word forms, extraction of phonological information, and top-down reading that holistically gain words' meanings (Norris, 2013; Pae et al., 2018). One of the most crucial activities involved in reading is to extract phonological information from orthographic representations, and this process is highly dependent on the grain size of a writing system (Pae & Lee, 2015; Ziegler & Goswami, 2005). A grain size refers to the minimal orthographic unit that readers depend on for symbol-to-sound mappings during reading, and it can be a single grapheme or phoneme (e.g., *f*, *l*, *a*, *sh* in the word *flash*), onsets and rimes (Pae & Lee, 2015; e.g., *fl-ash*), body and coda (Pae et al., 2010; e.g., *fla-sh*) and even an entire syllable.

Among a total of approximately 7,000 languages currently in use in the world (Pae, 2020), some adopt shallow orthographic systems (e.g., Finnish and Spanish) because their decoding processes depend on small grain size (i.e., graphemes/phonemes) and consistent correspondence between grapheme and phoneme (Pae et al., 2017). Some other languages, on the other hand, make use of comparatively deep orthographies (e.g., English) because of their inconsistent correspondences between graphemes and phonemes and readers' reliance on both small- and large-unit of grain size for spelling-to-sound conversion during reading (Ziegler & Goswami, 2005).

Chinese is one of the most populous languages around the world with an estimation of 1.3 billion users (Lin et al., 2018; Pae, 2020). The Chinese writing system is considered a logographic writing system because each basic written unit (i.e., a character) (Leong & Cheng,

2003) represents a morpheme (Sun et al., 2020) as well as a syllable. As a result, it is also referred to as a morphosyllabic or morphophonological writing system (Leong, 1997; Lin, et al., 2018; Tan & Perfetti, 1997). In other words, the Chinese writing system manifests distinct orthographic features in terms of the grain size and symbol-to-sound mappings compared to alphabetic languages. Scholars argued that Chinese characters are deep in orthography (Lee et al., 2004; Yang et al., 2009) because its orthography-to-phonology correspondence is arbitrary and thus, readers count on large grain (i.e., syllables) for word reading (Tian et al., 2019). These unique features of the Chinese writing system add complexity to the reading process of it. It is of great importance to understand how the Chinese orthography plays a role in reading Chinese characters and words by both users of Chinese as a first (L1) and second/foreign language (L2/FL), how its reading processes are different from those of languages adopting shallower orthography, and how research on Chinese reading can shed some light on existing reading models and theories.

The Chinese Writing System

Orthographic Features

Chinese characters can have multiple levels of orthographic representations. A line of research supports the three-level orthographic representations of Chinese characters, which starts from the “stroke” level, then develops to the “radical level” and lastly ends at the “character level” (i.e., stroke → radical → character, e.g., Reichle & Yu, 2018; Tan & Perfetti, 1998; Wang et al., 2003; Yeh et al., 2017; Yum et al., 2016). Another line of studies, on the other hand, proposes the four-level orthographic system (i.e., stroke → stroke pattern (group) → radical → character) (e.g., Ban & Zhang, 2004; Ho et al., 2003; Lin et al., 2018; Shu et al, 2003; Tong & Yip, 2015), which argues for the importance of “stroke pattern” in a Chinese character’s orthography. The following parts introduces each level in detail.

Strokes (笔画). Regardless of the above differences, almost all studies in literature recognized that strokes are the fundamental orthographic units constituting Chinese characters. A stroke is defined as a continuous line that stems from a point and moves toward different directions in various manners to form diverse visual features (McBride, 2016). Based on the directions and manners that a line is formed, there are eight types of strokes: “dot, horizontal, vertical, slant, press down, hook, curve, and raise” (Kalindi et al., 2018, pp. 100-101; McBride, 2016, p. 526). However, Honorof and Feldman (2006) claimed that the eight types of strokes should be “dot, horizontal, vertical, hook, rise, fall (toward left), short fall, and fall (toward right)” (p. 199). Some other studies indicated five types of strokes (Yang et al., 2009) and 24 basic strokes (Wang et al., 2003) existed in Chinese characters. The discrepancy in number of strokes or stroke types resulted from varied definitions and standards of strokes that the researchers have adopted. This dissertation uses Honorof and Feldman (2006)’s version to avoid confusions.

Strokes only serve as basic constructional units of a character, and each individual stroke does not have phonological or morphological values (Lin et al., 2018). A character has at least one stroke, but there is no limit to the maximum number of strokes in a character. A stroke connects to, intersects with, or is parallel to another radical/other radicals to form a character. Also, a stroke can repeatedly appear in a character, and there is no limit to where within a character a stroke should appear. Even two simple strokes can form various characters based on their positions, length/size, and how many times they repeat themselves within a character. For instance, vertical and horizontal line(s) can form the following characters: 十, 士, 土, 干, 工, 王, 上, 丰, 止, 正, 圭, 華. Lastly, strokes number is one important measurement of how complicated a Chinese character is visually (Kalindi et al., 2018; Lin et al., 2018; Shu et al., 2003).

Stroke Patterns (Groups). A stroke pattern, or a stroke group (Honorof & Feldman, 2006), is defined as a group of strokes that are combined with each other following certain positional, spatial, and visual principles to constitute a special level of orthographic occupation within a Chinese character (Ho et al., 2003; Lin et al., 2018; Tong & Yip, 2015). Shu et al. (2003) defined it as the “recurrent” “subcomponent” of radicals that has no semantic or phonological values (p. 28). Ban and Zhang (2004) referred to this level of orthographic representation as a “*bujian* (部件)” in Chinese.

How Stroke Patterns Function? Strokes within a stroke pattern either intersect with one another or are adjacent or very close to one another. A stroke pattern may or may not bear phonological and morphological values depending on whether it can serve as a radical or even a pictographic or ideographic simple character. For example, the character 赣 (*gan4*) has at least six stroke patterns, which are: 立 (top-left), 日(middle-left), 十(bottom-left), 夂(top-right), 工 (middle-right), and 贝(bottom-right). These example stroke patterns can stand alone as simple characters, while other stroke patterns cannot (e.g., 鸟, 虍, 彐, etc.). Regardless of stroke pattern’s lexicality (i.e., being independent simple characters or not), they do not contribute their semantic or phonological values to the host character. In other words, stroke pattens carry no phonological, semantic, or morphological values (Shu et al., 2003). This feature is similar to strokes. As a result, stroke patterns can be perceived as a level of orthographic representation that connects the level of strokes and that of radicals. For this reason, this dissertation adopts the “four-level” orthographic structure of Chinese characters (see Figure 1).

How Many Stroke Patterns are There? Shu et al. (2003, p. 28) suggested a total of 650 stroke patterns. However, the *Chinese Character Component Standard of GB 13000.1 Character*

Set for Information Processing (*《信息处理用 GB13000.1 字符集汉字部件规范》*)[1] published by the State Language Commission (国家语言文字工作委员会)[2] of the Chinese government indicated a complete number of 560 stroke patterns (pp. 6-12). The number is based on simplified Chinese characters used in Mainland China.

Importance of Stroke Patterns. As mentioned above, the number of strokes in a character serves as an important measurement about how visually complicated a Chinese character is (Shu et al., 2003). Some studies, however, indicated that the number of stroke patterns should be treated as a more reliable measurement of orthographic complexity than stroke numbers (Ho et al., 2003). Also, Lin et al. (2018) suggested that stroke patterns be regarded as the most fundamental orthographic representations of Chinese characters, instead of strokes (p. 27). Tong & Yip (2015) summarized relevant studies published between 2000 and 2014 and concluded that L1 Chinese speakers were able to decompose a Chinese character into stroke-pattern-level representations (p. 177). These studies emphasized the importance of stroke patterns.

Radicals. A stroke pattern can be combined with another one or more strokes or stroke patterns to further form a radical, which is a component that either provides phonological or semantic information of a host character. Sometimes, a stroke pattern itself can represent a radical as well (e.g., 由). There are two types of radicals in the contemporary Chinese characters: a semantic radical (形旁 or 意符, 形符)[3] that signals the host character's semantic information and a phonetic radical (声旁 or 音符, 声符), which in part or in whole informs the host

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[1] The document can be downloaded from the official website: http://www.moe.gov.cn/jyb_sjzl/ziliao/A19/201001/t20100115_75616.html

[2] The English translation is based on this site: http://www.china.org.cn/china/leadership/2013-03/11/content_28206251.htm

[3] The Chinese terms of "semantic radical" and "phonetic radical" are based on Ban & Zhang (2004, p. 64).

character's pronunciation at the syllable level (Tan & Perfetti, 1998; Zhou, et al., 2013).

Terms Referring to Phonetic and Semantic Radicals. It is vital to notice that a variety of English terms referring to these two types of radicals existed in literature. For the semantic radicals, at least five different terms have been used as listed below:

(1) "*semantic portions*" (Tan & Perfetti, 1998).

(2) "*semantic elements*" (Williams & Bever, 2010).

(3) "*semantic components*" (Chen et al, 2016; Chen, 2019; Kim et al., 2016; Lin & Collins, 2012; Shu et al., 2003; Tan & Perfetti, 1998; Yang et al., 2009).

(4) "*radicals*" (Feldman & Siok, 1997; Kim et al., 2016; Shu et al., 2003; Williams & Bever, 2010; Yang et al., 2018).

(5) "*semantic radicals*" (Chen, 2019; Feldman & Siok, 1997; Ho et al., 2003; Hsu et al., 2009; Lee et al., 2005; Lee et al., 2015; Li et al., 2011; Li et al., 2016; Li et al., 2020; Lin & Collins, 2012; Lin et al., 2018; Lü et al., 2015; Ma & Ai, 2018; Perfetti et al., 2005; Reichle & Yu, 2018; Tong & Yip, 2015; Tong et al., 2017; Wang & Zhang, 2011; Wang et al, 2017; Williams & Bever, 2010; Yum et al., 2014; Yum et al., 2016; Zhao et al., 2012; Zhou et al., 2013).

As for the phonetic radicals, the following alternative terms appeared in literature:

(1) "*phonetics*" (Feldman & Siok, 1997; Kim et al., 2016; Shu et al., 2003; Yang et al., 2018).

(2) "*phonetic elements*" (Williams & Bever, 2010).

(3) "*phonetic components*" (Chen et al, 2016; Chen, 2019; Feldman & Siok, 1997; Kim et al., 2016; Lin & Collins, 2012; Lin et al., 2018; Shu et al., 2003; Tan & Perfetti, 1998; Yang et al., 2009; Yang et al., 2018).

(4) "*phonological radicals*" (Ma & Ai, 2018; Williams & Bever, 2010).

(5) "*phonetic radicals*" (Chang et al., 2016; Ho et al., 2003; Hsu et al., 2009; Lee et al., 2005; Lee et al., 2007; Lee et al., 2015; Lee, 2008; Li et al., 2011; Li et al., 2016; Li et al., 2020; Lin & Collins, 2012; Lin et al., 2018; Lü et al., 2015; Perfetti et al., 2005; Reichle & Yu, 2018; Tong & Yip, 2015; Tong et al., 2017; Wang & Zhang, 2011; Wang et al, 2017; Williams & Bever, 2010; Yum et al., 2014; Yum et al., 2016; Zhao et al., 2012; Zhou et al., 2013).

More published studies chose the terms "semantic radical" and "phonetic radical". As a result, this dissertation used these two terms as well.

Functions of Radicals. In contrast to strokes and stroke patterns, a radical possesses phonological or semantic values that are key to a host semantic-phonetic compound character. In addition, most radicals can stand alone as a simple Chinese character and has its own pronunciation and meaning, which do not necessarily contribute to the host character. For example, the semantic radical "木 (*mu4*; meaning: *a tree*)" represents a meaning of "tree" or "tree-related" items. The phonetic radical "支 (*zhi1*; meaning: *to support*)" implies that any semantic-phonetic compound characters containing it may be pronounced as */zhi/*. When this two radicals come together, they form a semantic-phonetic compound character, 枝, the meaning of which is "tree branches" and the pronunciation of which is */zhi1/*.

In this example, the semantic radical contributes its semantic value whereas the phonetic radical contributes its phonological value to the host character 枝. It is important to understand that neither the phonological value of the semantic radical (i.e., 木/*mu4*/) nor the semantic value of the phonetic radical (i.e., 支 "to support") contributes to the construction of this semantic-phonetic compound character 枝.

How Many Radicals Are There? Shu et al. (2003) and Williams & Bever (2010) suggested a total of 200 semantic radicals and 800 phonetic radicals in the contemporary Chinese characters. Lin et al. (2018) provided the information that there were 200 semantic radicals and 1,100 phonetic radicals in Chinese characters (p. 28). Li and colleagues (2016) suggested 190 semantic radicals and 1,100 phonetic radicals (p. 1367). Zhou (1980, p.2) and Kim et al. (2016, p. 1413) indicated a total of 1,348 phonetic radicals, and Lü et al. (2015) informed that the number of frequently used semantic radicals was 214 (p. 170).

Despite the differences in the numbers, these published studies agreed that the number of semantic radicals is around 200 and that of phonetic radicals more than 1,000 in modern Chinese characters. It can be concluded that more phonetic radicals exist in modern Chinese characters than semantic radicals.

How Many Radicals in L2 Chinese Learners' Curriculum? Very few studies have investigated into this issue, but according to Kim and Shin (2005a, p. 23), there were approximately 720 phonetic radicals in the semantic-phonetic compound characters that appeared in the *International Curriculum for Chinese Language Education* (*国际汉语教学通用课程大纲*) published by the Confucius Institute Headquarters (Hanban, 2014). Kim and Shin (2005a) did not explicitly indicate the number of semantic radicals. Based on their semantic-phonetic compound characters dataset, this dissertation study estimated that there were approximately 160 semantic radicals existing in the L2 Chinese curriculum (in Mainland China).

Positions of Radicals. A semantic radical is mostly positioned in the left (e.g., "木" in "枝") or the top part (e.g., "艹" in "菜") of a compound character while a phonetic radical is most of the time arrayed in the right (e.g., "支(*zhi1*)" in "枝(*zhi1*)") or the bottom component (e.g., "采(*cai3*)" in "菜(*cai4*)") of a compound character (Williams & Bever, 2010). Lee et al. (2015,

p. 538) indicated that approximately 90% of compound characters place their semantic radicals on the left side and their phonetic radicals on the right side. Shu et al. (2003, p.34)'s analyses informed that semantic-phonetic compound characters whose phonetic radicals are in the right position accounted for 64% of the primary-school-level educational characters (as cited in Li et al. (2016, p. 1367)). Zhou et al. (2013) mentioned that 72% of compound characters have a "left-right" structure and that 90% of them have the semantic radical on the left and the phonetic radical on the right (p. 969). Thus, it is reasonable to conclude that the "left-semantic-right-phonetic" structure is the majority among all semantic-phonetic compound characters.

Aside from that, other structures are also important. For instance, the semantic radical "皿" (meaning: *container*) is posited in the bottom proportion of the host compound character "盆" (meaning: *a wash basin*). The semantic radical "鸟" (meaning: *birds*) is placed in the right component of "鸡" (*chicken*), "鸭" (*ducks*), and "鹅" (*geese*).

Exceptional positions for phonetic radicals include but are not limited to: the phonetic radical "工(*gong1*)" is located in the left part of the following host compound characters "功(*gong1*)", "攻(*gong1*)", and "巩(*gong3*)". The phonetic radical "衣 (*yi1*)" in the character "裔 (*yi4*)" and the phonetic radical "乃 (*nai3*)" in the character "鼐 (*nai3*)" are located in the top part of the characters. Very special examples include "裹(*guo3*)" and "衷(*zhong1*)" whose phonetic radicals "果(*guo3*)" and "中(*zhong1*)" are placed in the central part of the characters respectively (examples are selected from Zhou (1980)).

Bound Radicals. A proportion of radicals cannot stand alone independently as simple characters and must be integrated in a host character (e.g., 充). These radicals, whether it be semantic or phonetic, are referred to as bound radicals (Kim et al., 2016; Shu et al., 2003; Yang et al., 2009). Examples of such semantic radicals in simplified Chinese characters include but are not limit to: 氵 (water-related), 纟 (silk-related), 讠 (speech-related), 钅 (metal-related), 饣 (food-related), 忄 (emotion-related), 扌 (action-related), and so forth (examples selected from Lü et al., 2015). Some of them resulted from characters simplification in Mainland China, such as 言→ 讠 (e.g., 話 → 话), 金→钅 (e.g.,銀 → 银), and 食→饣 (e.g.,飯 → 饭), indicating that they are not bound semantic radicals in traditional Chinese characters. Some are not the consequences of characters simplification and exist in both the traditional and simplified characters (e.g., 辶, 艹, 扌, 亻 , etc.)

Examples of bound phonetic radicals in simplified Chinese characters include but are not limit to: 肙 (in 娟, 绢, 捐, 鹃, 涓, 狷), 㕣 (in 沿, 铅), 粦 (in 磷, 璘, 麟, 鳞, 粼), 喿 (in 燥, 澡, 躁, 噪, 藻, 操), and so forth (Kim et al., 2016; Zhou, 1980). Kim et al. (2016) stated that bound phonetic radicals accounted for 13% of the total phonetic radicals (p. 1413). Lastly, bound phonetic radicals exist in both traditional and simplified characters (Lee et al., 2005).

Radicals That Have Dual Functions. Some radicals can function as a semantic radical in certain characters and as a phonetic radical in other characters. For example, the simple character 米(/*mi*/, meaning: rice) can function as a phonetic radical in characters 迷, 眯, 咪, 脒, and 洣 (all pronounced as /*mi*/) but can also serve as a semantic radical in 糊, 糍, and 粑, indicating their rice-related meaning. However, not all radicals have such dual functions. Most radicals can only function as one type of radical (i.e., either phonetic or semantic) in contemporary Chinese characters.

Characters. The four-level orthographic structure of Chinese characters informed that characters were formed through the "strokes → stroke patterns → radicals → characters" procedures. But not all characters go through the four steps. Some simple characters can be constituted via simpler route. For example, “十” (/*shi2*/, meaning: ten) can be formed via the “strokes → character” route; “全” (/*quan2*/, meaning: all) can be constituted via the “strokes → stroke patterns (人 and 王) → character” route; “冻” (/*dong4*/, meaning: to freeze) can be formed through the “strokes → radicals (冫 and 东)→ character” route. Complicated characters go through the four-level route. For example, “诠” (/*quan2*/, meaning: to explain) is formed through the “strokes → stroke patterns (人 and 王) → radicals (讠 and 全) → character (诠)” route.

How Many Types of Characters? Based on how a character is formed or constituted and whether it can be further decomposed to lower-level components, previous studies proposed two major categories of Chinese characters: Simple characters and compound characters. Simple characters are those which cannot be further divided into “meaningful” sub-components (Kim et al., 2016, p. 1411). Simple characters have two subcategories: pictograph and ideograph (Ho et al., 2003; Lin et al., 2018; Shu et al., 2003; Williams & Bever, 2010). Compound characters, on the other hand, comprise two or more meaningful subsets of orthographic representations. Most studies recognized that the majority of compound characters are semantic-phonetic compound characters, but there are also other types of compound characters, as detailed in the following sections.

Simple Character Type 1: Pictographs. Pictographs (Shu et al., 2003; Williams & Bever, 2010) are also referred to as “pictograms” (Lin et al., 2018) or “pictographic characters” (Ho et al., 2003). They originated from ancient drawing of real or concrete items, and then these drawings developed to the contemporary writing of Chinese characters. Examples included:  → 日 (/*ri4*/, meaning: Sun);  → 山 (/*shan1*/, mountain);  → 水 (/*shui3*/, water),  → 目

(/*mu4*/, an eye), → 木 (/mu4/, a tree or wood), and so forth.

Simple Character Type 2: Ideographs. Ideographs (Shu et al., 2003; Williams & Bever, 2010), or "ideograms" (Lin et al., 2018), "ideographic characters" (Ho et al., 2003), are a group of characters using orthographic features to represent concepts which cannot be visualized via pictures (Ho et al., 2003, p. 851) or are "abstract" (Lin et al., 2018, p. 27). Most published studies used 上 (/*shang4*/, meaning: up) and 下 (/*xia4*/, meaning: down) as the examples of ideographs because the central vertical stroke of the two characters points toward up or down respectively. Few other examples were found in literature.

Pictographs and ideographs constitute the majority of simple characters in modern Chinese (Lin et al., 2018), which account for 17% of all characters (p. 27). However, Ho et al. (2003) estimated that the percentage was around 10% (p. 851). In conclusion, simple characters (i.e., mainly pictographs and ideographs) only make up a small proportion of the contemporary Chinese characters.

Compound Character Type 1: Ideogrammic Compounds. Ideogrammic compound characters refer to the compound characters which combine the meanings of two or more sub-components to form a new character, and these sub-components only contribute their semantic features to the host ideogrammic compound characters instead of their phonological features. For example, the character 林 (*/lin2/*, meaning: woods, forest, or multiple trees) consists of two identical subcomponents: 木 (/*mu4*/, meaning: wood or tree). This subcomponent only contributes its meaning to the compound character; its pronunciation /*mu4*/ has nothing to do with the compound character 林 (/*lin2*/)'s pronunciation. Ideogrammic compound characters have several alternative names in literature, including:

(1) *Ideogrammic compound characters* (Luo et al, 2014, p. 716; Ma & Ai, 2018, p.

519).

(2) *Ideographic compound characters* (Lin et al., 2018, pp. 27-28).

(3) *Associative compound characters* (Perfetti et al., 2005, p. 45; Tan & Perfetti, 1998, p. 167).

(4) *Semantic compounds* (Shu et al., 2003. p. 29).

(5) *Non-phonetic complex characters* (Kim et al., 2016, p. 1411).

Despite these different terms, previous studies recognized that ideogrammic compound characters only account for a small proportion of compound character (Perfetti et al., 2005; Shu et al., 2003) and that they have not been extensively studied compared to semantic-phonetic compound characters (Luo et al., 2014).

Compound Character Type 2: Semantic-Phonetic Compound Characters. Semantic-phonetic compound characters (形声字) are the focus of this dissertation. They consist of one phonetic radical partially or completely informing the pronunciations at the syllable level and a semantic radical suggesting meaning-related information. The definitions, functions, and positions of the phonetic and semantic radicals within a character have been introduced in previous sections.

Semantic-phonetic compound characters have a number of different names in different published studies. They were summarized in the following table.

Table 1.1

English Terms Referring to Semantic-Phonetic Compound Characters (形声字)

Terms	Studies that Used the Terms
Complex characters	Tong & Yip (2015)
Composite characters	Koda & Miller (2018); Lin et al. (2018)
Compound characters	Kim et al. (2016); Leong & Cheng (2003); Li et al. (2011); Tong & Yip (2015)
Ideophonetic compounds	Shu et al. (2003)

Ideophonetic compound characters	Ho et al. (2003)
Phonetic compound characters	Kim et al. (2016)
Phonetic compounds	Kim et al. (2016); Lin & Collins (2012); Luo et al. (2014); Shu et al. (2003)
Phonograms	Chang et al. (2016); Chen et al. (2016); Hsu et al. (2009); Hsu et al. (2014); Lee et al. (2005); Lee et al. (2015); Wang et al. (2016); Wang et al. (2017); Yum et al. (2014); Yum et al. (2016)
Phono-semantic compounds	Ma & Ai (2018)
Semantic-phonetic characters	Lü et al. (2015)
Semantic-phonetic compound characters	Li et al. (2016); Lin et al. (2018);Tong & Yip (2015); Tong et al. (2017); Wang & Zhang (2011)
Semantic-phonetic compounds	Chen (2019); Lü et al. (2015); Shu et al. (2003); Williams & Bever (2010)

It seems that the term “phonogram” has appeared more frequently in literature than the other alternative terms. However, this dissertation used the term “semantic-phonetic compound characters” for the following reasons: (1) this term clearly states that the focus of this dissertation is not simple characters, but compound characters; (2) this term explicitly indicates that each of the stimuli used in this dissertation consists of a semantic radical and a phonetic radical and that the two radicals are important factors of this dissertation; (3) this term helps readers understand that the majority of stimuli used in this dissertation have their semantic radicals on the left and their phonetic radicals on the right (as it is “semantic-phonetic” instead of “phonetic-semantic”).

Why is it so important to study “semantic-phonetic compound characters”? One important reason is that they account for a large proportion of the modern Chinese characters. However, previous studies provided mixed information, which is summarized in this table:

Table 1.2

Percentage of Semantic-Phonetic Compound Characters as Indicated in Literature

Percentage	Studies	Direct Quotations and Page Numbers
	Reichle & Yu (2018)	"approximately 80% - 90% of characters are phonograms…" (p. 1155)

80% - 90%	Chen (2019)	"most characters (80-90%) in modern Chinese are semantic-phonetic compound (i.e., multi-unit) characters" (p. 130)
	Ho et al. (2003)	"… about 80% to 90% of Chinese characters are ideophonetic compound characters…" (p. 851)
	Koda & Miller (2018)	The vast majority of characters (80 to 90%) are composite characters…" (p. 296)
	Shu et al. (2003)	"an estimated 80% to 90% of modern characters are semantic-phonetic compounds…" (p. 28)
> 85%	Lee et al. (2007)	"more than 85% of all Chinese characters, however, are phonograms;" (p. 147)
	Lee (2008)	"although more than 85% of all Chinese characters are phonograms, …" (p. 180)
	Lee et al. (2005)	"since more than 85% of Chinese characters are phonograms" (p. 78)
85%	Yang et al. (2009)	"the majority (85%) of characters in Chinese are phonograms… " (p. 239)
	Tan & Perfetti (1998)	"although about 85 percent of present-day characters are phonetic compounds…" (p. 13)
	Zhao et al. (2012)	"about 85% of Chinese characters are semantic-phonetic compounds…" (p. 1)
	Perfetti et al. (2005)	"about 85% of present-day characters are phonetic compounds" (p. 45)
82%	Li et al. (2016)	"about 82% of modern Chinese characters are compound characters…" (p. 1367)
81%	Kim et al. (2016)	"Complex characters can be divided… phonetic compound characters, with a frequency estimated at 81%" (p. 1411)
	Williams & Bever (2010)	"This last category comprises the vast bulk of the language - roughly 81%" (p. 591)
	Lü et al. (2015)	"among the compound characters, 81% are semantic-phonetic characters" (p. 170)
	Lin et al. (2018)	"81% of the characters are made up of a phonetic and a semantic component…" (p. 27)
> 80%	Dang et al. (2019)	"more than 80% of characters are phonograms" (p . 2)
	Lee et al. (2015)	"more than 80% of Chinese characters are phonograms" (p. 538)
	Feldman & Siok (1997)	"more than 80% of characters are made up of a phonetic component and a semantic radical" (p. 776)
	Qian et al. (2015)	"[publication in Chinese] 超过 80%的汉字都是形声字，由声旁和形旁组成" (p . 26)
	Li et al. (2011)	"however, more than 80% of Chinese characters are compound characters, consisting of a phonetic radical and a semantic radical" (p. 36)
	Tong et al. (2017)	"… and most characters (over 80%) are semantic-phonetic compound characters that…" (p. 1252)

	Tong & Yip (2015)	"most characters (over 80%) are complex characters that can be decomposed into semantic and phonetic radicals" (p. 160)
	Yum et al. (2014)	"more than 80% of all Chinese characters are phonograms…" (p. 2)
	Yum et al. (2016)	"more than 80% of all Chinese characters are phonograms…" (p. 341)
80%	Zhou et al. (2013)	"as many as 80% of sinograms are phonograms…" (p. 986)
	Hsu et al. (2009)	"approximately 80% of the characters are phonograms that…" (p. 57)
	Chang et al. (2016)	"… approximately 80% of traditional Chinese characters are phonograms…" (p. 113)
	Wang et al. (2016)	"[publication in Chinese] 而在合体字中又有 80%的字为形声字" (p. 130)
70% - 80%	Yeh et al. (2017)	"most compound characters (70% - 80%) are systematically constructed by a semantic radical and a phonetic radical" (p. 1)

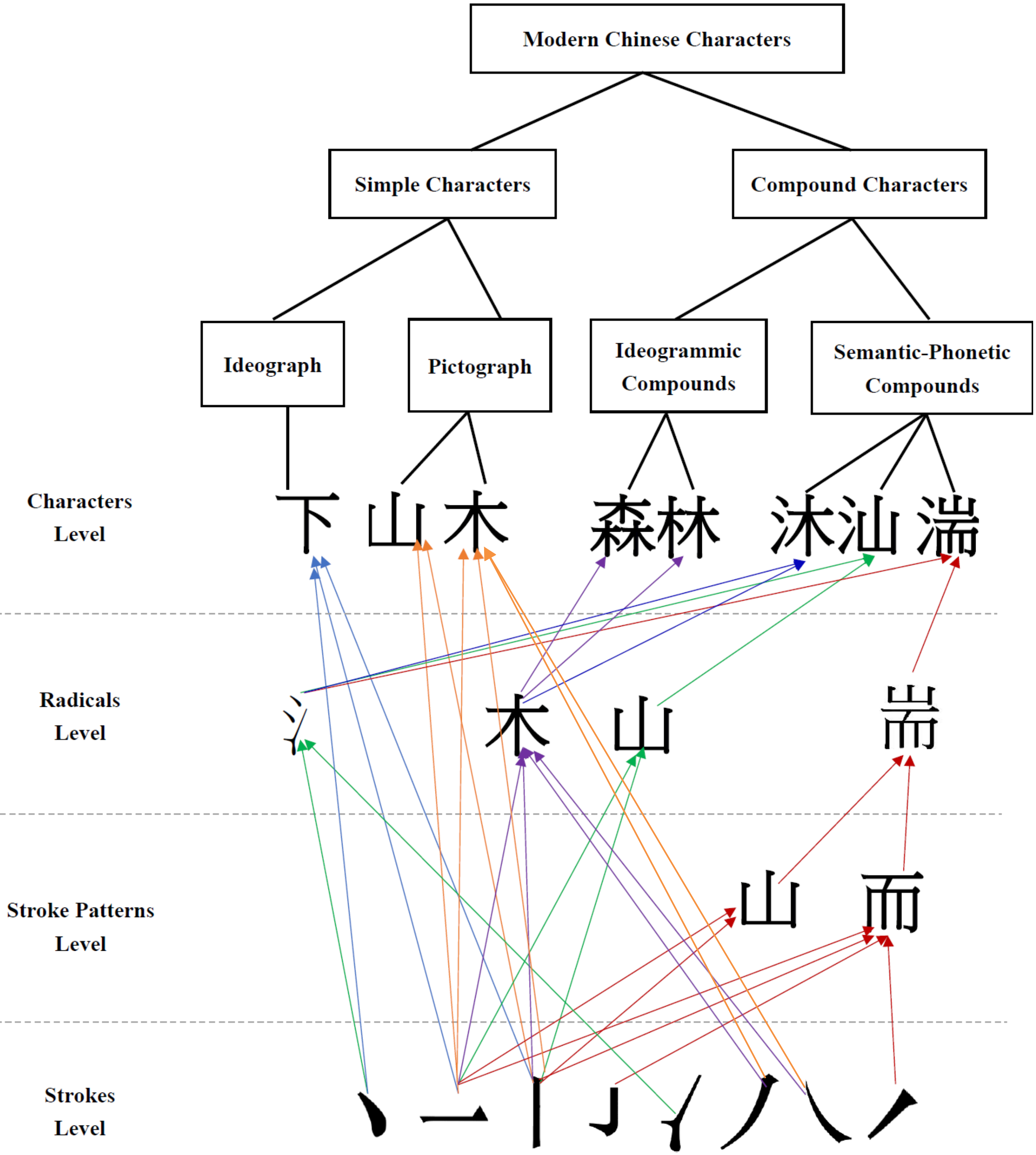
The percentage varied from study to study, but it is certain that no less than 70% of the modern Chinese characters are semantic-phonetic compound characters and that most of these studies (96.8%, i.e., 30 out of 31) listed in Table 1.2 recognized that 80% or more of the contemporary Chinese characters are semantic-phonetic compound characters. As a result, it is of great importance to study this type of Chinese characters.

What is the percentage of semantic-phonetic compound characters in L2 Chinese curriculum? To the best of the author's knowledge, very few studies have investigated this issue. Only Kim and Shin (2015a) systematically analyzed all characters appearing in *International Curriculum for Chinese Language Education* (*国际汉语教学通用课程大纲*) and summarized that there were 1,697 semantic-phonetic compound characters, accounting for 62.2% of the total number of characters in this curriculum (i.e., 2,729) (p. 21).

This percentage of semantic-phonetic compound characters (i.e., 62.2%) is lower than that in L1 speakers' use of Chinese characters (i.e., 80%), but it is still more than half of all required L2 Chinese characters. As a result, it is still important to research this type of characters among L2 Chinese learners.

Figure 1.1

Orthographic Structures and Types of Modern Chinese Characters



Phonological Features

Syllable Structure of Modern Chinese. This section discusses the phonemic and phonological features of contemporary Mandarin Chinese. Those of ancient Chinese and other modern Chinese dialects are not discussed.

Chinese Syllables' Structures. A Chinese syllable can be divided into two major parts: an initial (声母) and a final (韵母) (Luo et al., 2019; Třísková, 2011). An initial (声母)[4] (Svantesson, 1984) or an onset (Chang et al., 2016) is a consonant that appears in the initial part of a syllable. A final (韵母)[5] or a rime (Chang et al., 2016)/rhyme (Svantesson, 1984) is the remaining part of a syllable aside from the initial, which can be further divided into a medial (or a glide; 韵头 or 介音), a main vowel (or a nucleus or a kernel; 韵腹 or 主元音), and an ending (i.e., mainly a nasal consonant, or a vowel that can combine with a main vowel ahead of it to form a diphthong; 韵尾,鼻音, or 韵核) (Duanmu, 2013; Svantesson, 1984; Třísková, 2011; Yang & van de Weijer, 2021). This structure can be written as CGVX[6] (Duanmu, 2006, 2013). In addition, four major tones exist in modern Chinese: including 1st tone (e.g., ā) , 2nd tone (e.g., á), 3rd tone (e.g., ǎ), and 4th tone (e.g., à) plus one light tone. For example, in the syllable /*guāng*/ (character: 光, meaning: light), the initial is the first /*g*/ sound; the final is the rest part of the syllable /-*uang*/, which consists of the medial /-*u*/, the main vowel /*a*/, and the ending /*ng*/; the tone of the syllable is the first tone.

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[4] The *Hanyu Pinyin Fang'an* (*汉语拼音方案*, 1958) and *Xinhua Zidian Dictionary* (*新华字典*, 2004) listed the following initials (声母): /b/, /p/, /m/, /f/, /d/, /t/, /n/, /l/, /g/, /k/, /h/, /j/, /q/, /x/, /zh/, /ch/, /sh/, /r/, /z/, /c/, and /s/.

[5] The *Hanyu Pinyin Fang'an* (*汉语拼音方案*, 1958) and *Xinhua Zidian Dictionary* (*新华字典*, 2004) listed the following finals (韵母): /a/, /o/, /e/, /i/, /u/, /ü/, /ai/, /ei/, /ao/, /ou/, /ia/, /ua/, /uo/, /ie/, /üe/, /uai/, /uei/, /iao/, /iou/, /an/, /en/, /ian/, /uan/ /üan/, /in/, /uen/, /ün/, /ang/, /eng/, /ong/, /iang/, /uang/, /ing/, /ueng/, and /iong/.

[6] C = initial; G = glide; V= main vowel; X = ending.

How Many Chinese Syllables? In this light, Chinese syllables' structure can vary from C (e.g., /*a*/), V (e.g., /*n*/), CV (e.g., /*da*/, VX (e.g., /*an*/), CGV (e.g., /*zhua*/), CVX (e.g., /*dan*/), to CGVX (e.g., /*duan*/). There are 404 syllables in total in modern Chinese (Duanmu, 2013) when tones are not considered. *Xinhua Zidian* (*新华字典*, 2004) suggested that the number is 416. Certain syllables do not exist in modern Chinese, such as /*kia*/, /*hiang*/, /*fun*/, and so forth.

How many syllables are there in Chinese if tones are considered (e.g., /*dā*/, /*dá*/, /*dǎ*/, and /*dà*/ are treated as four different syllables)? Duanmu (2006) indicated that not all the 404 syllables can be pronounced with all the 4 tones. To be more specific, 178 syllables can pronounce all the four tones (e.g., /*dā*/, /*dá*/, /*dǎ*/, and /*dà*/ all exist); 130 syllables can pronounce three tones (e.g., /*ān*/, /*ǎn*/, and /*àn*/ exist, but /*án*/ does not); 59 syllables have only two tones (e.g., /*gǔn*/ and /*gùn*/ exist, but /*gūn*/ and /*gún*/ do not); 53 syllables only have one tone (e.g., only /*hēi*/ exists for the /*hei*/ syllable) (data is from Duanmu, 2006, pp. 351-355; examples were selected from *Xinhua Zidian Dictionary* (2004)). As a result, when tones are considered, there are approximately 1,300 syllables in modern Chinese (Duanmu, 2006). Among them, 26.85% are first-tone syllables, 20.32% are the second tone, 25.18% are the third tone, and 27.65% are the fourth tone (Duanmu, 2006, pp. 351-355).

Functions of Tones. Tones differentiate characters who share the same sound. According to the *List of Common Standard Chinese Characters* (*通用规范汉字表*)[7] published by the State Council of China (2013), there are 3,500 frequent characters and another 3,000 less frequent characters. In total, these 6,500 characters are sufficient for publication, dictionary compilation, and information processing. If tones are not considered, then the 404 syllables are shared by the

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[7] The document can be downloaded from the official website: http://www.gov.cn/zwgk/2013-08/19/content_2469793.htm. The English title of the document is based on this site: http://english.www.gov.cn/archive/state_council_gazette/2015/12/02/content_281475246478052.htm

6,500 characters. On average, each syllable corresponds to 16 different characters, resulting in a large number of homophones. If tones are considered, then the 6,500 characters share 1,300 syllables. Each syllable corresponds to 5 different characters on the average. Thus, the number of homophones decreases significantly because of the existence of tones.

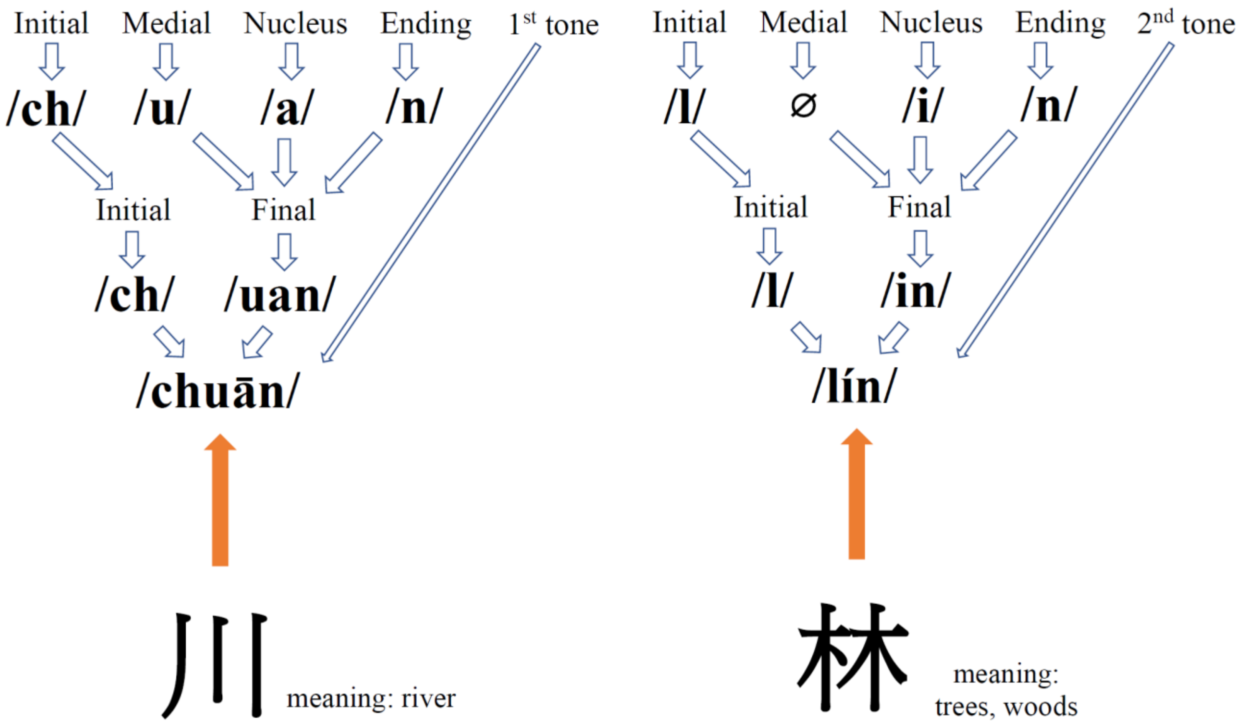
How Chinese Characters Represent Phonology? As mentioned above, the Chinese writing system (i.e., Chinese characters) is deep in terms of orthographic depth due to its opaque and inconsistent graph-to-sound correspondence as well as a lack of phonemic segmentation in orthography. In addition, the correspondence between orthography and phonology is vague. Similarly written characters have different sounds (e.g., 土/*tu3*/ vs. 士/*shi4*/; 刀/*dao1*/ vs. 刃/*ren4*/). Identically pronounced characters are written differently (e.g., 医/*yi1*/ vs. 衣/*yi1*/ vs. 一/*yi1*/).

Phonologically, one Chinese character corresponds to one syllable, and this correspondent relation is “nearly deterministic” according to Perfetti and Tan (1998, p. 170). They used the word “nearly” because sometimes a Chinese character can have two or more pronunciations, and such characters are called heteronyms in Chinese (多音字). For example, 重 has one pronunciation /*zhong4*/, meaning “heavy” and another pronunciation /*chong2*/, meaning “double”. Since heteronyms are not the majority of Chinese characters, they are not the focus of this dissertation. Lastly, despite the “nearly deterministic” orthography-to-phonology correspondence, a syllable can correspond back to multiple characters (i.e., 5 characters on average if tones are considered, as discussed above).

Simple Characters, Ideogrammic Compounds, and Phonology. A simple character, whether it be a pictograph or ideograph, corresponds directly to its pronunciation at the syllable level. Their sub-components (i.e., strokes, stoke patterns) cannot inform or correspond to the simple character's initial, final, or the complete syllable. An ideogrammic compound corresponds to its pronunciation at the syllable level as well. Its sub-components (i.e., strokes, stroke patterns, or radicals, e.g., 木 in 林) do not inform or correspond to the character's initial, final, or pronunciation.

Figure 1.2

Examples of Simple Characters (Left), Ideogrammic Compounds (Right), and Their Syllables' Structures



Semantic-Phonetic Compounds and Phonology. A semantic-phonetic compound character also corresponds to its pronunciation at the syllable level. However, different from simple characters and ideogrammic compounds, the sub-component of a semantic-phonetic compound character (i.e., phonetic radical) can partially or wholly inform its pronunciation at the syllable level if tones are not considered. There are two ways to look at the relation between phonetic radicals and the host semantic-phonetic compound characters.

Regularity. One way is to look at the pronunciation of a semantic-phonetic character and that of its phonetic radical to see if they are identical, partially identical, or completely different. For example, “介” (/*jie*/) is the phonetic radical of “阶” (/*jie*/, meaning: stairs)[8], and they have the identical pronunciation if tones are not considered. Thus, it is considered that the phonetic radical “介” can in whole inform the semantic-phonetic compound (“阶”)’s pronunciation (Feldman & Siok, 1997; Kim et al., 2016; Lee, 2008; Tan & Perfetti, 1998; Zhou, 1980). However, for another semantic-phonetic compound “价” (/*jia*/, meaning: price)[9], the phonetic radical, “介” (/*jie*/) can only partially inform its pronunciation as they only share the same initial and glide while the main vowels are different from each other. Lastly, for “尬” (/*ga*/, meaning: awkward), the phonetic radical “介” (/*jie*/) cannot inform its initial, final, or the whole pronunciation[10].

The above three examples demonstrate how and to what degree a phonetic radical can represent a semantic-phonetic compound character’s pronunciation in modern Mandarin Chinese. Scholars argued that when a semantic-phonetic compound’s pronunciation is the same as its phonetic radical (without considering tones), it is referred to as a “regular” character (规则字); otherwise, it is “irregular” (不规则字) (Fang et al., 1986; Kim et al., 2016; Lee et al., 2005;

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[8] In this dissertation, only simplified Chinese characters are discussed. This example character is written as “階” in traditional Chinese character.

[9] This example character is written as “價” in traditional Chinese character.

[10] However, “介” (/*jie*/) is still considered as “尬” (/*ga*/)’s phonetic radical. This is because they were pronounced the same in ancient Chinese. According to *Guang Yun* (*廣韻*), both of them were recorded as “古拜切，誡小韻”, meaning that they both had the initial/onset of “古” and the final/rime of “拜” and that they had the same pronunciation as “誡” in the Song Dynasty. In addition, “介” and “尬” have the same pronunciation in some of the modern Chinese dialects. For example, they are pronounced identically in modern Cantonese as /*gaai3*/.

Lin & Collins, 2012; Yum et al., 2014; Yum et al., 2016). For instance, when referring to the phonetic radical "介" (*/jie/*) , "阶" (*/jie/*) is regular whereas "价" (*/jia/*) and "尬" (*/ga/*) are irregular.

What is the percentage of regular semantic-phonetic compounds? Most studies recognized that the percentage is low. Zhou (1980) indicated that only 39% of the modern simplified semantic-phonetic compounds are regular (in Mandarin). This percentage has been cited by Tan and Perfetti (1998), Lee (2008), Kim et al. (2016), and other studies. It must be emphasized that the percentage is based on simplified characters and modern Mandarin pronunciations. Some other studies suggested that the percentage varied from 18.5%, 26.3%, to 33% (Feldman & Siok, 1997, p. 776; Lin et al., 2018, p. 28; Williams & Bever, 2010, p. 593).

Many reasons have led to this phenomenon. One possible reason is the change of characters' pronunciations in history. As explained above, "介" (*/jie/*) and "尬" (*/ga/*) shared the same pronunciation in history, but not in modern time. In summary, phonetic radicals alone may not effectively inform semantic-phonetic compound characters' pronunciations.

Consistency. Another way is to look at the pronunciations of a group of semantic-phonetic compounds sharing the same phonetic radical and see if they are identical, partially identical, or completely different. Such group is referred to as a phonetic family (声旁家族, Kim & Shin, 2005a), a phonetic radical family (Jiang & Zhang, 2014), or an orthographic neighborhood (Li et al., 2011; Li et al., 2020)[11].

For example, the 丑(*/chou/*, meaning: ugly) neighborhood has 9 members: 妞(*/niu/*, girl or female), 忸(*/niu/*, ashamed or shy), 扭(*/niu/*, to twist), 纽(*/niu/*, knot), 狃(*/niu/*, to be

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[11] If a group of semantic-phonetic compounds share the same semantic radical, they are referred to as orthographic neighborhood as well (Li et al., 2011). But they are semantic-radical-based neighborhood. In this dissertation, the term "orthographic neighborhood" particularly refers to phonetic-radical-based neighborhood.

accustomed to; to be bound by; to yearn for), 钮(/*niu*/, button), 羞(/*xiu*/, shy), 衄(/*nü*/, nosebleeds, to bleed), and the phonetic radical itself 丑. None of the semantic-phonetic compound in this neighborhood has the same pronunciation as the phonetic radical, so all of them are irregular characters. However, 6 of them are pronounced identically as /*niu*/, so these 6 characters are "friends" to each other (Kim et al., 2016, p. 1411) and are consistent in pronunciation with each other. 羞(/*xiu*/) and 衄(/*nü*/), on the other hand, are "enemies" to the other characters.

To index the degree of consistency in pronunciation in a neighborhood, Fang et al. (1986) provided the following formula: $Consistency_{type} = \frac{Number\ of\ friends}{Neighborhood\ Size}$. Here, neighborhood size (NS for short) refers to the total number of characters in an orthographic neighborhood, including the phonetic radical itself if it can stand alone as a character. For the 丑(/*chou*) neighborhood, the consistency degree of 妞(/*niu*/) is calculated as $0.67 = \frac{6}{9}$. The consistency degree of 羞(/*xiu*/) is calculated as $0.11 = \frac{1}{9}$. Consistency degree is larger than 0.0 and can be equal to or smaller than 1.0. Also, because this kind of consistency is calculated based on the number of friends and that of total neighborhood members, this dissertation refers to it as "type consistency". Many published studies investigating the consistency effect adopted this calculation method of consistency (e.g., Chang et al., 2016; Kim & Shin, 2015a; Kim et al., 2016; Lee et al., 2005; Li et al., 2011; Lin & Collins, 2012; etc.).

Aside from type consistency, some scholars proposed frequency-driven consistency, which involves characters' frequency values into the calculation of consistency degree (Lee, 2008; Lee et al., 2015; Shu et al., 2003). This dissertation refers to this kind of consistency as "token consistency". The formula is $Consistency_{token} = \frac{Sum\ of\ frequency\ of\ friends}{Sum\ of\ frequency\ of\ the\ neighborhood}$. For example, the frequency (per million characters) of these characters are listed in the parentheses: 妞(/*niu*/, 2.20), 忸(/*niu*/, 0.90), 扭(/*niu*/, 42.25), 纽(/*niu*/, 23.55), 狃(/*niu*/, about 0.05), 钮(/*niu*/, 10.70), 羞(/*xiu*/, 21.80), 衄(/*nü*/, 0.35), and 丑(/*chou*/, 28.80). Based on the definition and the calculation method, the token consistency degree of 妞(/*niu*/) is calculated as 0.61 = $\frac{2.20 + 0.90 + 42.25 + 23.55 + 0.05 + 10.70}{2.20+0.90+42.25+23.55+0.05+10.70+21.80+0.35+28.80}$. The token consistency degree of 羞(/*xiu*/) is calculated as 0.17 = $\frac{21.80}{2.20+0.90+42.25+23.55+0.05+10.70+21.80+0.35+28.80}$. Token consistency is also larger than 0.0 and is smaller than or equal to 1.0.

In light of the 丑(/*chou*) neighborhood, the syllable /*niu*/ has a consistency degree higher than 0.5 whereas the other syllables, /*chou*/, /*xiu*/, and /*nü*/, have lower consistency degrees. Thus, /*niu*/ is dominant in this neighborhood, and this suggests that a semantic-phonetic compound character containing the phonetic radical 丑(/*chou*) is more likely to be pronounced as /*niu*/ rather than /*chou*/. In summary, when regularity is not reliable for a phonetic radical to inform pronunciation, consistency can be an alternative indicator. Some scholars even argued that consistency is a more reliable indicator of the correspondent relation between the pronunciation of a phonetic radical and that of its host semantic-phonetic compound (Kim et al., 2016).

Neighborhood Size. Phonetic radical-based neighborhood size ("NS" for short), as explained above, is the number of characters sharing the same phonetic radical. NS is also referred to as "combinability", "phonetic combinability", or "phonetic radical combinability" (Chang et al., 2016, p. 3; Hsu et al., 2009, p. 56; Zhou et al., 2013, p. 971).

Semantic Features

Chinese Characters and Meanings. A Chinese character generally represents a morpheme (i.e., the minimum unit representing meanings), which can correspond to one or multiple meanings. These meanings can be closely related to each other or are totally irrelevant to each other. As a result, Tan and Perfetti (1998) considered that the correspondence from a character to its meaning(s) is “under-deterministic” (p. 170). Also, a character/morpheme can combine with another one or more characters/morphemes to form a two- or three-character word.

Simple Characters, Ideogrammic Compounds, and Meanings. A pictograph represents the meaning of the item that it originally depicts, and the meaning can generate more related meanings. For example, the pictograph 日 (*/ri4/*) originally means the sun, and it developed from the picture . In modern Chinese, this pictograph keeps its original meaning and developed more relevant meanings, including (1) morning; (2) a day or a date of a month; (3) everyday (adverb); (4) time; and (5) Japan, according to the *Xinhua Zidian* (2004). Similarly, the pictograph 月(*/yue4/*) developed from  and originally means the moon. It generated the following related meanings in modern Chinese: (1) month; (2) monthly (adverb); and (3) moon-shaped (*Xinhua Zidian*, 2004).

An ideograph generally represents “abstract” meaning(s) (Lin et al., 2018, p. 27) and can also produce more relevant meanings. For example, “上” (/shang4/) originally means “up” and “above”, and it has the following relevant meanings: (1) to climb or to go (verb); (2) to increase (verb); (3) attend to class or work (verb); (4) to reach certain levels (verb); and so forth. In summary, a simple character can have one or more meanings, and these meanings may be related to one basic meaning or to each other. Also, a simple character may have various parts of speech.

Ideogrammic compound characters are made up of two or more semantic radicals. As a result, an ideogrammic compound’s meaning is the combination or integration of all its radicals’ meanings.

Semantic-Phonetic Compounds and Meanings. Different from simple characters whose meanings are expressed via drawings or visualizing abstract concepts and ideogrammic compounds whose meanings are delivered by combining two or more semantic radicals, a semantic-phonetic compound character has only one semantic radical suggesting its "semantic category" (Chen, 2018, p. 130; Lü et al., 2015, p. 170; Tong et al., 2017, p. 1252; Williams & Bever, 2010, p. 593), rather than an exact meaning. For example, the semantic radical "讠" (i.e., "speech") only indicates a speech-related semantic category, not the exact meanings or parts of speech of its host semantic-phonetic compounds (e.g., 讲 (*/jiang3/*, to speak), 说(*/shuo1/*, to say), 词(*/ci2/*, words), 诗(*/shi1/*, poem, poetry), etc.). However, the semantic radicals are still considered effective when it comes to its usefulness of indicating meaning categories (Williams & Bever, 2010).

Zhou et al. (2013) suggested that the correspondent relationship between a semantic radical and the meaning(s) of its host semantic-phonetic compounds be seen from the following three aspects. They are transparency, consistency, and combinability (p. 971).

Semantic Radical Transparency. Transparency refers whether a semantic radical accurately informs a semantic-phonetic compound's meaning category. For example, the semantic radical "氵" (i.e., three drops of water) indicates water-related meaning. It accurately informs the meaning category of a series of characters (e.g., 海(*/hai3/*, sea), 洗(*/xi3/*, to wash), 河 (*/he2/*, river), etc.) but cannot accurately inform the meaning category of 法 (*/fa3/*, law). This concept can be analogous to "regularity" of phonetic radicals.

Semantic Radical Consistency. This concept is analogous to "consistency" of phonetic radicals. It can be calculated by dividing the total number of semantic-phonetic compounds of the same semantic category by the total number of semantic-phonetic compounds sharing the same semantic radical.

Semantic Radical NS (Combinability). This concept refers to the total number of semantic-phonetic compounds sharing the same semantic radical. Again, this concept is similar to the NS of phonetic radicals.

Problem and Significance Statement

Previous sections introduced the orthographic, phonological, and semantic features of the Chinese writing system and concluded the following points: (1) Chinese orthography has a complicated multi-level structure, and the mechanisms constituting a basic written unit of Chinese (i.e., a Chinese character) is different from those of alphabetic languages; (2) the Chinese writing system is deep in terms of orthographic depth, and the orthography-to-phonology correspondence is opaque and inconsistent; orthographic cues providing phonological information are somewhat unreliable; (3) A Chinese character represents one or more meanings, and the orthography-to-semantics correspondence is under-deterministic. Considering its complexity and uniqueness compared to other writing systems, it is reasonable to argue that Chinese characters imposes tremendous challenges for not only L1 Chinese readers, but also for L2 Chinese learners to learn to read Chinese characters.

Today, the field of teaching Chinese as a second language witnesses a fast-growing number of L2 Chinese learners from around the world. The majority of them use alphabetic writing systems to read and write their native languages. As a result, they experience considerable difficulties achieving the goal of reading Chinese characters fluently, accurately, effectively, and confidently. To solve this problem, it is of great importance to understand (1) what is the underlying mechanism or framework that can predict and explain L2 Chinese learners' reading of Chinese characters; (2) what are the similarities and differences in the process of recognizing Chinese characters between L1 Chinese speakers and L2 Chinese learners? (3) what factors facilitate and what factors attenuate L2 Chinese learners' reading of Chinese characters?

After understanding these problems, L2 Chinese educators are able to use the correct theory to guide their design of textbook, classroom activities, homework, and tests. They are also able to adjust their teaching method by making use of facilitatory factors that benefit L2 Chinese learners' reading of characters and avoiding harmful factors and method. In this way, L2 Chinese learners' stress can be lessened, their learning efficiency of characters can improve, and the learning outcome and quality can be ensured. Also, their learning motivations can be maintained. As a result, it is important to conduct this dissertation study.

Purpose Statement

Considering the research problems, this dissertation has the following research purposes. Firstly, this dissertation aims to know how L2 Chinese learners read semantic-phonetic compound characters. In particular, this dissertation attempts to understand how the NS effect influences the reading process. It is of great significance to learn the reading process of semantic-phonetic compound characters because they account for a large proportion of modern Chinese characters, as reviewed above. It is crucial to learn the NS effect because prior research has suggested significant inhibitory NS effects on the reading of semantic-phonetic compound characters by L1 Chinese speakers (Chang et al., 2016; Li et al., 2011). This effect on L2 Chinese learners' reading, however, has not been investigated.

Secondly, this dissertation aims to understand how L1 Chinese speakers and L2 Chinese learners read two-character words containing one semantic-phonetic compound characters (e.g., 跑步) and how the NS effect plays a role. It is important to learn this because two-character words make up 70% of modern Chinese words (Reichle & Yu, 2018). In addition, the effect of a semantic-phonetic compound character's NS on the recognition of two-character words have not been learned.

Theoretical Framework

To achieve the research purposes, this dissertation needs a guiding theory. A variety of theoretical frameworks have been proposed by different scholars in an effort to understand the reading process of single Chinese characters (Chang et al., 2016; Perfetti et al., 2005; Taft, 2006; Yang et al., 2009) and two-character Chinese words (Li et al., 2017; Sun et al., 2020; Zhou & Marslen-Wilson, 1995). Among them, Perfetti and colleagues (2005)'s Lexical Constituency Model is identified as guiding theoretical framework for this dissertation.

The Lexical Constituency Model

According to the Lexical Constituency Model (Perfetti & Liu, 2006; Perfetti et al., 2005), both the sublexical- and lexical-level processing serve as important constituents for Chinese words reading and identification. The sublexical orthographic units consist of the semantic and phonetic radicals of compound Chinese characters, and the recognition and processing of them are imperative for successful Chinese word reading. The lexical-level representations comprise orthographic, semantic, and phonological information of a compound Chinese character. Two routes constitute the lexical level processing. The first is the lexical route which starts from the orthographic representation through semantic representation and then accesses a word's phonological information. The second route is the non-lexical route which departs from the orthographic representation to phonological information directly. The Lexical Constituency Model has the following important assumptions.

Firstly, the model believes that a word's identity should consist of three "interlocking" components: orthography, phonology, and semantics (Perfetti et al., 2005, p. 46). Failure to correctly activate any of these three components will lead to the failure in recognizing a whole character. Secondly, phonology plays an important role in reading Chinese characters but neither "prelexical phonology" nor "phonological mediation" does not apply in Chinese (Perfetti et al., 2005, p. 56). Thirdly, the model assumes that naming Chinese characters adopts threshold-style phonological activation instead of cascaded style (Perfetti et al., 2005), which means tthe lexical-level phonological activation does not take place before a complete orthographic identification of the target character. Fourthly and the most importantly, Perfetti and colleagues (2005) claimed that a model addressing Chinese reading should include the representational units at the sub-lexical level (i.e., radicals) (Perfetti et al., 2005). This is because the sublexical units in Chinese (i.e., radicals) are different from those in alphabetic writing systems (i.e., letters). In Chinese, most sublexical units (i.e., radicals) are stand-alone characters themselves and have their own meanings and pronunciations while letters in alphabetic writing systems do not. Empirical studies demonstrated that character recognition is the result of radical input, and that radical-based inputs facilitates processing (Perfetti et al., 2005).

The Lexical Constituency Model and This Dissertation

This model is selected as the guiding theory of this dissertation because of the following reasons. Firstly, it is because this dissertation aims to explore the orthographic consistency and neighborhood size effects, both of which are closely related to semantic-phonetic compound characters' radical features.

Secondly, the model explains the orthographic consistency effect in reading Chinese characters: according to the model, through threshold-style processing, when the activation of the radical-level representations (i.e., the radicals) of a target compound character reaches certain threshold, the activation spreads to the orthographic-level representations. As a result, all compound characters that share the same phonetic radical will be activated. If a target character happens to be pronounced differently (i.e., inconsistently) from its neighboring characters (i.e., characters sharing the same phonetic radical), the pronunciations of these neighbors tend to compete with the target character's pronunciation and thus, "interfere with the phonological retrieval of the target" compound characters (Li et al., 2011, p. 38). More details were provided in the literature review.

Thirdly, the model captures the orthographic neighborhood size effect in the following manner: the presentation of a target semantic-phonetic compound character is able to activate its orthographic input units at the sublexical and lexical level. At the sublexical level, the radicals have facilitatory effects "in the early orthographic processing" (Hsu et al., 2009, p. 57) and can activate all its neighbors (Li et al., 2011). At the orthographic level, lateral inhibition influences the activation of target character's orthographical features. This is because the orthographic level representation is localized and have within-level connections, which result in the lateral inhibition at this level. If an activated radical activates more neighboring characters to threshold, inhibitory effects then will be strengthened at the lexical level (Hsu et al., 2009). In other words, the model argues that the larger a target compound character's neighborhood size is, the more inhibition it produces on naming the target character (Li et al., 2011; Perfetti et al., 2005).

The Lexical Constituency Model and Hypotheses

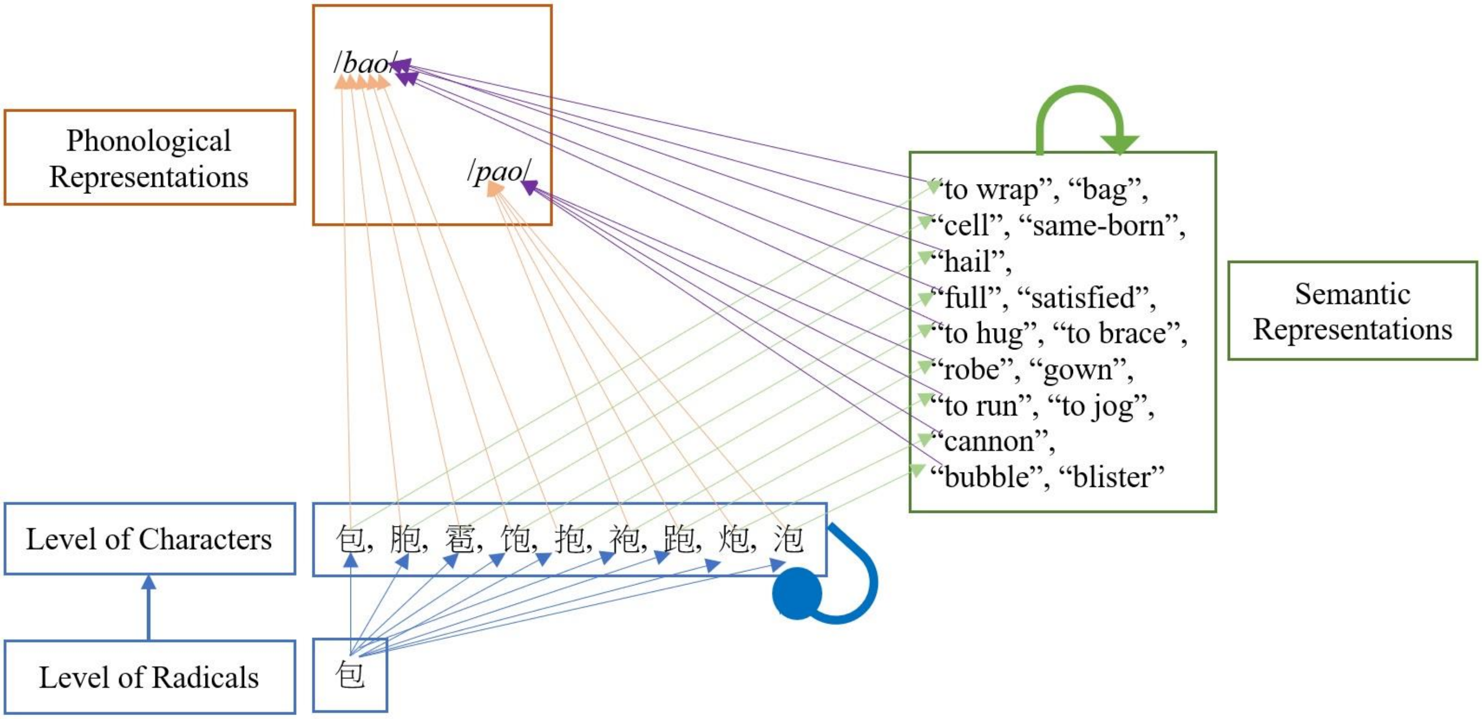
Based on the model, this dissertation has the following two hypotheses. First, the NS effect on reading single characters would be inhibitory. This means that the larger a neighborhood is, reading a semantic-phonetic compound character from such neighborhood would yield longer reaction times and lower accuracy for both L1 Chinese speakers and L2

Chinese learners. This is because, according to Perfetti et al. (2005), the activation at the character (orthographic) level is “negative”, and the “connections” between activated characters at this level are “inhibitory” (p. 49) (see Figure 1.3).

The second hypothesis is that the NS effect on reading two-character words would be inhibitory as well. This is because, if a single semantic-phonetic compound character has a large NS, then its reaction times and accuracy would be negatively affected, which in turn would prolong the RT and attenuate the accuracy of the whole word.

Figure 1.3

A Visualization of the Lexical Constituency Model Based on Perfetti et al. (2005) and An Example of the Phonetic Radical Neighborhood “包”



An Overview of this Dissertation

This dissertation aims to investigate the phonetic radical-based neighborhood size (NS) effect on L2 Chinese learners' recognition of semantic-phonetic compound characters and two-character Chinese words. The following two main research questions guided the design and conduction of this dissertation:

- Research question 1: *What is the NS effect on L2 Chinese learners' recognition of semantic-phonetic compound characters?*
- *Research Question 2: What is the NS effect on L2 Chinese learners' recognition of two-character Chinese words that contain one semantic-phonetic compound character?*

Two studies were administered on L1 Chinese speakers (n = 35) and L2 Chinese learners (n = 17). Chapter 2 reports the literature review, methodology, and results of the first study, which concerns about participants' recognition of single semantic-phonetic compound characters. Participants finished two lexical decision (LD) tasks to judge if the characters they saw were real characters or pseudo-characters. In the first study, participants saw regular characters while in the second study, they saw irregular characters. Participants' reaction times (RTs) and accuracy served as the dependent variables. Data analyses adopted 2 (NS: large/small) x 2(consistency) x 2(Groups) repeated-measures ANOVAs, correlation analyses, and hierarchical regression analyses. Results were reported in Chapter 2 as well.

Chapter 3 contains the literature review, methodology, and results of the second study, which aimed to investigate participants' recognition of two-character Chinese words that contain one semantic-phonetic compound character and one non-semantic-phonetic compound character. Participants finished one lexical decision (LD) tasks to judge if the words they saw were real words or pseudo-words. A 2 (NS: large/small) x 2(consistency) x 2(Groups) repeated-measures ANOVA was conducted on participants' reaction times (RTs) and accuracy, together with correlation analyses and hierarchical regression analyses. Results were reported in Chapter 3.

Chapter 4 provides general discussions regarding the results, theoretical and pedagogical implications, limitations, and future research directions. Chapter 5 includes a summary of conclusions.

Chapter Summary

This chapter introduces the orthographic, phonological, and semantic features of Chinese characters as well as key concepts, including regularity, consistency, and neighborhood size (NS), reviews the problems that these features have brought to L2 Chinese learners, and then states the research purposes, significance, and central research questions. This chapter also explains the theoretical frameworks that guides this dissertation: the Lexical Constituency Model. Lastly, this chapter provides an overview of the whole dissertation by chapters.

Chapter 2

Study 1: The Effect of Neighborhood Size and Consistency on Character Recognition by L2 Chinese Learners and L1 Chinese Speakers

Study 1 aims to investigate the NS effect on character recognition by L2 Chinese learners. Participants included both L1 Chinese speakers (n = 35) and L2 Chinese learners (n = 17). They completed two lexical decision tasks to judge if the semantic-phonetic compound characters they saw were real characters or pseudo-characters. Experiment 1(a) used regular semantic-phonetic compounds whereas Experiment 1(b) used irregular ones. Results and discussions were provided.

Literature Review

Literature review covered studies about regularity effect and consistency effect on L1 and L2 Chinese users' reading of semantic-phonetic compounds. The NS effect on L1 Chinese speakers has also been reviewed. However, the NS effect has not been learned among L2 Chinese learners.

The Regularity Effect

Regularity, as reviewed above, refers to the situation where a semantic-phonetic compound character has the same pronunciation as that of tis phonetic radical without considering tones (Fang et al., 1986). This section mainly reviews studies investigating the regularity effect on L2 Chinese reading.

The Regularity Effect on L2 Chinese Reading. To investigate the regularity effect on L2 Chinese learning and reading, Chen (2001) invited L2 Chinese learners from two different language proficiency levels (i.e., beginning and intermediate) to finish a "character pronunciation" test. Forty (40) semantic-phonetic compound characters were printed on papers, and participants were asked to write down the characters' *pinyin* (i.e., Romanized alphabetic system for Chinese character's pronunciation). The forty stimuli were further divided into three types: regular (i.e., semantic-phonetic compound character's pronunciation is in congruent with that of the phonetic radical); semi-regular (i.e., the semantic-phonetic compound character and its phonetic radical only share onset or final); and irregular (i.e., the semantic-phonetic compound character and its phonetic radical share no onset, rime, or pronunciation). The results showed that L2 Chinese learners had more error responses because they inferred a compound character's pronunciation based on its phonetic radical and regarded the phonetic radical's pronunciation as the semantic-phonetic compound character's pronunciation. The author concluded that L2 Chinese learners tend to deal with unknown semantic-phonetic compound characters' pronunciation based on their phonetic radicals and their regularity features of being regular or not (Chen, 2001).

Behavioral studies supported Chen (2001)'s conclusion. Mo (2014) invited L2 Chinese learners to complete a Lexical Decision (LD) task on both real- and pseudo-characters and a Delayed Naming (DN) task on real characters. Simple t-test results showed a significant regularity effect in LD task for L2 Chinese learners as they reacted to regular characters faster than irregular ones. Mo (2014) further explored the interaction between regularity (regular/irregular) and tasks (LD/DN) in response latency: there was a regularity effect in the DN task as regular characters were named with more accuracy than irregular character in the DN task. On the whole, Mo (2004)'s results indicated that regular characters consistently produced facilitatory regularity effect in both LD and DN task, which further supported Chen (2001)'s conclusion that semantic-phonetic compound character's regularity is an important source for L2 Chinese learners to learn to read.

Hao and Shu (2005) conducted a learning-and-testing experiment was conducted, in which they recruited a total of twenty-five L2 Chinese learners (n = 25) who were from diverse L1 backgrounds and learned Chinese for approximately four months. Similar to Chen (2001), the experiment materials consisted of three types of stimuli: regular (e.g., “枫” (*feng*) and “风” (*feng*)), half-regular (e.g., “浩” (*hao*) and “告” (*gao*)), and non-familiar (i.e., the phonetic radical is not familiar to participants). The learning phase of the experiment included three times of instruction on 24 “learning characters”. Each time, the instruction was followed by an immediate test to investigate if participants could write down the pronunciations of “learning characters” correctly. The same procedure repeated for the second- and third-time learning. After the completion of the learning phase, the testing phase started immediately. Twenty-four “transfer characters” were shown to participants, who were required to write down the correct pronunciations. The “transfer characters (e.g., 沨)” were novel to the participants, but their phonetic radicals were identical to the “learning characters (e.g., 砜)”.

Hao and Shu (2005) found a main effect of regularity type because regular characters had significantly higher correct rate than half-regular characters and characters containing unfamiliar phonetic radicals. The main effect of time of learning was significant as well, with more times of learning resulting in higher correct rate. The interaction between regularity type and times of learning was significant. The authors concluded that phonetic regularity played an important role in L2 Chinese learners’ learning process of semantic-phonetic compound characters. Hao and Shu (2005) also concluded that learning process enabled learners to implicitly discover the principle of phonetic regularity and to use such principle to read novel characters with learned phonetic radicals (Hao & Shu, 2005). Further, this study extended Chen (2001) and Mo (2014)’s conclusion because it discovered that regularity effect was not static, instead it developed as the learning process repeated.

Regularity and Frequency. The interaction between regularity and other variables is another research topic of interest regarding L2 Chinese reading. For example, Jiang (2001)'s study examined the interaction between regularity and character frequency by adopting a 2 (L2 Chinese grades: $2^{nd}/3^{rd}$) x 2 (regularity: regular/irregular) x 2 (frequency: high/low) mixed factorial design. In this study, L2 Chinese learners were asked to write down the pronunciations of presented semantic-phonetic compound characters as fast and accurately as possible. Accuracy data showed not only mains effects of the three independent variables, but also a significant three-way interaction. Post-hoc comparisons further confirmed the regularity effects in L2 Chinese reading: regular characters were responded to more accurately than irregular characters for high-frequency characters regardless of learners' level; however, regularity effect was significant in low-frequency characters only for 3^{rd}-grade learners, not for 2^{nd}-grade learners (as 2^{nd} graders only demonstrated marginally significant regularity effect when reading low-frequency characters) (Jiang, 2001). Based on the results, Jiang (2001) concluded that L2 Chinese learners demonstrated as similar regularity effects as L1 Chinese children. In addition, higher-level L2 Chinese learners showed more robust regularity effect relative to lower-level learners, which meant that regularity effect developed as learners' proficiency level increased, and this partially supported Hao and Shu (2005)'s stance that regularity effect was not static but developing in the course of learning.

Jiang (2001)'s study confirmed significant regularity effect for both high- and low-frequency characters in L2 Chinese character recognition. This conclusion, however, was not in accordance with Lee et al. (2005)'s study, which claimed that regularity effect was significant only for low-frequency characters in L1 Chinese naming. One possible reason for the difference lies in the experimental instruments and tasks. Jiang (2001)'s study used a pen-and-paper experimental instrument, and the task was asking participants to write down stimuli's pronunciations whereas Lee and colleagues (2005) used computer-related devices and naming tasks. Due to the differences in instruments and tasks, it may not be wise to directly compare and contrast the results and conclusions of the two studies.

To replicate Lee et al. (2005)'s results regarding the regularity effect, Lin & Collins (2012) adopted a similar experimental design and asked two groups of L2 Chinese learners (i.e., English- and Japanese-speaking L2 Chinese learners) to finish a naming task. Stimuli were all single-character Chinese words. The study used a 2 (L1s: English/Japanese) x 2 (frequency: high/low) x 4 (character types: consistent/regular (C/R), inconsistent/regular (IC/R), inconsistent/irregular (IC/IR), and non-phonetic compounds) mixed factorial design. Results demonstrated significant main effects of the three independent variables. In addition, the authors found a significant two-way interaction between stimuli frequency and stimuli's types based on accuracy data. Post-hoc comparisons indicated that low-frequency regular stimuli were responded to significantly more accurately than irregular ones, indicating a facilitatory regularity effect in naming characters by L2 Chinese learners; however, such facilitatory regularity effect was not detected in high-frequency stimuli.

Lin & Collins (2012) replicated the same regularity effect among L2 Chinese learners as among L1 Chinese speakers (Lee et al., 2005), and this conclusion partially reflected that L2 Chinese learners demonstrated a similar "trajectory for developing orthography-to-phonology knowledge" as the L1 Chinese users (Lin & Collins, 2012, p. 1747). It also suggested that sub-character level phonological information, such as the phonological clues provided by phonetic radicals play a crucial role in the process of naming semantic-phonetic compound characters by

L2 Chinese learners.

Regularity and Other Factors. In addition to character frequency, Chen and Wang (2001) investigated the interaction between regularity and other variables, such as character's level and learner's proficiency level. Fifty-two L2 Chinese learners from 2 different proficiency levels (i.e., basic and intermediate) were asked to finish a "character pronunciation" test. The study adopted a 2 (proficiency: basic/intermediate) x 4 (character level[12]: A/B/C/D) x 2 (single-/two-character word) x 3 (regularity: regular/semi-regular/irregular) mixed factorial design was employed. The regularity main effect was significant, which demonstrated that regular characters were answered better than semi-regular and irregular stimuli. A two-way interaction between character level and regularity was significant: significant differences in accuracy were found between regular, semi-regular and irregular characters for level B, level C, and level D characters. For level C and D characters, regular characters earned "significantly more accurate responses" than semi-regular and irregular characters (Chen & Wang, 2001, p. 78).

In summary, prior studies showed that phonetic radicals of the semantic-phonetic compound characters provided useful information for L2 Chinese learners to learn and read such characters, and the regularity effect was consistently robust across different types of tasks for L2 Chinese learners. In addition, the regularity effect appeared at the very early stage of learning as learners who learned Chinese for only four months showed facilitatory regularity effect during learning (Hao & Shu, 2005), and it kept developing as learners' amount of training, experiences of reading semantic-phonetic compound characters, and proficiency level in L2 Chinese increased. The regularity effect in L2 Chinese reading showed similar developmental features as

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[12] Character level refers to the characters categorization method based on the old version HSK (i.e., The Proficiency Test in Chinese) vocabulary. Level A (甲级) characters were the most basic and fundamental ones used in teaching Chinese as a foreign language. As characters level increased, characters became more difficult and less frequent. Such character levels are no longer used in the new HSK test.

those in L1 Chinese children's reading. As for naming semantic-phonetic compound characters, regularity effect demonstrated similar functioning pattern among L2 Chinese learners as L1 Chinese users in that facilitatory regularity effect was robust when naming low-frequency characters; when naming high-frequency characters, such regularity effect disappeared. Moreover, regularity interacted with other important variables, such as stimuli's difficulty levels, and learner's proficiency levels.

The Consistency Effect

Psycholinguistic research has indicated that orthographic consistency is an important factor that influences the reading process of printed words in English and other alphabetic languages. In English, consistency refers to the degree to which orthography has consistent pronunciation (Lee et al., 2005; Lee et al., 2015). For example, certain orthographic bodies or rimes consistently have identical pronunciation in different words (e.g., *-ake* in *cake*, *sake*, *fake* etc.) while some others lack such consistency (e.g., *-eight* in *weight* and *height*). Previous studies showed facilitatory orthographic consistency effect in reading English, which indicates that words with consistent orthography-to-pronunciation correspondences were reacted to faster and more accurately. Such consistency effect was found significant in reading low-frequency words, relative to high-frequency ones (Lee et al., 2005; Seidenberg, 1985).

The Consistency Effect on L1 Character Reading. Prior studies found that orthographically consistent characters were named with shorter reaction time and lower error rates. Fang and colleagues (1986) used three types of semantic-phonetic compound characters, including regular and consistent characters (R/C), regular but inconsistent ones (R/IC), and irregular and inconsistent ones (IR/IC) stimuli in Experiment 1 to elicit participants' naming. Results showed that the R/C type was reacted to significantly faster than the R/IC type and IR/IC type while there were no significant differences in naming latencies between the R/C and IR/IC type. The results indicated that there was a significant consistency effect in reading Chinese compound characters (Fang et al., 1986) regardless of character frequencies.

However, there were two issues with regards to the consistency effect found in Fang and colleagues (1986)'s study. Firstly, the consistency effect was detected by comparing the naming performance between R/C and R/IC characters, meaning that the consistency effect was only restricted to regular characters and might be confounded by the regularity effect. It is worth exploring if the consistency effect is still detectable when the regularity effect is lacking. Secondly, as Lee et al. (2005) indicated, Fang et al. (1986)'s study did not examine how frequency interacted the consistency effect. When referring to studies concerning English reading, consistency effect is stronger for reading low-frequency words relative to high-frequency ones (Seidenberg, 1985). It is worth exploring if such consistency-by-frequency interaction exists in reading Chinese phonetic compounds characters as well.

To fill the research gap in Fang et al. (1986), Lee and colleague (2005)'s study addressed the interaction between consistency, frequency and regularity. In Experiment 1, they used four types of semantic-phonetic compound characters as stimuli: consistent and regular (C/R), inconsistent and regular (IC/R), inconsistent and irregular (IC/IR), and non-semantic-phonetic compound characters (NON). Participants' naming latency data showed that for high-frequency stimuli, C/R characters were read faster than IC/R ones, indicating a consistency effect. Similar facilitatory consistency effects were detected among low-frequency characters, as the C/R stimuli were reacted to more accurately than IC/R words. Lee et al. (2005) concluded that consistency effects were significant for reading both high- and low-frequency characters.

In Lee et al. (2005)'s study, any semantic-phonetic compound characters that were not consistently pronounced were considered as inconsistent characters, even they may have high consistency value (e.g., 0.9). To further examine how consistency level (i.e., high and low) affects naming, Lee et al. (2005) manipulated inconsistent stimuli's consistency level into high (i.e., consistency value between 0.5 and 0.89) and low (i.e., between 0.1 and 0.47). Participants' accuracy data showed a significant 3-way interaction between frequency (low/high), regularity (regular/irregular) and consistency level (low/high), indicating that for low frequency stimuli, high-consistency characters were named more accurately relative to low-consistency characters for both regular and irregular stimuli. Such consistency-level effect, however, was absent in high-frequency characters.

To further examine the consistency level effect, Lee et al. (2005) manipulated consistency level into high (i.e., consistency=1), middle (i.e., consistency= 0.44 to 0.88), and low (i.e., consistency= 0.1 to 0.33) in Experiment 2. Significant interaction effects were found between frequency (high/low) and consistency level (high/middle/low): for low-frequency stimuli, high-consistency characters were read faster and more accurately than middle-consistency ones, which in turn were reacted to faster and more accurately than low-consistency characters. However, such consistency-level effect was not significant for high-frequency stimuli (Lee et al., 2005).

To further confirm if frequency-by-consistency interaction could be possible for high-frequency characters, in Experiment 3, Lee and colleagues (2005) calculated "token consistency" of characters, which was the ratio of summed frequency of target character's "friends" (i.e., characters with the same pronunciation in a neighborhood) to the summed frequency of phonetic compounds in the neighborhood), instead of "type consistency". Lee et al. (2005) found that for high-frequency stimuli, high-consistency (i.e., token consistency = 1) characters were named with shorter reaction latencies and higher accuracy compared to low-consistency stimuli (i.e., token consistency < 0.3), indicating that different from English, consistency effect is detectable for both high- and low-frequency words in Chinese (Lee et al., 2005)

Taken together, Lee et al. (2005)'s study yielded the following important conclusions regarding the consistency effect in reading Chinese characters: Firstly, semantic-phonetic compound characters with higher consistency level were read faster and more accurately, which is referred to as a facilitatory consistency effect in Chinese. Secondly, even though regularity effect was majorly found in low-frequency characters, consistency effects were found in both low- and high-frequency characters, meaning that consistency effect was frequency-independent. Thirdly, according to the authors, consistency is a better index to describe the orthography-to-pronunciation correspondence in Chinese rather than regularity. Fourthly, it is worth noting that neither regularity nor consistency alone can represent the print-to-sound mapping relationship of semantic-phonetic compound characters (Lee et al., 2005; Lee, 2008).

Yang et al. (2009)'s study attempted to replicate the results of Lee et al. (2005). In Experiment 1, three types of phonetic compounds were used as stimuli to elicit naming accuracy (for simulation data) and response latencies data (for behavior data). The three types included regular and consistent characters (R/C), regular but inconsistent characters (R/IC), and irregular and inconsistent ones (IR/IC). All the inconsistent stimuli had low degree of token consistency. Both the behavioral data and stimulation data demonstrated a significant 2-way interaction between frequency (high/low) and stimuli type (R/C, R/IC, IR/IC). To be more specific, for low-frequency stimuli, there was a significant difference in naming between R/C and R/IC types, indicating a significant consistency effect whereas, for high-frequency stimuli, such consistency effect was absent.

A Discussion about the Consistency Effect. The result of Yang et al. (2009) conflicts with that of Lee et al. (2005)'s study: Lee et al. (2005) claimed that consistency effect was frequency-independent whereas Yang et al. (2009) did not agree. Three explanations may be able to account for the difference in conclusions. Firstly, as Yang et al. (2009) has pointed out, the manipulations of character frequency were different between the two studies. In the third experiment of Lee et al. (2005), high frequency referred to the average occurrence of around 693 and 613 per million for high- and low-consistency level respectively. However, high frequency in Yang et al. (2009) was defined as approximately 465 to 490 per million. Stimuli in Lee et al. (2005) seemed to have higher frequency mean than those in Yang et al. (2009), and this could result in the difference in conclusion regarding the frequency-by-consistency interaction (Yang et al., 2009).

Another possible explanation is that the experimental designs and materials selection were different between the two studies. In Lee et al. (2005)'s Experiment 3, only phonetic compounds whose phonetic radicals could not stand alone as a simple character were used as experimental materials, and this kind of design eliminated "regularity effect" (because such semantic-phonetic compound characters' phonetic radicals do not have pronunciations). However, in Yang et al. (2009)'s study, consistency effect was calculated by subtracting the accuracy rate or response latencies between the R/C and R/IC types, which informs that regularity effect was confounded in consistency effect in Yang et al. (2009). It can be further explained in this way: the consistency effect detected in high-frequency stimuli (Lee et al., 2005) was only restricted to the phonetic compounds who does not have a pronounceable phonetic radical and does not have regularity effect, and the absence of consistency effect in high-frequency stimuli (Yang et al., 2009) may only be limited to regular phonetic compounds and there is a possible interference of regularity effect in Yang et al. (2009)'s result.

The third potential explanation concerns about consistency level. Even though both Yang et al. (2009) and Lee et al. (2005; Experiment 3) adopted "token consistency" instead of "number consistency", the two studies demonstrated distinct consistency value means for inconsistent stimuli. Yang et al. (2009)'s study had an average consistency degree of 0.47 for the R/IC type and 0.4 for the IR/IC type for high-frequency stimuli and an average consistency level of 0.31 and 0.25 for the R/IC and IR/IC type respectively for low-frequency stimuli. In Lee et al. (2005)'s study, however, inconsistent characters had a consistency value of 0.11 and 0.03 for high- and low-frequency stimuli respectively. In other words, the differences in consistency values between consistent and inconsistent stimuli were large between the two studies, and this may be one of the reasons that led to the detection of consistency effect in reading high-frequency characters (Lee et al., 2005). This might also account for the failure to detect such consistency effect in Yang et al. (2009)'s study because the difference in consistency values between consistent and inconsistent characters was not large enough to detect any consistency effect for reading high-frequency characters.

Prior conclusions with respect to the consistency effects in naming Chinese characters have important implications for the future studies. Firstly, the consistency effect cannot only address if stimuli are consistent or inconsistent. Rather, stimuli's consistency level should be taken into consideration as higher consistency value facilitated naming (Lee et al., 2005). Secondly, it is questionable if the consistency effect found in the above-reviewed studies is modulated by any other factors, such as neighborhood size. The above-discussed studies regarding consistency effect did not strictly match neighborhood size across different conditions. For example, Lee et al. (2005)'s study had no explicit statements or explanations with regards to the matching of neighborhood size; in Yang et al. (2009)'s study, "R-C items have a smaller family size than the others” and the authors “matched the family size for inconsistent items only” (p. 244). It is unknown as to if the consistency effect found in previous studies was confounded by the potential neighborhood size effect. As a result, it is plausible to explore the interaction effect between consistency and neighborhood size in reading Chinese characters.

In summary, this session reviewed previous studies that examined the consistency effect in reading semantic-phonetic compound characters by L1 Chinese speakers. Consistency effect exists in Chinese: consistent characters facilitated naming compared to inconsistent characters; characters that have higher level of consistency value exerted more facilitation on naming than those with lower level of consistency value. Different from English, consistency effect was found in both high- and low-frequency semantic-phonetic compound characters, but low-frequency characters demonstrated much larger consistency effect relative to high-frequency characters.

The Consistency Effect on L2 Character Reading. In L1 Chinese reading, consistent semantic-phonetic compound characters or those with high consistency value had facilitatory consistency effects on naming (Fang et al., 1986; Lee et al., 2005; Yang et al., 2009), and some scholars even argued that consistency effect was not depending on frequency (Lee et al., 2005). However, it remains a research topic worth exploring as to whether consistency effect works in a similar manner in L2 Chinese reading.

The above-reviewed studies examining regularity effect (Chen & Wang, 2001; Chen, 2001; Hao & Shu, 2005; Jiang, 2001) did not match the consistency level of their stimuli across different conditions. Hao and Shu (2005)’s study did not take character’s consistency into consideration. It was unclear if participants’ correct responses to regular stimuli were due to the regularity effect alone or an interaction between regularity and consistency. For example, for the regular “learning” character “沨 (*feng*)” and “transfer” character “砜 (*feng*)”, it was unclear if participants' correct responses were only because the two compound characters were regular or because they were regular and consistent at the same time. A solution to this issue is to use the phonetic radicals which are not stand-alone simple characters and have no sound value (i.e., bound phonetic radical, e.g., 叚), while another solution is to examine if regularity and consistency interact with each other on L2 Chinese reading. However, it was not until recent years that consistency effect was studied among L2 Chinese learners.

Lexical Decision and Delayed Naming. Mo (2014) studied the consistency effect in L2 Chinese learner's performances in a Lexical Decision (LD) and a Delayed Naming (DN) task. Different from regularity effect, behavioral data showed no significant consistency effect in LD task. By using a 2 (task: LD/DN) x 2 (consistent/inconsistent) factorial design, Mo (2014) found no significant main effects or interaction effects of consistency. It was important to notice that the consistency effect did not play a role in L2 Chinese reading in LD or DN tasks, but the regularity effect did. Considering scholars argued that consistency was a better index than regularity in terms of representing the orthography-to-phonology correspondence in Chinese (Lee et al., 2005; Lee, 2008), the absence of the consistency effect in LD and DN tasks was worth careful examining. The null consistency effect in Mo (2014)'s study may be because of the tasks used (i.e., LD and DN), which are different from naming tasks (as used in Lee et al., 2005).

Yum and colleagues (2016) reconfirmed the lack of consistency effect in Delayed Naming (DN) tasks. However, they detected a significant consistency effect in a Lexical Decision (LD) task. By adopting a 2 (regular/irregular) x 2 (consistent/inconsistent) within-subject factorial design, analysis on the response latency data demonstrated a significant main effect of consistency: inconsistent stimuli were responded to faster compared to consistent stimuli, which means there was an inhibitory consistency effect in lexical decision tasks by L2

Chinese learners. In addition, there was a marginally significant interaction effect between regularity and consistency. Post-hoc comparisons demonstrated a significant inhibitory consistency effect for irregular stimuli as inconsistent and irregular characters were reacted to faster than consistent and irregular ones. Nevertheless, such inhibitory consistency effect did not exist in regular characters (Yum et al., 2016).

Both Mo (2014) and Yum et al. (2016)'s study employed Lexical Decision and Delayed Naming tasks, which were unable to capture the observed consistency effect in naming tasks as used in Lee et al. (2005). The use of different tasks may lead to the fact that Mo (2014) and Yum et al. (2016) found inhibitory consistency effect among L2 Chinese learners while Lee et al. (2005) found facilitatory consistency effect among L1 Chinese users. To understand if the consistency effect in L2 Chinese naming works in a similar manner as that in L1 Chinese, studies adopting naming tasks are needed. To the best of the author's knowledge, Kim et al. (2016), Lin & Collins (2012), and Wu (2008) are the three representative studies so far that explored the consistency effect in reading/recognizing semantic-phonetic compound characters among L2 Chinese learners.

Learning to Read and Naming. Kim et al. (2016)'s study consisted of a learning stage and a transfer test stage. During the learning stage which further comprised three trials, learners of Chinese as L2 with various L1 backgrounds were required to complete a naming test after each learning trial. A linear mixed-effects modals analysis on both the naming latency and accuracy data of each test showed the following results: as learners received more training on selected semantic-phonetic compound characters, their naming accuracies increased and their naming latency became shorter, showing a facilitatory learning effect. In addition, consistent characters produced higher naming accuracy rate than semi-consistent ones, which in turn elicited more accurate responses than inconsistent ones, indicating a facilitatory consistency effect in naming Chinese characters. However, such facilitatory consistency effect was not found when analyzing the latency data. In addition, Kim et al (2016)'s results showed that consistency effect interacted with learners' vocabulary knowledge based on both accuracy and latency data.

In the transfer test stage, learners were required to name new semantic-phonetic compound characters whose phonetic radicals were learned during the learning phase. Even though naming accuracy data showed marginal significance for facilitatory consistency effect, naming latency data confirmed that consistent stimuli were named with significantly shorter latency than semi-consistent ones which in turn were responded to faster than inconsistent stimuli, demonstrating facilitatory consistent effects in naming Chinese characters by L2 Chinese learners. It is worth noting that, different from the learning phase, in the transfer test phase consistency did not interact with individual L2 Chinese learner's vocabulary knowledge.

Kim et al. (2016)'s study further confirmed the important role of consistency in the process of learning and reading semantic-phonetic compound characters by L2 Chinese learners. Consistent semantic-phonetic compound characters (i.e., consistency value equals to 1) consistently facilitated naming process more than semi-consistent characters (i.e., consistency value equals to 0.67 for this study) which in turn exerted more facilitation than inconsistent characters (i.e., consistency value equals to 0.33 for this study) based on both the accuracy and latency data of the transfer test (Kim et al., 2016). This indicated that consistency level had a crucial role in L2 Chinese character acquisition.

However, Kim et al. (2016)'s stimuli consisted of low-frequency phonetic radicals and low-frequency semantic-phonetic compound characters that contained these phonetic radicals during the learning stage. In the transfer test stage, Kim et al. (2016) used pseudo-characters or very low-frequency characters, which meant that it was unclear how characters frequency had an influence in the process of naming Chinese characters and how characters frequency interacted with consistency levels. Furthermore, it was unclear if Kim et al. (2016)'s conclusion could be applied in the situation where L2 Chinese learners learn to read higher-frequency real Chinese characters.

Another arguable issue concerns whether Kim et al. (2016) has balanced the regularity effect well, and this issue is similar to that of Hao and Shu (2005)'s study. In Kim et al. (2016), all consistent stimuli in the learning phase were regular characters, including the stand-alone phonetic radicals. Likewise, all semi-consistent characters in the learning phase were semi-consistent and semi-regular (Hao & Shu, 2005). It was worth exploring whether the facilitatory effect detected among consistent characters was partially due to regularity effect (i.e., an interaction between consistency and regularity), or it was solely because of the consistency effect.

Consistency, Frequency, Regularity, and L1 Backgrounds. To the best of the author's knowledge, Lin & Collins (2012) was the only study that comprehensively examined the regularity, consistency, and L1 effects in L2 Chinese reading. In their study, a 2 (L1: Japanese/English) x 2 (frequency: high/low) x 4 (phonetic compound types: C/R, IC/R, IC/IR, NON) mixed factorial design with duration of learning as the covariate was used in a naming task. Participants who learned Chinese as L2 and spoke different L1s participated in this study. A three-way ANCOVA analysis on accuracy data showed that the between-subject factor (i.e., L1 backgrounds) was significant as Japanese participants named stimuli more accurately than their English counterparts. Within-subject factors (i.e., stimuli frequency and types) had main effects as well: high-frequency stimuli were named significantly more accurately than low-frequency ones; consistent and regular (C/R) stimuli were named with significantly higher accuracy rate compared to inconsistent and regular (IC/R), which in turn were more accurately responded to than non-phonetic compound stimuli (NON) and then the inconsistency and irregular characters (IC/IR) (Lin & Collins, 2012). Additionally, there was a significant two-way interaction between frequency (high/low) and stimuli types (C/R, IC/R, IC/IR, NON).

Lin & Collins (2012) further calculated the magnitude of the facilitatory consistency effect by subtracting the mean accuracy of C/R stimuli from that of non-phonetic compounds as well as the amount of the inhibitory consistency effect by subtracting the mean accuracy of IC/R and IC/IR from that of non-phonetic compounds. Repeated ANCOVA analyses showed a more robust consistency effect for high-frequency stimuli relative to low-frequency stimuli, which was "surprising" to the authors (p. 1757) as according to Lee and colleagues (2005), consistency effect was found more robust when reading low-frequency characters relative to high-frequency ones by adult L1 Chinese readers.

Lin & Collins (2012) did not give explicit explanations as to why a more robust consistency effect was detected for high-consistency stimuli rather than low-consistency ones. They only provided explanations that "CLL (Chinese language learners) were still developing decoding skills; therefore, they were not about to fully use analogies or orthographic consistency to name novel characters" (p. 1761). As a result, how consistency interacts with character frequency remains a research question worth exploring for the future studies.

In addition to ANCOVA analysis, Lin & Collins (2012) conducted hierarchical regression analyses, in which they focused on four orthographic features of phonetic compound Chinese characters: familiarity (i.e., textbook frequency for L2 Chinese learners), stroke numbers, regularity and consistency. Regularity was placed as the third step of the analysis in Order 1 and the fourth step in Order 2. Consistency was put as the fourth step of the analysis in Order 1 and the third step in Order 2. Stepwise regressions analyses demonstrated that "consistency plays a more robust role than regularity" in terms of explaining the variance of naming accuracy for the whole participants (Lin & Collins, 2012, p. 1760). This conclusion agreed with the studies regarding L1 Chinese naming in that consistency is a better index in predicting the naming efficiency of semantic-phonetic compound characters.

The Development of the Consistency Effect. Wu (2008) explored how L2 Chinese learners' proficiency level and the consistency effect influenced their reading of semantic-phonetic compound characters. A total of 60 L2 Chinese learners from South Korea and Japan participated the character pronunciation judgement test, in which participant was required to judge whether each demonstrated pair of Chinese characters share the same sound. A 3 (class year: 1st, 2nd, or 3rd year) x 2 (proficiency level: high/low) x 2 (consistent/inconsistent semantic-phonetic compound) factorial design was adopted. Results demonstrated that the main effect of consistency was significant. In addition, the main effect of class year was significant and so was its interaction with consistency. First-year L2 learners had not developed the awareness of consistency, but the 2nd- and 3rd-year learners had developed such consistency awareness as they demonstrated significant consistency effect respectively.

Wu (2008) concluded that the consistency effect was not detected among the first year L2 Chinese learners. However, the consistency effect emerged when learners had attained higher level of proficiency and kept developing.

A Summary of the Consistency Effect. In summary, similar to L1 Chinese reading, L2 Chinese learners demonstrated strong reliance on the consistency feature of semantic-phonetic compound characters, and consistency played a critical part in learning to read and reading semantic-phonetic compound characters by L2 Chinese learners. In addition, as L2 Chinese learners obtained more exposures to target characters, they demonstrated more facilitatory consistency effects in naming target stimuli, indicating a development of consistency effect among L2 Chinese learners (Kim et al., 2016). Furthermore, characters with higher consistency degree exerted more facilitatory effects on naming compared to characters with lower consistency degrees in L2 Chinese reading (Kim et al., 2016; Lin & Collins, 2012), which was similar to L1 Chinese reading (Lee et al., 2005). Consistency effect also interact with other variables, such as learners' vocabulary knowledge during learning stages (Kim et al., 2016), characters' frequency and regularity (Lin & Collins, 2012). Different from L1 Chinese speakers, L2 Chinese learners showed more significant consistency effects when reading high-frequency characters rather than low-frequency characters (Lee et al., 2005; Lin & Collins, 2012).

Type Consistency vs. Token Consistency. Two types of consistency existed in the research of consistency effect in Chinese reading. As introduced earlier, type consistency is defined as the ratio of total number of characters with the same pronunciation regardless of tonal differences in a neighborhood to the total number of characters in the neighborhood (Fang et al., 1986) while token frequency is defined as the ratio of summed frequency of friends (i.e., characters with identical pronunciations) in a neighborhood to summed frequency of all the characters in the neighborhood (Lee, 2008; Shu et al., 2003). Token consistency is also named as frequency-weighted consistency (Chen et al., 2003; Lee et al., 2015).

Both types of consistency have been used in a variety of previous studies. In research about L1 Chinese reading, some studies employed type consistency only (Chang et al., 2016; Fang et al., 1986; Li et al., 2011; Shu et al., 2000; Yang et al., 2009) while some other studies used both token and type consistency in one single studies (Lee et al., 2004; Lee et al., 2005;

Yum et al., 2014). For example, Lee et al. (2005) used type consistency in their first and second experiment and token consistency in the third experiment. Lee et al. (2004) set the consistency values of inconsistent stimuli in their study lower than 0.2 by depending on both token and type consistency as criteria. Similarly, type and token consistency were favored by different studies investigating L2 Chinese reading. Kim et al. (2016) and Lin & Collins (2012)'s studies employed type consistency while Yum et al. (2016) used token consistency. In addition, Mo (2014) relied on both types of consistency.

For one single semantic-phonetic compound character, its type- and token consistency can be distinct from each other. Both Shu et al. (2003, p.39) and Chen et al. (2003, p.116) gave the same example of the phonetic neighborhood of 半(*/ban4/*), which has five members: 半(*/ban4/*), 伴(*/ban4/*), 绊(*/ban4/*), 拌(*/ban4/*), and 判(*/pan4/*). The character 判(*/pan4/*)'s type consistency is 0.2 (=1/5). Its frequency, however, is much higher than the other four neighbors. As a result, after calculation based on the token consistency's definition, its token consistency is 0.51 (Chen et al., 2003). Chen and associates (2003) argued that "the frequency-weighted consistency may be more representative of a child's language experience" (p. 120).

In Lee et al. (2005)'s study, by using type consistency, they obtained contradictory results between Experiment 1 and Experiment 2. Experiment 1 indicated that for L1 Chinese users, the consistency effect was similar for both high- and low-frequency characters while Experiment 2 attested that the consistency effect was only significant for low-frequency characters. To solve the discrepancy in conclusions between the two experiments, Lee and colleagues adopted token consistency instead of type consistency in Experiment 3 and noticed that both high- and low-frequency characters had significant consistency effects when the low-consistency stimuli had low enough summed frequencies of friends (i.e., characters having the same pronunciation in a neighborhood) and high summed frequencies of enemies (i.e., target stimuli had very low consistency value by frequency). Lee et al. (2005) explained one of the major reasons that led to the difference in results between the first two experiment might be that by using type consistency, some inconsistent characters were not "inconsistent" enough for a consistency effect to be detected while by using token consistency, "inconsistent" characters have a low consistency value that can capture the consistency effect.

In summary, both type and token consistency served as important measurements of an orthographic neighborhood's phonological consistency. Also, both type and token consistency helped psycholinguistic scholars yield significant conclusions regarding the consistency effect on reading semantic-phonetic compound characters for both L1 Chinese speakers and L2 Chinese learners. There were no standards or criteria indicating which kind of consistency is superior to another. However, researchers are advised to be careful when they consider which consistency index to use. The choices may take into account their research questions, experimental designs, data analysis methods, and other factors.

The Neighborhood Size (NS) Effect

As introduced in Chapter 1, this dissertation focuses on phonetic radical-based neighborhood size. NS refers to the total number of semantic phonetic compound characters sharing the same phonetic radical (Chang et al., 2016; Hsu et al., 2009; Hsu et al., 2014; Li et al., 2011; Li et al., 2017; Wang & Zhang, 2011; Zhao et al., 2012). For example, the phonetic radical 者 (*/zhe3/*) has a large NS of 14: 猪, 诸, 煮, 著, 都, 睹, 堵, 赌, 署, 暑, 奢, 都, 绪, and 者. Other phonetic radicals may form a smaller NS. For example, the phonetic radical 两 forms a NS of three (i.e., 两, 辆, and 俩).

The Neighborhood Size Effect on L1 Character Reading. Feldman and Siok (1997) is one of the earliest studies that examined the NS effect in reading Chinese characters. In Experiment 2, they explored the interaction between “phonetic radical combinability” (i.e., the number of characters that a phonetic radical can enter legally; a concept equal to ‘phonetic NS’) and “phonetic radical’s position” on L1 Chinese speakers’ character decision. Response latencies data demonstrated that stimuli of high phonetic radical combinability (i.e., large phonetic NS) elicited faster responses than those of low phonetic radical combinability (i.e., small phonetic NS). Further investigation into the interaction between phonetic radical’s position and combinability revealed that, regardless of phonetic radical’s position, high phonetic combinability always produced facilitation compared to low phonetic combinability, indicating a facilitatory phonetic NS effect in visually identifying Chinese characters by L1 Chinese speakers.

In spite of Feldman and Siok (1997)’s findings, it was unclear how the NS effect interacts with other factors, such as characters’ frequency, regularity, and consistency. To fill this research gap, Bi and colleagues (2006) explored the interaction between semantic-phonetic compound characters’ frequency, regularity, and NS. In the first experiment of their study, a 2 (frequency: high/low) x 2 (regularity: regular/irregular) x 2 (NS: large/small) within-subject factorial design was implemented in a naming task. Accuracy data showed that the main effect of NS was significant, with smaller NS produced more accurate responses than large NS, indicating an inhibitory NS effect in naming. A two-way interaction between NS and characters’ regularity was significant as: for regular semantic-phonetic compound characters, large NS led to more errors than small NS and indicated an inhibitory NS effect; however, for irregular phonetic compounds, large NS elicited fewer errors compared to small NS, which denoted a facilitatory NS effect. Additionally, a three-way interaction between character’s frequency, regularity and NS was also significant. Post-hoc comparison tests on accuracy data showed inhibitory NS effects for both high-frequency and low-frequency regular characters, but a facilitatory NS effect for low-frequency irregular characters. No NS effect was detected for low-frequency regular characters (Bi et al., 2006).

Because the results of Bi et al. (2016)'s Experiment 1 showed consistent frequency effects across all conditions and that the stimuli of Experiment 1 contained semantic-phonetic compounds that share the same phonetic radicals, the authors did not manipulate the frequency condition in Experiment 2 but reselected new phonetic compounds as stimuli. A 2 (NS: large/small) x 2 (regularity: regular/irregular) within-subject design was carried out in Experiment 2. The response latency data showed a significant 2-way interaction between characters' NS and regularity: there was an inhibitory NS effect for irregular characters as smaller NS elicited shorter reaction time compared to large NS; however, NS effect did not exist for regular characters. Besides, the accuracy data showed a significant 2-way interaction as well: there was an inhibitory NS effect for regular characters because large NS resulted in more errors than small NS for regular characters but not for irregular characters.

In summary, based on Bi and colleague (2006)'s study, NS exerted inhibitory influence on character naming regardless of character's regularity: the larger a semantic-phonetic compound character's neighborhood is, readers are more likely to have longer reaction time and make more errors naming the character. This result is contrary to Feldman and Siok (1997)'s results, which suggested a facilitatory NS effect for visual processing Chinese characters. One of the reasons that could account for the discrepancy is that the two studies adopted different tasks, as Feldman and Siok (1997)'s study used a character decision task while Bi and colleague (2006)'s study used a naming task.

The Neighborhood Size Effect and L1 Children. Zhao and colleagues (2012) explored the developmental stages of NS effect in reading Chinese characters by Chinese-speaking children. They recruited 3rd-, 5th-, and 7th-grade elementary school students complete a naming task and used a 2 (NS: large/small) x 3 (grades: 3rd/5th/7th) mixed factorial design. All stimuli in this study were irregular characters with low consistency values. Response latency data showed a main effect of grades: both 5th- and 7th-graders read characters faster than 3rd graders. Post-hoc comparisons demonstrated an interesting pattern of the development of NS effects: 3rd-grade students responded to stimuli having a large NS significantly faster than those having a small NS; on the contrary, 7th graders read larger-NS stimuli significantly slower than those from a small-NS. There was no significant difference in response latencies between large- and small-NS stimuli for 5th graders. The results led to the following important conclusions: 1) there was a facilitatory NS effect for 3rd graders; 2) there was an inhibitory NS effect for 7th graders; 3) there was null NS effect for 5th graders. The authors concluded that young Chinese readers benefited from large NS at the very early stage of learning to read characters; however, as their proficiencies developed, their naming process was undermined by large NS, which means older elementary school students demonstrated similar NS effect as adult L1 Chinese readers (Bi et al., 2006; Li et al., 2011).

Based on the Lexical Constituency Model (Perfetti et al., 2005), Zhao and colleagues (2012) explained the facilitatory NS effect for 3rd graders as follows: the visual presentation of a stimuli at the level of features (i.e., strokes and radicals) enabled the activation of every semantic-phonetic compound character that shares the identical phonetic radical at level of orthography (i.e., character level), and via the “bi-directional connections between the ‘feature’ and ‘orthographic’ levels, the activation of orthographic units is strengthened” (Zhao et al., 2012, p. 3). As a result, for 3rd graders, when they saw a character that had more neighboring characters, it became facilitatory to name the target stimuli. Additionally, Zhao et al. (2012) explained that, like adults, 7th graders' inhibitory NS effect may be due to the possible "high(er) frequency neighbor" effect (HFN effect). As 7th graders have acquired more characters, they encountered more high-frequency characters which could be HFNs of the target stimuli of Zhao et al. (2012)'s study. The visual presentation of a target stimuli can fast activate both target stimuli and their HFNs, but the HFNs exerted inhibitory influences on the naming of target stimuli (Li et al., 2011; Zhao et al., 2012).

Some other studies have also explored the NS effect among L1 Chinese-speaking children. Table 2.1 included more detailed information.

Neighborhood Size and Consistency. Since both the consistency effect and NS effect play important roles in naming semantic-phonetic compound characters, it is necessary to examine how the two factors interact with each other. Li and colleagues (2011) addressed this problem. Their Experiment 1 aimed to understand how NS, consistency, and regularity interact with each other in naming, and used a 2 (NS: large/ small) x 2 (consistency: consistent/ inconsistent) x 2 (regularity: regular/irregular) within-subject factorial design. The study found significant main effects of the three independent variables. In addition, the study revealed a significant two-way interaction between regularity and NS, which indicated inhibitory NS effects for both regular and irregular stimuli and was in accordance with Bi et al. (2006)'s conclusion. Moreover, a two-way interaction between consistency and NS showed a significant inhibitory NS effect for inconsistent stimuli, but not for consistent ones. A significant three-way interaction demonstrated inhibitory NS effects for inconsistent/regular, consistent/irregular, and inconsistent/irregular characters, but no such NS effect for consistent/regular characters.

Li and colleagues (2011)'s study further confirmed Bi and colleagues (2006)'s conclusion that NS effect appeared to be inhibitory for reading Chinese semantic-phonetic compound characters. In addition, Li et al. (2011)'s revealed how NS effect interact with consistency effect and regularity effect, which can be deemed as an extension of Bi et al. (2006)'s study, because Li et al. (2011)'s Experiment 1 was the first attempt to investigate the interaction between the NS and consistency effects.

To further confirm if the inhibitory NS effect was due to the possible HFN (higher frequency neighbors) effect, in their Experiment 3, Li et al. (2011) used stimuli that were all irregular characters and had the highest frequencies in their own neighborhoods, which means that the selected stimuli had no HFNs. A single factorial design was implemented and the factor (i.e., the NS) had two levels: large and small. Stimuli's consistency level was controlled at a low level. Both the reaction latencies data and accuracy data showed that stimuli of large NS produced faster responses and fewer errors (i.e., facilitations) compared to those from small NS. Li et al. (2011) concluded that a facilitatory NS effect in reading Chinese characters was possible when HFNs effects were not available.

In summary, Li and colleague (2011)'s study was the first that investigated the interaction between NS, consistency, and regularity effects in reading single-character Chinese word, and they successfully captured an inhibitory NS effect for low-consistency characters regardless of character's regularity. In addition, they discovered an inhibitory NS effect for high-consistency irregular characters. All these inhibitory NS effects turned facilitatory when target stimuli do not have HFNs (high-frequency neighbors).

This dissertation tried to review as many studies relevant to the NS effect on Chinese reading as possible. Table 2.1 contained these studies' detailed information.

Table 2.1

A Literature Review Table Focusing on the Phonetic-Radical-Based Orthographic Neighborhood Size Effect in Chinese Reading

Study	Experiment	Task	Design	Participants	Major Findings
Bi et al. (2007)		Naming	2 (NS: large/small) x 2 (regular/irregular)	L1 Chinese-speaking adults	1. NS x regularity interaction was significant: 1(a) for regular characters: no NS effect. 1(b) for irregular characters: large-NS characters yielded longer RT than small-NS ones.
Zhang & Jiang (2008)	Experiment 2a	LD[13] (non-characters)	2 (NS: large/small) x 2 (HFN: with/without)[14] x 2 (frequency: high/low)	L1 Chinese-speaking adults	1. Main effect of NS was significant: (1a) large NS produced shorter RT and higher accuracy; this NS effect was significant in low-frequency characters.
	Experiment 2b	LD (pseudo-characters)			2. NS x frequency interaction was significant: (2a) large NS facilitated recognition of low-frequency characters but inhibited that of high-frequency ones.
Jiang (2008)	Study 1	LD	Three factors: NS, semantic radical-NS, and HFN	L1 Chinese-speaking adults	1. Large-NS and large semantic-radical-based NS had facilitatory effect on lexical decision. 2. HFN had inhibitory effect on lexical decision
	Study 2	Naming	Two factors: NS and HFN		3. NS produced inhibitory effect on naming.
	Study 3	Yes/No recognition test and forced choice recognition	Single factor: NS		4. Small-NS characters were responded to with higher accuracy
Hsu et al. (2009)		Naming and event-related potential analyses	2 (NS: large/small) x 2 (consistency: high/low)	L1 Chinese-speaking adults	1. early stage: characters of large NS and high consistency exerted facilitatory effect; decreased P200 was detected (p. 56). 2. late stage: characters of large NS and high consistency yielded increased N400 (p. 56).

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[13] LD = Lexical Decision Task

[14] HFN = Higher Frequency Neighbor

Li (2009)		Naming; fMRI	Two factors: NS and school years (3rd, 5th, and junior high school)	L1 Chinese-speaking children and teenagers	(Here only reports behavioral results) 1. NS produced facilitatory effects on students of 3rd- and 5th grades. 2. NS produced inhibitory effects on students at junior high school.
Jiang et al. (2011)	Experiment 1	Naming	2 (NS: large/small) x 2 (frequency: high/low) x 2 (regular/ irregular)	L1 Chinese-speaking adults	1. NS x frequency interaction was significant: 1(a) for low-frequency characters, small-NS characters produced more errors. 2. NS x frequency x regularity interaction was significant: 2(a) for high frequency and consistent characters: large NS produced longer RT. 2(b) for low frequency and inconsistent characters: large NS produced longer RT.
	Experiment 2	Naming	2 (NS: large/small) x 2 (frequency: high/low) x 2 (HFN and target character share the same/different sound(s))		3. Main effect of NS was significant: 3(a) large-NS characters produced longer RT and more errors than small-NS ones.
Zhao et al. (2011)		Naming	2 (NS: large/small) x 2 (high/low consistency) x 3 (primary school years: 1st, 3rd, or 5th grade students)	L1 Chinese-speaking children	1. NS x consistency x school year interaction was significant (1a) For low-consistency characters, 3rd-graders responded to large-NS characters longer than small-NS ones. 1st, 3rd, and 5th graders responded to large-NS characters with more errors. (1b) For high-consistency characters, – 1st- and 3rd -graders responded to large-NS characters faster than small-NS ones. – 5th graders responded to large-NS characters slower than small-NS ones. – Also, 3rd and 5th graders responded large-NS with fewer errors than small-NS ones.

Li et al. (2011)	Experiment 1	Naming	2 (NS: large/small) x 2 (consistent/inconsistent) 2 (regular/irregular)	L1 Chinese-speaking adults	1. NS x consistency x regularity interaction was significant: 1(a) NS effect was not significant and inhibitory for the "consistent and regular" condition only but was significant for the other conditions (p. 38).
	Experiment 3	Naming	Single factor: NS: (large/small) (characters were irregular; also characters had no HFNs)		2. NS effect became facilitatory when a targeted character has the highest frequency in its own orthographic neighborhood.
Bi & Li (2012)		Naming and fMRI	Single factor: NS (large/small)	L1 Chinese-speaking children	1. Behavioral data: facilitatory NS effect for children 1(a) large-NS characters were responded to with shorter RT; 1(b) large-NS characters yielded fewer errors. 2. fMRI results: 2(a) "left middle frontal gyrus" demonstrated "significant activations" when participants were naming small-NS characters (p. 127).
Zhao et al. (2012)		Naming	2 (NS: large/small) x 3 (school years: 3rd, 5th, or 7th grade students)	L1 Chinese-speaking children and teenagers	1. main effect of NS was not significant. 2. NS x school year interaction was significant: 2(a) 3rd grade: large-NS characters yielded shorter RT. 2(b) 5th grade: no NS effect 3(c) 7th grade: large-NS characters yielded younger RT.
Jiang & Zhang (2014)	Experiment 1	Yes/No recognition test	2 (NS: large/small) x 2 (regular/irregular) x 2 (learned or not)	L1 Chinese-speaking adults	1. Small-NS characters had facilitatory effects for memorizing characters or for learning and recalling characters.
	Experiment 2	Forced choice recognition			

Hsu et al. (2014)		Naming and then pronunciation judgement task; MEG	2 (NS: large/small) x 2 (consistency: high/low)	L1 Chinese-speaking adults	1. “At 170ms, the right fusiform gyrus” demonstrated NS effect (p.1). 2. from 200 to 250ms, more activations in “the left anterior insula” were detected when participants read small-NS characters (p. 1).
Zhao et al. (2016)		Naming and fMRI	2 (NS: large/small) x 3 (school years: 3rd, 5th, or 7th grade students)	L1 Chinese-speaking children and teenagers	1. NS x school year interaction was significant: 1(a) for 3rd grade students: larger-NS was responded to faster than small-NS ones (i.e., facilitatory NS effects). 1(b) for 5th grade students: no NS effects 1(c) for 7th grade students: large-NS was responded to slower than small-NS ones (i.e., inhibitory NS effects).
Chang et al. (2016)		Naming	2 (NS: large/small) x 2 (consistent/inconsistent)	L1 Chinese-speaking adults	1. NS x consistency interaction was significant: 1(a) for consistent characters: NS effect was facilitatory 1(b) for inconsistent characters: NS effect was inhibitory
Liang (2016)	Experiment 1 & 2	Semantic judgement task	2 (NS: large/small) x 2 (regular/irregular)	L1 Chinese-speaking adults	1. NS effect tended to be inhibitory. 2. The inhibitory NS effect was more robust when readers read regular characters, relative to irregular characters. 3. Inhibitory NS effect was independent from tasks.
	Experiment 3	Character decision task	Single factor: NS (large/small)		
	Experiment 4	Naming	2 (NS: large/small) x 2 (regular/irregular)		
Zhong & Leng (2017)	Experiment 1	Character decision task	2 (NS: large/small) x 2 (consistency: high/low) x 2 (regular/irregular)	L1 Chinese-speaking adults	1. In “high consistency and irregular” condition, large NS yielded significantly higher accuracy than small NS.
	Experiment 2	Naming			2. In “high consistency and irregular” condition, large NS yielded higher accuracy. 3. In “low consistency and irregular” condition, large NS yielded higher accuracy” 4. In “low consistency and regular” condition, NS effect tended to be inhibitory. 5. Tasks mattered: in LD, NS effect tended to be facilitatory; in naming, NS effect was mixed.

Mao (2018)	Experiment 1	Character decision task	Single factor: NS: large/small. (used low-frequency characters)	L1 Chinese-speaking adults	1. Large NS yielded faster and more accurate responses.
	Experiment 2		Single factor: NS: large/small. (used high-frequency characters, i.e., stimuli had no HFN.		2. Large NS yielded faster responses. 3. Regardless of a character's frequency, NS effect was significant. But it was more robust in reading low-frequency characters.
	Experiment 3		Single factor: NS: large/small. (used irregular characters)		4. Large NS yielded faster responses. 5. Decreased P200, N400
Liang (2019)	Experiment 1	Same character judgement; ERP	2 (NS: large/small) x 2 (regular/irregular)	L1 Chinese-speaking adults	1. NS effect was facilitatory when reading irregular characters; decreased P200 was detected.
	Experiment 2	Priming and LD; ERP	Single factor: reading condition (3 categories: homophonous priming and large NS/non-primed large NS/non-primed small NS)		2. Homophonous priming and large NS condition elicited increased P200 than non-primed large NS, which in turn yielded increased P200 than non-primed small NS.
Li et al. (2020)	Experiment 1a	Naming	2 (NS: large/small) x 2 (with/without HFN) (Experiment 1 used irregular-inconsistent characters. Experiment 2 used regular-consistent characters.)	L1 Chinese-speaking adults	1. Having HFNs produced longer RT. 2. Larger NS produced longer RT.
	Experiment 1b	LD			
	Experiment 2a	Naming			3. Larger NS produced longer RT.
	Experiment 2b	LD			
Gu & Bi (2021)	Experiment 1	Naming	2 (NS: large/small) x 3 (school years: 3rd, 5th, or 7th year)	L1 Chinese-speaking children and teenagers	1. NS x school year interaction was significant: 1(a) NS effect was only significant for 7th grade students, and the NS effect was inhibitory.

A Discussion on Li et al. (2011) and Chang et al. (2016). Li and colleague (2011)'s conclusions were further examined by Chang et al. (2016), which displayed a different picture regarding the NS effect. Chang et al. (2016)'s study used a 2 (consistency level: high/low) x 2 (NS: large/small) within-subject factorial design to elicit L1 Chinese speakers' naming of Chinese characters. Results demonstrated a significant main effect of consistency on the latencies as well as the accuracy data; however, there was no main effect of NS. The interaction between consistency and NS was significant for the latencies data, and the post-hoc comparisons showed that there was an inhibitory NS effect for low-consistency stimuli but a facilitatory NS effect for high-consistency stimuli.

The facilitatory NS effect found in Chang et al. (2016) conflicted with Li et al. (2011)'s study, because Li et al. (2011) found that high-consistency stimuli either had no NS effect (for regular characters) or had an inhibitory NS effect (for irregular characters). Chang and colleagues (2016) explained that the difference in NS effect between the two studies may be due to the different definitions of "high consistency". In Li et al. (2011), "high consistency" was defined as a consistency value higher than 0.5 and the average consistency degree was 0.6 whereas in Chang et al. (2016), "high-consistency" had an average consistency value of 0.91, which was significantly higher than Li et al. (2011)'s study. In other words, Chang et al. (2016)'s study displayed a stricter manipulation of the consistency level of high-consistency stimuli relative to Li et al. (2011).

In addition, the two studies also differed in terms of their criteria for NS. Even though Li et al. (2011) and Chang et al. (2016) had similar standard for small NS, they differed slightly with respects to large NS. Li and colleagues (2011)'s study had a "larger" large NS (i.e., average NS = 13, ranging from 10 to 16) than that of Chang et al. (2016)'s study (i.e., average 9.83 and

11.27 for high- and low-consistency stimuli respectively), and this could be a possible explanation as to why the two studies yielded different conclusions regarding the NS effect.

Moreover, the two studies applied distinct ranges of stimuli frequencies. Chang et al. (2016)'s study used a much higher frequency (i.e., average 31 per million) than Li et al. (2011)'s study (i.e., ranging from 3.4 per million to 5.6 per million for the eight different conditions). As a result, it is worth discussing if the facilitatory NS effect for consistent characters detected by Chang et al. (2016) was partially due to their choice of stimuli that had comparatively higher degree of frequency.

In conclusion, the NS effect existed in naming single-character Chinese word. Especially, such NS effect was robust and inhibitory for low-consistency character (Chang et al., 2016; Li et al., 2011) and irregular characters (Li et al., 2011) when character frequency was comparatively low. However, conclusions regarding NS effect on high-consistency characters remains debatable as some scholars obtained facilitative NS effect (Chang et al., 2016) while others observed inhibitory NS effect when high-consistency stimuli were irregular and null NS effect when high-consistency stimuli were regular (Li et al., 2011). Future studies are expected to carefully address the issues of stimuli selection in terms of manipulating and controlling for their frequency, consistency level, and NS.

The Neighborhood Size Effect on L2 Character Reading. As reviewed above, in recent years, a growing number of studies have showed that in L1 Chinese reading, phonetic-radical-based orthographic neighborhood size (i.e., NS) is a critical variable that affects visual word recognition of semantic-phonetic compound characters (Bi & Li, 2012; Bi et al., 2006; Chang et al., 2016; Jiang & Zhang, 2014; Jiang et al., 2011; Li et al., 2011; Li et al., 2020; Qian et al., 2015; Zhang & Jiang, 2008; Zhao et al., 2011; Zhao et al., 2012; Zhao et al., 2016).

According to these studies, the NS effect tended to be inhibitory in naming and interacted with characters' frequency, regularity, and consistency. However, these studies were about L1 Chinese reading. To the best of the author's knowledge, NS effect has not been explored in L2 Chinese reading.

Phonetic-radical based consistency and NS are closely related to each other in Chinese characters. However, the studies that explored the consistency effect in L2 Chinese reading did not address the NS effect. For example, Kim et al. (2016)'s study used low-frequency characters during the learning phase, and the NS of the learning-phase characters were controlled as three while the NS of the test-phase pseudo-characters were controlled as six across different consistency conditions. In other words, NS effect was not a variable of interest in Kim et al. (2016)'s study. In Lin & Collins (2012)'s study, the authors did not indicate if NS was matched across different stimuli conditions, and it was unclear if the stimuli's neighborhood size exerted any influence on the results of their study.

In Yum et al. (2016)'s study, even though stimuli's "total orthographic neighborhood size" (i.e., the complete number of neighboring characters that shared either semantic radicals or phonetic radicals with target characters) were matched across different stimuli types (p. 344), their phonetic neighborhood sizes were not matched. Stimuli with high consistency levels had significantly fewer phonetic neighbors than those with low consistency degrees. In their study design, however, phonetic neighborhood size was not a variable of interest under investigation and, thus, it was unknown how NS effect played a role in their study.

Additionally, in an fMRI study, Tian et al. (2019) found that L2 Chinese learners showed more activation in "the left fusiform gyrus and the left lingual gyrus" when reading inconsistent characters and that L1 Chinese users demonstrated larger activation of "the right MOG" during reading inconsistent characters as well (p. 211). They explained that the results might “reflect the influence of the orthographic neighborhood size” and further indicated that “only one previous study has explored the neural basis of the orthographic neighborhood size effects in inconsistent character reading in native speakers (i.e., Li et al., 2011)” (p. 211). Given that their study was published in 2019, it was reasonable to argue that the interaction between consistency and NS effect has been rarely studied in L2 Chinese reading.

In summary, different from the studies concerning L1 Chinese reading, research about L2 Chinese reading did not address the NS effect. NS effect was either matched across different conditions (Kim et al., 2016) or was not considered (Lin & Collins, 2012; Yum et al., 2016). As a result, it is crucial to investigate how NS effect plays a part in reading semantic-phonetic compound characters by L2 Chinese learners.

Research Gaps

Based on the literature review, one major research gap has been identified in the research field of reading Chinese characters by L2 Chinese learners: how the neighborhood size effect has an influence in L2 Chinese naming remains unknown. More details regarding the four research gaps will be provided below.

No study has addressed the neighborhood size effect on reading semantic-phonetic compound characters by L2 Chinese learners, and no study has investigated how the NS effect interacts with other variables. In L1 Chinese reading, neighborhood size and consistency interact with each other according to the analyses on naming data, with larger neighborhood size producing more inhibition on inconsistent compound characters (L1 et al., 2011). However, to the author’s knowledge, no such results have been yielded in research about L2 Chinese reading. As a result, it is necessary to investigate neighborhood size effect in L2 Chinese reading.

The inclusion of neighborhood size as an important independent variable has theoretical supports. According to the Lexical Constituency Model, even two characters have the same consistency degree, the one with large NS tends to activate more neighboring characters which will compete with the target character for phonological activation and thus, receives more inhibition during naming. As a result, when using the Lexical Constituency Model to study L2 Chinese naming, it is reasonable to involve NS as an important variable in the study.

Why is it that NS has not been studied in previous studies? One of the possible reasons is that researchers may have different or wrong understanding about consistency. Yum et al. (2016) argued that "low consistency character also tended to have more orthographic neighbors sharing their phonetic radicals than those with high consistency" (p. 343-344). This statement is correct. However, it does not necessarily mean that large neighborhood size always results in smaller consistency degree or that small consistency degree is always because of large neighborhood size. "Large neighborhood size" and "small consistency degree" are not interchangeable conceptions. It is important to separate the two concepts even though they are closely related to each other and involve both into research regarding L2 Chinese reading.

Research Questions

Building upon the general research questions stated in Chapter 1, the following specific research questions were asked to guide Study 1:

Research Question 1: *What is the NS effect and its interaction with the consistency effect on L2 Chinese learners' recognition of semantic-phonetic compound characters*?

Research Question 2: *What are the differences between L1 speakers and L2 learners in reading semantic-phonetic compound characters*?

Two experiments were conducted using lexical decisions tasks. Experiment 1 (a)? used regular semantic-phonetic compound characters, while Experiment 1 (b)? used irregular semantic-phonetic compound characters as the stimuli.

Experiment 1(a)

Participants

A total of 42 participants with normal or corrected-to-normal vision were invited to participate in Experiment 1, and they received incentives for participation. Aside from 35 native Chinese speakers, 17 learners of Chinese as L2 were recruited as well. All L2 Chinese learners achieved a proficiency level in Chinese higher than HSK level 5 (i.e., *Hanyu Shuiping Kaoshi*/*汉语水平考试*: The Proficiency Test in Chinese) or an equivalent proficiency level. Participants' information was demonstrated in Table 2.2.

Table 2.2

Participants' Information

Groups	L1 Chinese Speakers (N = 35)	L2 Chinese Leaners (N = 17)
Gender	Female: N = 21 (60%) Male: N = 14 (40%)	Female: N = 8 (47%) Male: N = 9 (53%)
Participants' L1 Backgrounds	Native speakers (N = 35) (All from Mainland China)	Korean speakers (N = 9) Spanish speakers (N =2) Persian speakers (N = 2) Russian speakers (N = 1) Urdu speakers (N =1) Bahasa Indonesia speakers (N = 1) Japanese speakers (N =1)
Participants' Chinese Proficiency	Native	Advanced (HSK-5 or higher)

The HSK is administered by the Confucius Institute Headquarters (孔子学院总部) which is commonly known as *Hanban* (国家汉办), a subordinate unit of the Ministry of Education of People's Republic of China. It aims to promote the teaching of Chinese language and culture internationally and provide assistances and services for Chinese learners inside and outside of China. The new HSK test comprises six proficiency levels (from level 1 to 6) with level 6 as the highest proficiency level. The official explanation provided by *Hanban* with regards to HSK level 6 is that Chinese learners who have attained this level of proficiency should experience no difficulties understanding spoken Chinese or written Chinese and have the ability to demonstrate their meanings by writing or speaking in Chinese with no difficulties (Chinese Testing International Co., Ltd., n.d.). In addition, HSK level 6 is equivalent to the level of C2 in CEFR (Common European Framework of Reference for Languages), and Chinese learners of this proficiency level are expected to master equal to or more than 5,000 Chinese vocabulary.

Design

To examine the NS effect on naming, Li et al. (2011) adopted a 2 (NS) x 2 (consistency) x 2 (regularity) design and Chang et al. (2016) used a 2 (NS) x 2 (consistency) design. This dissertation did not learn from Li et al. (2011)'s design because that led to many factors in the ANOVA model. Also, having three within-subject factors (i.e., NS, consistency, and regularity) resulted in difficulties of searching for proper materials from the list of L2 Chinese words and characters. As a result, Study 1 adopted Chang et al. (2016)'s design by adding one between-subject factor: the L1/L2 group.

In summary, Experiment 1(a) used a 2 (NS) x 2 (Consistency) x 2 (Groups) factorial design. Each factor contained two categories. NS had large NS and small NS. Consistency contained consistent semantic-phonetic compound characters and inconsistent ones. Groups included L1 Chinese speakers and L2 Chinese learners. NS and consistency were the within-subject factors, whereas groups served as the between-subject factor. Participants completed a lexical decision task.

Materials

A total of 60 semantic-phonetic compound characters were selected as the real characters. Another 60 pseudo-characters were created by combining one semantic and phonetic radical. All stimuli must satisfy the inclusion criteria as listed in Table 2.3.

Table 2.3

Inclusion Criteria for the Stimuli of Experiment 1(a)

	Number	Inclusion Criteria
Real characters	1	All real characters were semantic-phonetic compound characters that have a phonetic radical and a semantic radical.
	2	All real characters were left-right structure (e.g., 泳) or left-right-like structures (e.g., 趟[15]). Top-bottom (e.g., 究) structure and other types of structures (e.g., 辨, 问, 国) were not included.
	3	For all the real characters, their semantic radicals were on the left, and their phonetic radicals were on the right.
	4	No phonetic radicals were bound radicals. All real character's phonetic radicals must be able to stand alone as characters and have their own pronunciations. For example, 泽 (/*ze2*/) was not selected as a stimulus because its phonetic radical (i.e., 睪) cannot stand alone as a character and did not have its own pronunciation.
	5	All phonetic radicals must be a character that appeared in the HSK vocabulary list. If not, the semantic-phonetic compound characters that contain such phonetic radicals were not selected. For example, the phonetic radical (e.g., 艮) did not appear as a character in the HSK vocabulary list, so its semantic-phonetic compound character 根 was not selected as a stimulus.
	6	Real characters must not be heteronyms in Chinese (多音字) that have more than one pronunciation (e.g., 便 can be pronounced as /*bian4*/ and /*pian2*/ and was not selected as a stimulus).

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[15] This study counted left-right-like structure as a variation of the left-right structure because of the following two reasons: Firstly, there is a limited number of stimuli that satisfied all inclusion criteria. Secondly, this dissertation regards the left-right-like structure as a variation of the left-right structure per se because it also consists of two radicals, with one on the left and the other on the right. The only difference is that a certain stroke of the left-side radical extends to the right side (i.e., 连, 趟, etc.)

	7	All real characters were selected from the HSK vocabulary list, which was officially published by *Hanban* in *International Curriculum for Chinese Language Education* (Confucius Institute Headquarters/Hanban, 2014). The reason for using HSK vocabulary-based characters was that it was necessary to make sure the selected stimuli are known to L2 Chinese learners. The count of NS and consistency value were based on HSK vocabulary list as well. [16]
	9	All real characters were regular semantic-phonetic compounds, which a semantic-phonetic compound character's pronunciation is the same as that of its phonetic radical without considering tones.
Psudo-characters	10	All pseudo-characters consisted of a semantic radical and a phonetic radical that exist in modern Chinese.
	11	All pseudo-characters had the semantic radical on the left and the phonetic radical on the right.
	12	All pseudo-characters' phonetic radicals must not be a bound phonetic radical and must be a character that appeared in the HSK vocabulary list.
	13	All pseudo-characters were made sure that they do not exist in modern Chinese by using https://www.zdic.net/. This website allowed researchers to enter one semantic radical and one phonetic radical to check if the combination existed as a real character.

All stimuli of Experiment 1(a) were listed in Appendix A. The features of all the real characters were summarized in Table 2.4. For the real characters, the Large-NS condition and the small-NS condition were significantly different in the number of NS ($p < .001$). The consistent condition and the inconsistent condition were significantly different in the type consistency ($p < .001$) and in the token consistency ($p < .001$). Other feathers were attempted to be balanced across the four conditions (i.e., large NS and consistent, large NS and inconsistent, small NS and consistent, and small NS and inconsistent). These features were explained below:

Number of strokes. Number of strokes is a measurement of a character's visual

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[16] Two studies (Kim & Shin, 2015a, 2015b) extracted and compiled characters from the HSK vocabulary list. The present dissertation study utilized their database.

complexity. It refers to how many strokes that constitute a character. This feature was balanced across the four conditions to avoid any potential confounding effect (*p* = .241).

Character Frequency. Information of character frequency was obtained from the following corpus: http://corpus.zhonghuayuwen.org/CnCindex.aspx. The database named "现代汉语语料库字频表" (Modern Chinese Corpus Character Frequency Database) provided the information of character frequency for this dissertation. The database is based on a 20-million-character corpus. All frequency data has been recalculated to the data per 1 million characters. To avoid any confounding effect, character frequency was balanced across the four conditions (*p* = .210).

Semantic Radical Neighborhood Size. Semantic radical neighborhood size refers to the number of characters that share the same semantic radical. This feature was counted based on semantic-phonetic compound characters that appeared in the HSK word and character list. This feature was not balanced across the four experimental conditions (*p* = .035).

Semantic Radical Familiarity. Semantic radical familiarity is an index of how well L1 Chinese speakers thought they were aware of the semantic radicals' functions based on a four-point scale (Lü et al., 2015, p. 173). A higher score indicates a higher degree of familiarity. This feature was balanced across the four conditions (*p* = .518) to avoid any confounding effect.

Phonetic Radical Frequency. The frequency of the phonetic radical of each stimulus was examined based on the "现代汉语语料库字频表" (Modern Chinese Corpus Character Frequency Database) mentioned above. This feature was balanced across conditions (*p* = .170).

Neighborhood Frequency Sum. This feature refers to the total frequency of all characters in a phonetic-radical-based orthographic neighborhood. This feature was not perfectly balanced across the four conditions (*p* = .013). However, this is understandable as larger NS contained larger number of characters, which in turn led to larger neighborhood frequency sum.

Number of Homophone. Number of Homophone refers to the number of characters that share the same pronunciation as the targeted stimulus without considering tone. This feature was counted based on all the characters that appeared in the HSK word and character list. To avoid any possible confounding effect, this feature was balanced across the four conditions (p = .279).

Number of Homophone (Considering Tones). Number of Homophone (considering tones) means the number of characters that have the identical pronunciation as the targeted stimulus including the whole syllable and the tone. This feature was counted based on all the characters that appeared in the HSK word and character list. This feature was balanced across the four conditions (p = .401) to avoid any possible confounding effect.

Number of Meanings. Number of meanings refer to how many meanings a character has. This feature is based on the *Xinhua Zidian Dictionary* (2004). This feature was matched across the four conditions (*p* = .513) to avoid any possible confounding effect.

Number of Associated Syllables. This feature is equal to the number of syllables that a phonetic-radical-based neighborhood has. For example, the phonetic radical “京” is associated with three (n = 3) syllables: /*liang*/(凉, 谅, 晾), /*jing*/(惊, 京), and /*lüe*/(掠) in the HSK word and character list. This feature was not balanced across the four condition (*p* < .001), but it makes sense because consistent characters tend to have less associated syllables than inconsistent characters.

Number of Phonological Neighbors. Phonological neighbor is defined as the character that can be generated by replacing one phoneme of a targeted character with another phoneme without considering tones (Chang et al., 2016). This feature was balanced (*p* = .443)

Table 2.4

Means (Standard Deviations) and Ranges of Real Characters of Experiment 1(a)

	Large NS		Small NS		p
	Consistent (n = 15)	Inconsistent (n = 15)	Consistent (n = 15)	Inconsistent (n = 15)	
NS	5.4 (0.51) 5 - 6	5.67 (0.62) 5 - 7	3.13 (0.35) 3 - 4	3.27 (0.46) 3 - 4	between large- and small-NS: t (52.39) = 18.22, $p < .001$
Type consistency value	1.00 (0.00) 1.00 - 1.00	0.56 (0.13) 0.33 - 0.67	1.00 (0.00) 1.00 - 1.00	0.62 (0.08) 0.50 - 0.67	between consistent and inconsistent: t (29) = 20.71, $p < .001$
Token consistency value	1.00 (0.00) 1.00 - 1.00	0.62 (0.28) 0.11 - 0.98	1.00 (0.00) 1.00 - 1.00	0.55 (0.24) 0.21 - 0.93	between consistent and inconsistent: t (29) = 8.75, $p < .001$
Number of strokes	8.20 (2.57) 5 - 15	10.07 (3.35) 7 - 19	10.33 (3.79) 4 - 16	9.33 (2.41) 5 - 13	F (3, 56) = 1.44, p = .241
Frequency (per million characters)	162.17 (159.99) 5.80 - 437.35	69.04 (79.77) 6.80 - 251.05	90.79 (95.24) 11.05 - 319.80	83.77 (159.16) 2.70 - 626.75	F (3, 56) = 1.56, p = .210
Semantic radical NS	69.87 (34.00) 12 - 118	33.33 (32.75) 8 - 139	46.60 (35.18) 9 - 139	70.07 (54.43) 5 - 139	F (3, 56) = 3.07, p = .035 [17]
Semantic radical familiarity	3.50 (0.25) 2.88 - 3.76	3.38 (0.22) 3.04 - 3.73	3.45 (0.27) 2.68 - 3.73	3.42 (0.21) 2.92 - 3.76	F (3, 56) = .77, p = .518

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[17] Tukey HSD analyses showed no significant differences between any two conditions: “small NS and consistent” vs. “large NS and consistent” (p = .393); “large NS and inconsistent” vs. “large NS and consistent” (p = .072); “small NS and inconsistent” vs. “large NS and consistent” (p = .999); “large NS and inconsistent” vs. “small NS and consistent” (p = .802); “small NS and inconsistent” vs. “small NS and consistent” (p = .385); “small NS and inconsistent” vs. “large NS and inconsistent” (p = .069).

Phonetic radical frequency	741.71 (825.49) 27.80 - 2512.45	510.23 (489.23) 22.50 - 1328.00	469.55 (500.51) 31.70 - 1537.70	274.44 (317.76) 28.70 - 937.70	*F* (3, 56) = 1.73, *p* = .170
Neighborhood frequency sum	1653.73 (1179.08) 330.05 - 3437.55	1335.83 (1084.09) 156.10 - 3741.70	693.21 (532.16) 71.50 - 1910.20	702.51 (814.73) 115.30 - 3116.20	*F* (3, 56) = 3.90, *p* = .013[18]
Number of Homophones (without considering tones)	19.87 (12.79) 8 - 43	15.40 (11.15) 5 - 36	16.93 (11.60) 3 - 34	12.00 (8.19) 2 - 30	*F* (3, 56) = 1.31, *p* = .279
Number of Homophones (considering tones)	7.00 (3.95) 2 - 15	5.07 (3.06) 2 - 14	6.93 (6.45) 1 - 19	4.87 (3.76) 1 - 14	*F* (3, 56) = 1.00, *p* = .401
Number of meanings	2.33 (1.80) 1 - 6	1.93 (1.33) 1 - 5	2.67 (1.18) 1 - 5	2.00 (1.56) 1 - 7	*F* (3, 56) = .78, *p* = .513
Number of associated syllables	1.0 (0.0) 1.0 - 1.0	2.87 (0.74) 2.0 - 4.0	1.0 (0.0) 1.0 - 1.0	2.20 (0.41) 2.0 - 3.0	*F* (3, 56) = 71.11, *p* < .001
Phonological neighbors	163.27 (66.53) 86 - 276	131.33 (56.30) 64 - 260	125.80 (82.84) 2 - 265	138.73 (60.08) 69 - 274	*F*(3, 56) = .91, *p* = .443
Percentage of Stimuli that are the highest in frequency in a neighborhood	1/15 = 6.67%	1/15 = 6.67%	2/15 = 13.33%	2/15 = 13.33%	

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[18] Tukey HSD analyses demonstrated that this feature was significantly different between “small NS and consistent” and “large NS and consistent” conditions (*p* = .034) and between “small NS and inconsistent” and “large NS and consistent” conditions (*p* = .036).

Table 2.5

Means (Standard Deviations) and Ranges of Real- and Pseudo-Characters of Experiment 1(a)

	Real Characters (n = 60)	Pseudo-characters (n = 60)	*p*
NS	4.37 (1.28) 3 - 7	4.47 (1.20) 3 - 7	*t* (117.57) = .44, *p* = .659
Number of strokes	9.48 (3.12) 4 - 19	9.02 (2.52) 4 - 14	*t* (113.07) = -.90, *p* = .369
Semantic radical NS	54.97 (42.15) 5 - 139	61.58 (33.04) 11 - 139	*t* (111.64) = .96, *p* = .341
Semantic Familiarity	3.44 (0.24) 2.68 - 3.76	3.51 (0.19) 2.92 - 3.76	*t* (112.63) = 1.76, *p* = .081
Phonetic radical frequency	498.98 (574.41) 22.50 - 2512.45	594.83 (678.74) 9.00 - 3103.00	*t* (114.86) = .83, *p* = .406
Neighborhood frequency sum	1096.32 (1003.88) 71.50 - 3741.70	1230.32 (1108.03) 113.05 - 5615.20	*t* (116.87) = .69, *p* = .489
Number of associated syllables	1.77 (0.91) 1 - 4	1.82 (1.00) 1 - 5	*t* (116.94) = .29, *p* = .775

In addition to real characters' features, those of pseudo-characters were demonstrated in Table 2.5. According to this table, NS, number of strokes, semantic radical familiarity, phonetic radical frequency, and neighborhood frequency sum were balanced between real characters and pseudo-characters.

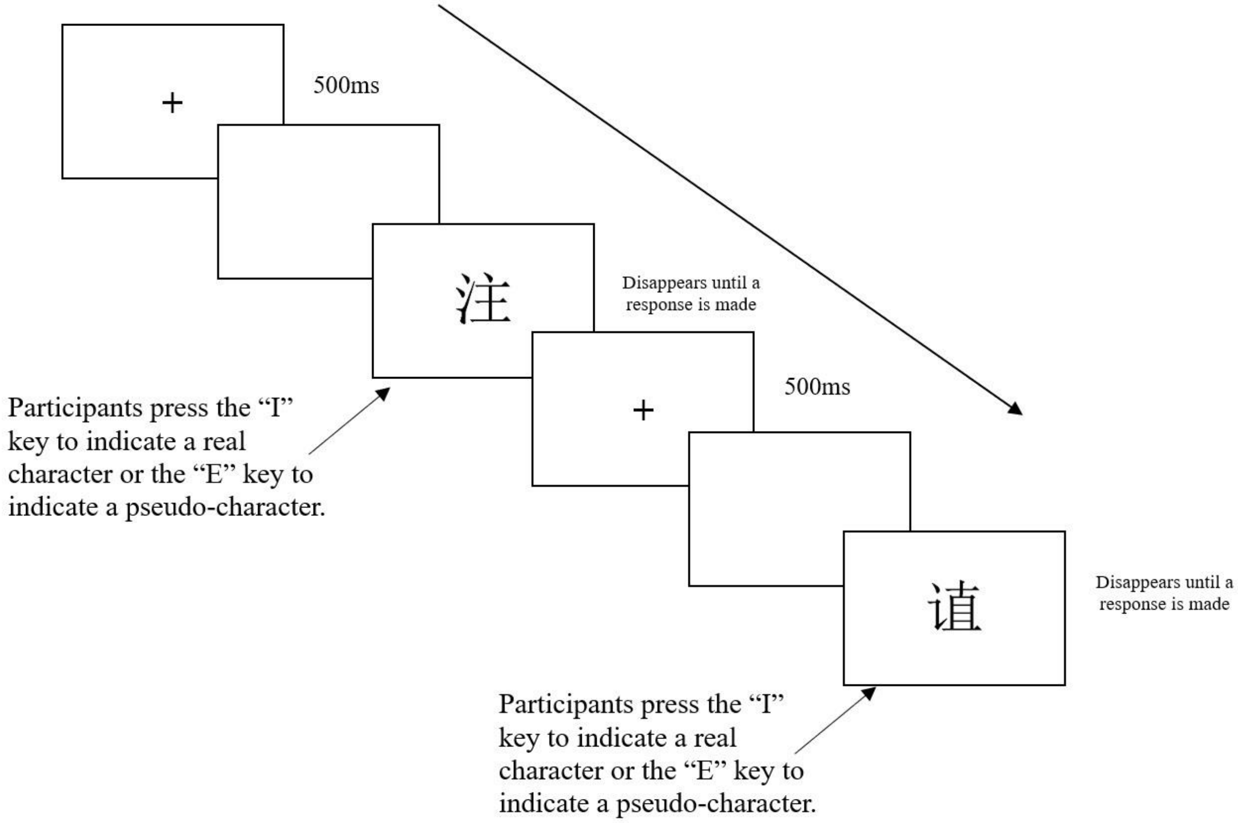
Procedures

A lexical decision task was administered using the *Inquisit 6* web online testing system (https://www.millisecond.com/products/inquisit6/weboverview.aspx/). Each participant was reached out by the researcher individually and finished the lexical decision task using their own laptops/PCs. Participants finished the tasks at their own locations. The researcher and participants did not meet in person to comply with the COVID-19 safety regulations.

The researcher emailed the experiment link to each participant along with the consent form. Participants accessed the experiment using the link. When the experiment started, participants first read instructions and then finished 20 trials of practice. After that, the experiment started. A fixation point (+) first appeared in the middle of the screen for 500 ms, and then a target character appeared. Participants press the "E" key to indicate a pseudo-character or the "I" key to indicate a real character as fast and accurately as possible. Then, the character disappeared. Then, the next character appeared and repeated the procedures until the experiment ended. Figure 2.1 shows the details of Experiment 1(a)'s procedures.

Figure 2.1

Procedures of Experiment 1(a)



Results of Experiment 1(a)

Experiment 1(a) adopted a 2 (Neighborhood size) x 2 (Consistency) x 2 (Groups) repeated measures mixed factorial design. Participants' RTs and accuracy data were the dependent variables. ANOVAs, correlation analyses, and hierarchical regression analyses were conducted.

As for the item analysis, all items yielded an accuracy rate higher than 70%. The accuracy rate for all items ranged from 70.45% to 100%. As a result, all items were included in the analyses. Data analyses was completed via *RStudio*.

Table 2.6

Descriptive Statistics of Experiment 1(a)'s Results (Means and Standard Deviations in Parentheses))

RT (ms)	Large NS		Small NS	
	Consistent	Inconsistent	Consistent	Inconsistent
L1 speakers	621.529 (87.355)	617.067 (78.382)	574.047 (59.005)	631.769 (77.895)
L2 learners	796.568 (101.211)	783.599 (102.467)	794.154 (96.438)	820.812 (113.282)
Accuracy (%)	Large NS		Small NS	
	Consistent	Inconsistent	Consistent	Inconsistent
L1 speakers	95.631 (6.243)	95.402 (6.691)	98.620 (3.276)	97.930 (3.610)
L2 learners	80.444 (9.583)	79.110 (16.498)	88.889 (10.886)	74.222 (14.879)

Data Trimming

Before data analysis, data trimming was performed. RT data points associated with incorrect responses were not included in data analysis. In addition, RT data points that were shorter than 300ms or longer than 1,500ms were excluded from data analysis to exclude outliers.

Table 2.7

Bivariate Correlation Matrix of Experiment 1(a)

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. RT (all participants)	1.00													
2. RT (L1 speakers)	.90***	1.00												
3. RT (L2 learners)	.63***	.29*	1.00											
4. Accuracy (all participants)	-.53***	-.66***	-.19	1.00										
5. Accuracy (L1 speakers)	-.31*	-.46***	.15	.67***	1.00									
6. Accuracy (L2 learners)	-.52***	-.62***	-.30*	.95	.40**	1.00								
7. NS	.09	.20	-.16	-.18	-.35**	-.07	1.00							
8. Consistency (type)	-.19	-.22	-.07	.17	.04	.19	-.19	1.00						
9. Consistency (token)	-.24	-.31*	-.07	.25	-.07	.34**	-.08	.72***	1.00					
10. Frequency	-.31*	-.21	-.37**	.36**	.04	.42***	.14	.14	.24	1.00				
11. Phonetic radical frequency	-.21	-.14	-.25	.13	-.07	.19	.23	.21	.25	.20	1.00			
12. Neighborhood frequency	.01	.15	-.31*	.00	-.21	.10	.45***	.13	-.02	.29*	.76***	1.00		
13. Number of strokes	-.12	-.24	.04	.21	.10	.22	-.19	-.03	.01	-.20	-.20	-.29*	1.00	
14. Semantic radical NS	-.22	-.21	-.08	.10	.17	.05	-.14	.12	.26*	.24	-.04	-.18	-.20	1.00

* $p < .05$. ** $p < .01$. *** $p < .001$

This resulted in a removal of 4.57% data points from the whole dataset. To be more specific, of a total of 2,580 data points, 35 were excluded from L1 Chinese speakers' group, and 83 were excluded from L2 Chinese learners' group. Table 2.6 presents descriptive statistics after data trimming.

Correlation analyses, ANOVAs, and hierarchical regression analyses were conducted on trimmed and log-transformed RT and accuracy data. The RT and accuracy data were transformed to their natural logarithmic values to improve

Correlation Analyses

To better understand how stimuli features were correlated with participants' RT and accuracy in the lexical decision task, Pearson's correlation coefficients were calculated based on participants' log-transformed RT, log-transformed accuracy, and stimuli's features, including: (1) NS (neighborhood size), (2) type-consistency value, (3) token-consistency value, (4) character's frequency, (5) phonetic radical's frequency, (6) sum of frequency of a stimulus' neighborhood, (7) number of strokes, (8) semantic radical-based NS, and (9) semantic radical familiarity (Lü et al., 2015). Results were demonstrated in Table 2.7.

Phonetic compound characters' NS was significantly correlated to L1 Chinese speakers' accuracy ($r = -.35$, $p < .01$) but was not significantly correlated to their RT. Also, NS was not significantly correlated to L2 Chinese learners' RT or accuracy.

Phonetic compound characters' type-consistency values were not significantly correlated to participants' RT or accuracy data. However, phonetic compound character's token-consistency values (i.e., frequency-based consistency value) were significantly correlated to L1 Chinese speakers RT ($r = -.31, p < .05$) but were not significant correlated to L2 Chinese learners' RT or accuracy.

Character frequency was significantly correlated to all participants' RT ($r = -.31$, $p < .05$), to L2 learners' RT ($r = -.37$, $p < .01$), to all participants' accuracy ($r = .36$, $p < .01$), and to L2 learners' accuracy ($r = .42$, $p < .001$), indicating a strong relationship between character frequency and participants' performance in the LD task, especially for the L2 Chinese learners. Lastly, a stimulus' neighborhood frequency sum (i.e., calculated by adding the frequency values of all characters in a stimulus' neighborhood) was significantly correlated to L2 Chinese learners' RT ($r = -.31$, $p < .05$).

ANOVA Results

A 2 (NS) x 2 (Consistency) x 2 (L1/L2 Groups) three-way ANOVA was performed on log-transformed RT and accuracy data. Results of by-subject (F_1) and by-item (F_2) analyses were reported.

Main Effects. Analyses on log-transformed RT data revealed a significant main effect of L1/L2 groups, F_1 (1, 35) = 78.914, $p < .001$, $\eta^2_p = .60$; F_2 (1, 56) = 297.928, $p < .0001$, $\eta^2_p = .65$. The main effect of NS was not significant, F_1 (1, 35) = .113, $p = .739$, $\eta^2_p < .001$; F_2 (1, 56) = .008, $p = .930$, $\eta^2_p < .0001$. The main effect of consistency was not significant as well, F_1 (1, 35) = 3.166, $p = .084$, $\eta^2_p = .03$; F_2 (1, 56) = 2.074, $p = .155$, $\eta^2_p = .02$.

Analyses on log-transformed accuracy data suggested that the main effect of group was significant, F_1 (1, 42) = 50.346, $p < .0001$, $\eta^2_p = .44$; F_2 (1, 56) = 52.267, $p < .0001$, $\eta^2_p = .28$. The main effect of NS was significant as well, F_1 (1, 42) = 5.791, $p = .021$, $\eta^2_p = .02$; but not significant in the by-item analysis, F_2 (1, 56) = .613, $p = .437$, $\eta^2_p = .006$. The main effect of consistency was also significant, F_1 (1, 42) = 20.985, $p < .0001$, $\eta^2_p = .03$; but not significant according to the by-item analysis, F_2 (1, 56) = 2.658, $p = .109$, $\eta^2_p = .03$.

Two-way Interactions. Analyses on log-transformed RT data revealed a significant NS by consistency interaction, F_1 (1, 35) = 8.805, $p = .005$, $\eta^2_p = .03$; but this interaction was not significant in by-item analysis, F_2 (1, 56) = 2.823, $p = .098$, $\eta^2_p = .03$. The NS by group interaction was not significant, F_1 (1, 35) = 3.234, $p = .081$, $\eta^2_p = .007$; F_2 (1, 56) = 3.960, $p = 0.051$, $\eta^2_p = .02$. The consistency by group interaction was not significant as well, F_1 (1, 35) = 3.019, $p = .091$, $\eta^2_p = .008$; F_2 (1, 56) = 1.034, $p = 0.314$, $\eta^2_p = .006$.

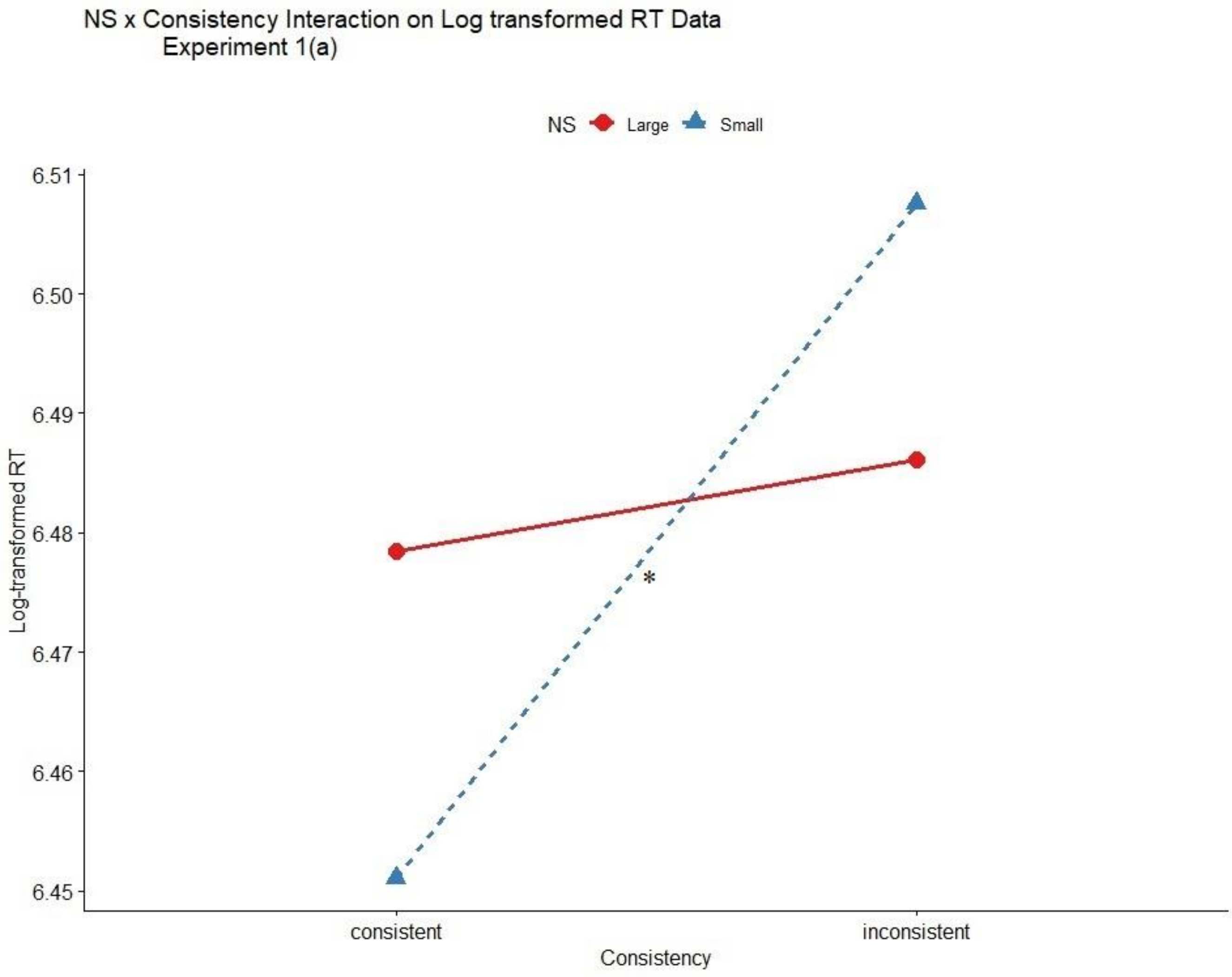
Analyses on log-transformed accuracy data suggested a significant group by consistency interaction, F_1 (1, 42) = 17.097, $p < .001$, $\eta^2_p = .05$; but not significant based on the by-item analysis, F_2 (1, 56) = 2.940, $p = .092$, $\eta^2_p = .02$. A significant NS by consistency interaction was found as well, F_1 (1, 42) = 10.808, $p = .002$, $\eta^2_p = .02$; but not in by-item analysis, F_2 (1, 56) = 2.104, $p = .153$, $\eta^2_p = .02$. The group by NS interaction was not significant, F_1 (1, 42) = 0.284, $p = .597$, $\eta^2_p = .0007$; F_2 (1, 56) = .045, $p = .833$, $\eta^2_p = .0003$.

Three-way Interaction. Log-transformed RT data suggested that the three-way interaction between NS, consistency, and L1/L2 group was not significant, F_1 (1, 35) = 3.180, $p = .083$, $\eta^2_p = .03$; F_2 (1, 56) = 1.134, $p = .291$, $\eta^2_p = .007$. However, analysis on log-transformed accuracy data suggested a significant three-way interaction, F_1 (1, 42) = 9.541, $p = .004$, $\eta^2_p = .03$; but the interaction was not significant according to the by-item analysis, F_2 (1, 56) = 2.570, $p = .115$, $\eta^2_p = .02$.

Post-hoc Analyses on RT Data (Tukey HSD). Pairwise comparisons using Tukey HSD analyses showed the following results. First of all, regarding the NS by consistency two-way interaction, post-hoc analysis indicated a significant consistency effect when participants read small-NS characters, by-subject analysis $p = .017$; but not significant in by-item analysis $p = .064$. To be more specific, participants responded to “small NS and consistent” characters significantly faster than when responding to “small NS and inconsistent” ones, suggesting a facilitatory consistency effect. However, this facilitatory consistency effect was not found when participants responded to large-NS characters (see Figure 2.2).

Figure 2.2

NS by Consistency Interaction (RT Data, Experiment 1(a))



* $p < .05$. ** $p < .01$. *** $p < .001$

Secondly, regarding the NS by L1/L2 group two-way interaction, post-hoc analyses revealed significant group effects. L1 Chinese speakers responded to large-NS characters significantly faster than L2 Chinese learners did, by-subject analysis $p < .0001$, by-item analysis

$p < .0001$. Additionally, L1 Chinese speakers used significantly shorter time responding to small-NS characters than L2 Chinese learners did, by-subject analysis $p < .0001$, by-item analysis $p < .0001$.

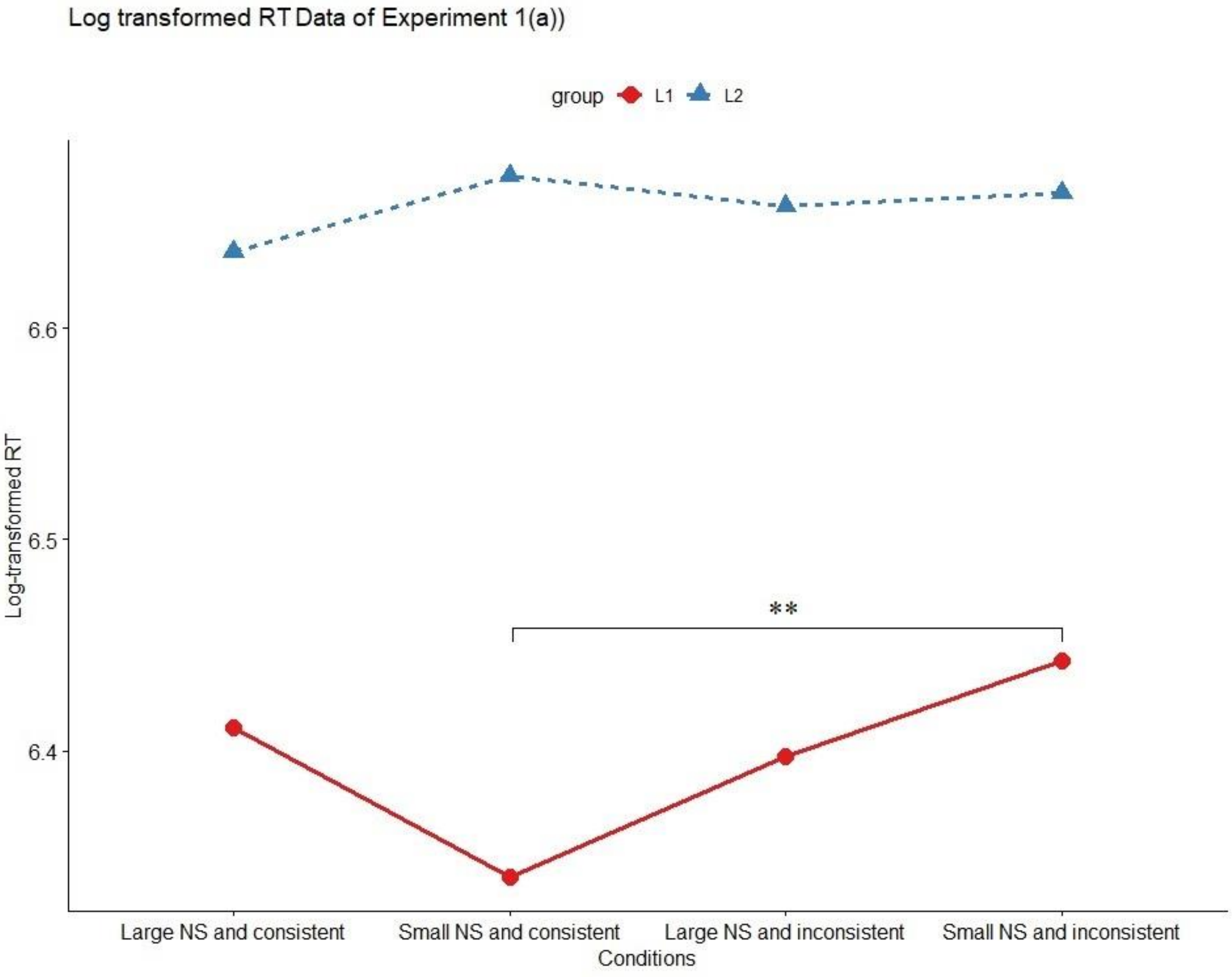
Thirdly, post-hoc analyses regarding the consistency by L1/L2 interaction revealed significant group effect as well. In other words, L1 Chinese speakers responded to consistent characters faster than L2 Chinese learners did, by-subject analysis $p < .0001$, by-item analysis $p < .0001$. In addition, L1 Chinese speakers responded to inconsistent characters faster than L2 Chinese learners did, by-subject analysis $p < .0001$, by-item analysis $p < .0001$.

Moreover, post-hoc analyses with regards to the three-way interaction between NS, consistency, and L1/L2 group revealed significant group effect as L1 Chinese speakers demonstrated significantly shorter RT than L2 Chinese learners in the following conditions, (1) “large NS and consistent”, by-subject analysis $p < .0001$, by-item analysis $p < .0001$; (2) “large NS and inconsistent”, by-subject analysis $p < .0001$, by-item analysis $p < .0001$; (3) “small NS and consistent”, by-subject analysis $p < .0001$, by-item analysis $p < .0001$; and (4) “small NS and inconsistent”, by-subject analysis $p < .0001$, by-item analysis $p < .0001$.

Lastly, post-hoc analyses on the three-way interaction revealed a significantly facilitatory consistency effect when L1 Chinese speakers read small-NS characters. This means that L1 Chinese speakers responded to “small NS and consistent” characters significantly faster than “small NS and inconsistent” characters, by-subject analysis $p = .005$; but not significant in by-item analysis $p = .150$. However, this consistency effect was not detected when L1 Chinese speakers responded to large-NS characters. Also, this consistency effect was not detected among L2 Chinese learners. Log-transformed RT data and post-hoc comparisons results of Experiment 1(a) were demonstrated in Figure 2.3.

Figure 2.3

Log-transformed RT Data of Experiment 1(a)

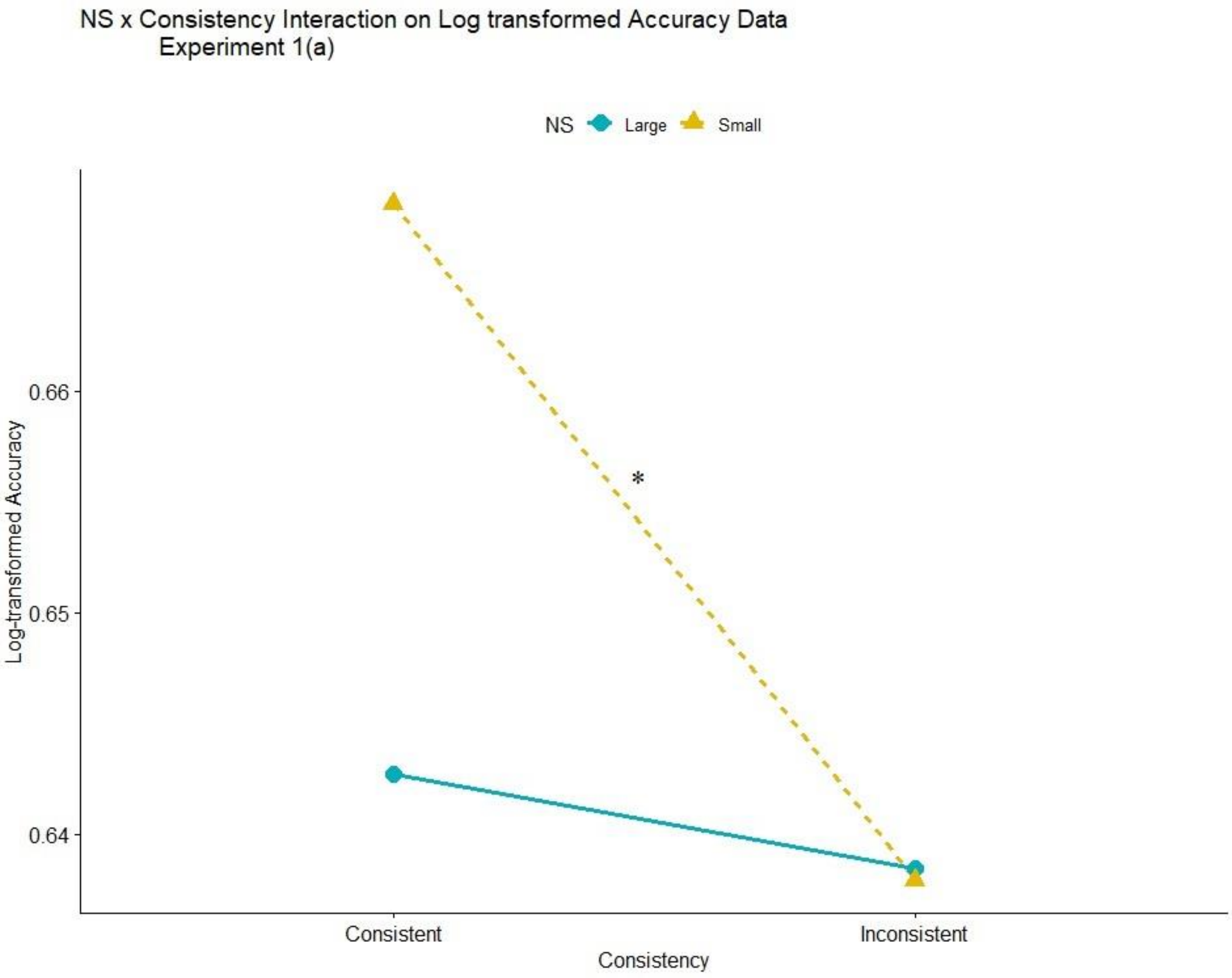


* $p < .05$. ** $p < .01$. *** $p < .001$

Post-hoc Analyses on Accuracy Data (Tukey HSD). Post-hoc analyses on participants' log-transformed accuracy data showed the following results. Firstly, regarding the NS by consistency two-way interaction, post-hoc comparisons revealed a significant consistency effect when reading small-NS characters. In other words, participants achieved significantly higher accuracy when responding to "small NS and consistent" stimuli than "small NS and inconsistent” ones, by-subject analysis $p = .020$; but not significant in by-item analysis $p = .095$. However, this consistency effect was not found in large-NS characters (see Figure 2.4).

Figure 2.4

NS by Consistency Interaction (Accuracy Data, Experiment 1(a))

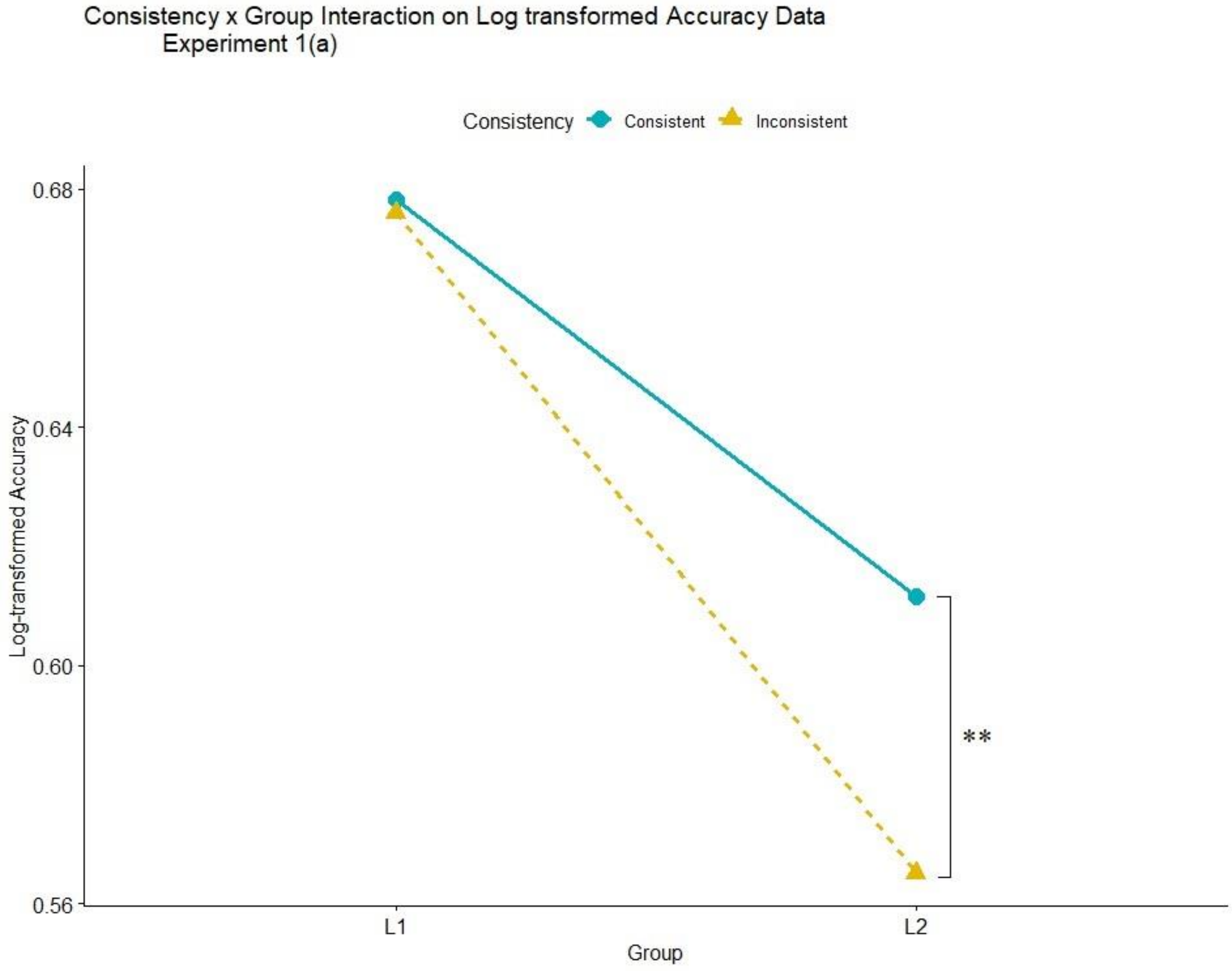


* $p < .05$. ** $p < .01$. *** $p < .001$

Secondly, post-hoc comparisons about the NS by L1/L2 group two-way interaction suggested a significant group effect. L1 Chinese speakers demonstrated higher accuracy when responding to Large-NS characters than L2 Chinese learners did, by-subject analysis $p < .0001$, by-item analysis $p < .0001$. In addition, L1 Chinese speakers showed higher accuracy rate when responding to small-NS characters than L2 Chinese learners did, by-subject analysis $p = .005$, by-item analysis $p < .0001$.

Figure 2.5

Group by Consistency Interaction (Accuracy Data, Experiment 1(a))



* $p < .05$. ** $p < .01$. *** $p < .001$

Thirdly, post-hoc analyses on the consistency by L1/L2 group interaction indicated significantly group effect was well. L1 Chinese speakers showed higher accuracy when reading consistent characters than L2 Chinese learners did, by-subject analysis $p < .0001$, by-item analysis $p = .003$. Also, L1 Chinese speakers demonstrated higher accuracy when they responded to inconsistent characters than L2 Chinese learners did, by-subject analysis $p < .0001$, by-item analysis $p < .0001$.

In addition, the post-hoc comparisons regarding L1/L2 group by consistency interaction suggested a significant consistency effect among L2 Chinese learners. L2 Chinese learners responded to consistent characters with higher accuracy than when they responded to inconsistent characters, by-subject analysis $p = .002$; but not significant in by-item analysis $p = .092$, suggesting that the consistency effect was facilitatory. However, this consistency effect was not found among L1 Chinese learners (see Figure 2.5).

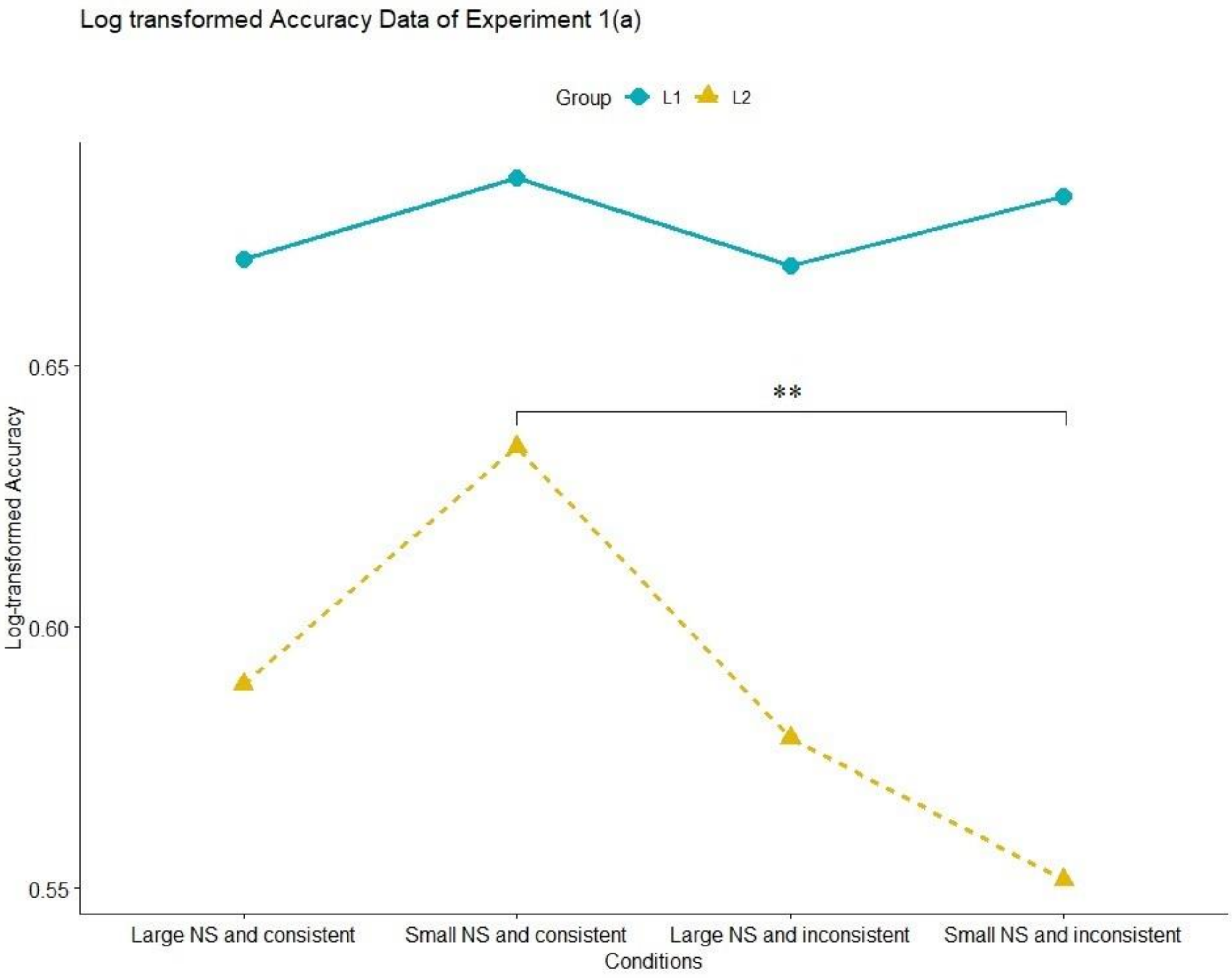
Post-hoc analyses regarding the three-way interaction revealed significant group effect. L1 Chinese speakers performed the LD task significantly better than L2 Chinese learners in all stimuli conditions, including (1) “large NS and consistent” characters, by-subject analysis $p < .0001$, by-item analysis $p = .039$; (2) “large NS and inconsistent”, by-subject analysis $p < .0001$, by-item analysis $p = .029$; (3) “small NS and consistent”, by-subject analysis $p = .023$, but not significant in by-item analysis $p = .555$; and (4) “small NS and inconsistent”, by-subject analysis $p < .0001$, by-item analysis $p < .0001$.

Interestingly, post-hoc analyses on three-way interaction suggested a significant consistency effect when L2 Chinese speakers responded to small-NS characters, by-subject analysis $p < .001$, by-item analysis $p = .039$. L2 Chinese speakers responded to “small NS and consistent” characters with higher accuracy than when they responded to “small NS and inconsistent” characters, suggesting that the consistency effect was facilitatory. This consistency effect was not found when they read large-NS characters. This consistency was not found among

L1 Chinese speakers as well. Meaningful pairwise comparisons regarding log-transformed accuracy data of Experiment 1(a) were demonstrated in Figure 2.6.

Figure 2.6

Log-transformed Accuracy Data of Experiment 1(a)



* $p < .05$. ** $p < .01$. *** $p < .001$

Hierarchical Regression Analyses

To evaluate the contributions of stimuli's orthographic features in participants' RT and accuracy, a set of hierarchical regression analyses were performed to examine how much variance in RT and accuracy was explained by phonetic compound characters' consistency, NS, and other features (i.e., predictors). Dependent variables included log-transformed RT and log-transformed accuracy of all participants, those of L1 Chinese speakers only, and those of L2 Chinese leaners only.

Frequency was first entered into the model. Also, since this dissertation study focused on consistency and NS effects, NS, type-, and token-consistency were entered in step 2. In step 3, other orthographic features, including number of strokes, semantic radical-based neighborhood size (i.e., number of phonetic compound characters sharing the same semantic radical), frequency of the phonetic radical, and neighborhood frequency (i.e., calculated by adding the frequency of all characters in a neighborhood), were entered as predictors. Results were demonstrated in Table 2.8.

For all participants' RT, character frequency made a significant contribution, $F(1, 58) = 6.031$, $p = .017$, which explained 9.42% of the variances. After entering NS, type-, and token consistency, the model did not significantly contribute to participants' RT, $F(4, 55) = 2.191$, $p = .082$, $R^2 = .137$. NS, type-, and token consistency together did not add significant additional contributions, $\Delta R^2 = .043$, $p > .05$. However, after adding other orthographic features, the model made significant contributions by explaining 28.4% of the variances in RT data, $F(8, 51) = 2.531$, $p = .021$. By adding these features, they significantly made additional contributions, $\Delta R^2 = .147$, $p < .05$. Especially, frequency of phonetic radical ($p = .011$), and neighborhood frequency ($p = .045$) became significant predictors. Character frequency remained a significant predictor ($p = .011$).

For L1 Chinese speakers' RT, entering character frequency first did not make a significant contribution, $F(1, 58) = 2.749$, $p = .103$, which only explained 4.52% of the variance in the log-transformed RT data. Adding NS, type-, and token-consistency significantly improve the model, $\Delta R^2 = .116$, $p = .037$, and the model explained 16.16% of the variance in the log-transformed RT data, $F(4, 55) = 2.649$, $p = .043$. In addition, adding the other orthographic features also significantly improved the model, $\Delta R^2 = .188$, $p = .010$. The whole model explained 34.96% of the variances in L1 Chinese speakers log-transformed RT, $F(8, 51) = 3.426$, $p = .003$. Especially, number of strokes ($p = .037$), frequency of the phonetic radical ($p = .005$), and neighborhood frequency ($p = .011$) appeared to be significant predictors. Character frequency remained a significant predictor ($p = .024$).

For L2 Chinese learners' RT, adding character frequency in the first step predicted significant variances in the dependent variable, $F(1, 58) = 8.978$, $p = .004$, $R^2 = .134$. Adding NS, type-, and token-consistency in the second step did not significantly improve the model, $\Delta R^2 = .016$, $p = .800$. The model explained 14.99% of the variance in L2 learners' log-transformed RT data, $F(4, 55) = 2.425$, $p = .059$. However, character frequency remained a significant predictor ($p = .008$). Lastly, adding the other orthographic features in the third step did not significantly improve the model, $\Delta R^2 = .047$, $p = .570$, and the model did not explain significant variances in L2 learners' log-transformed RT data as well, $F(8, 51) = 1.558$, $p = .161$, $R^2 = .196$. However, character frequency continued serving as a significant predictor for L2 learners' log-transformed RT data ($p = .048$).

For all participants' accuracy data, adding character frequency into the model significantly contribute to the model, $F(1, 58) = 8.533$, $p = .005$, $R^2 = .128$. In the second step, adding NS, type-, and token consistency together did not significantly improve the model ($\Delta R^2 = .079$, $p = 147$), but the model was still significant, $F(4, 55) = 3.588$, $p = .011$, $R^2 = .207$. Lastly, by adding the other orthographic features as predictors in the third step, the model explained 28.42% of the variance in all participants' log-transformed accuracy, which was significant, *F* (8, 51) = 2.531 *p* = .021. However, these orthographic features did not significantly improve the model, Δ R^2 = .077, *p* = .255. In the final model, number of strokes (*p* = .045) and character frequency (*p* = .004) were identified as significant predictors.

For L1 speakers' accuracy data, adding character frequency in the first step into the model did not explain significant variances of the dependent variable, *F* (1, 58) = .105, *p* = .747, R^2 = .002. However, adding NS, type-, and token-consistency significantly explained additional proportions of variances in L1 speakers' log-transformed accuracy, Δ R^2 = .150, *p* = .028, but the model, which explained 15.17% of the variances, was not significant *F* (4, 55) = 2.459, *p* = .056. Nevertheless, NS was found as a significant predictor (*p* = .006). Lastly, adding other orthographic features did not significantly improve the model, as these predictors only explained 7.6% additional variances in L1 speakers' log-transformed accuracy (*p* = .303), and the model did not explain significant variances, *F* (8, 51) = 1.875, *p* = .085, R^2 = .227. However, token consistency was recognized as a significant predictor (*p* = .037).

For L2 Chinese learners' accuracy data, adding frequency in the first step into the model explained significant variances, *F* (1, 58) = 12.55, *p* < .001, R^2 = .178, and character frequency was a significant predictor (*p* < .001). However, adding NS, type-, and token consistency into the model in the second step did not significantly improve the model (Δ R^2 = .080, *p* = .112), but the model was still significant, *F* (4, 55) = 4.77, *p* = .002, R^2 = .258. Character remained a significant predictor (*p* = .003) and token-consistency had a trend toward significance (*p* = .054). Lastly, adding the other important orthographic features in the third step explained additional 9.71% variances in L2 Chinese learners' log-transformed accuracy (Δ R^2 = .097, *p* = .122), and the modal explained in total 35.47% of the variances in the dependent variable, *F* (8, 51) = 3.504,

Table 2.8

Hierarchical Regression Analyses of Experiment 1(a)

	Log RT Data (All participants)				**Log RT Data (L1 Speakers)**				**Log RT Data (L2 Learners)**			
Predictors	R^2	ΔR^2	β	*Sig.*	R^2	ΔR^2	β	*Sig.*	R^2	ΔR^2	β	*Sig.*
Step 1	.094*				.045				.134**			
1. Frequency			-.000	.017*			-.000	.103			-.000	.004**
Step 2	.137	.043			.162*	.116*			.150	.016		
1. Frequency			.000	.033*			.000	.166			.000	.008**
2. NS			.007	.370			.015	.099			-.011	.356
3. Consistency (type)			-.007	.913			.025	.745			-.050	.592
4. Consistency (token)			-.039	.426			-.098	.107			.032	.667
Step 3	.284*	.147*			.350**	.188*			.196	.047		
1. Frequency			.000	.011*			.000	.024*			.000	.048*
2. NS			-.003	.743			.000	.986			-.004	.787
3. Consistency (type)			-.078	.238			-.086	.275			-.014	.896
4. Consistency (token)			.054	.338			.034	.609			.021	.822
5. Number of strokes			-.005	.113			-.008	.037*			-.004	.404
6. Semantic radical NS			.000	.336			.000	.456			.000	.522
7. Phonetic radical frequency			.000	.011*			.000	.005**			.000	.848
8. Neighborhood frequency			.000	.045*			.000	.011*			.000	.425

* $p < .05$. ** $p < .01$. *** $p < .001$

Table 2.8 (continued)

Hierarchical Regression Analyses of Experiment 1(a)

Predictors	**Log Accuracy Data (All participants)**				**Log Accuracy Data (L1 Speakers)**				**Log Accuracy Data (L2 Learners)**			
	R^2	ΔR^2	β	*Sig.*	R^2	ΔR^2	β	*Sig.*	R^2	ΔR^2	β	*Sig.*
Step 1	.128**				.002				.178***			
1. Frequency			.000	.005**			.000	.747			.000	.001***
Step 2	.207*	.079			.152	.150*			.258**	.080		
1. Frequency			.000	.007**			.000	.335			.000	.003**
2. NS			-.007	.067			-.006	.006**			-.010	.309
3. Consistency (type)			-.013	.684			.009	.611			-.064	.442
4. Consistency (token)			.029	.264			-.015	.288			.128	.054
Step 3	.284*	.077			.227	.076			.355**	.097		
1. Frequency			.000	.004**			.000	.195			.000	.002**
2. NS			-.006	.225			-.003	.190			-.011	.357
3. Consistency (type)			-.001	.971			.027	.169			-.065	.475
4. Consistency (token)			.012	.696			-.036	.037*			.120	.129
5. Number of strokes			.003	.045*			.001	.555			.010	.021*
6. Semantic radical NS			.000	.965			.000	.369			.000	.624
7. Phonetic radical frequency			.000	.332			.000	.107			.000	.612
8. Neighborhood frequency			.000	.633			.000	.090			.000	.858

* $p < .05$. ** $p < .01$. *** $p < .001$

p = .003. Among these predictors, number of strokes (*p* = .021) and character frequency (*p* = .002) were identified as significant predictors.

For L2 Chinese learners' accuracy data, adding frequency in the first step into the model explained significant variances, *F* (1, 58) = 12.55, $p < .001$, $R^2 = .178$, and character frequency was a significant predictor ($p < .001$). However, adding NS, type-, and token consistency into the model in the second step did not significantly improve the model ($\Delta R^2 = .080$, *p* = .112), but the model was still significant, *F* (4, 55) = 4.77, *p* = .002, $R^2 = .258$. Character remained a significant predictor (*p* = .003) and token-consistency had a trend toward significance (*p* = .054). Lastly, adding the other important orthographic features in the third step explained additional 9.71% variances in L2 Chinese learners' log-transformed accuracy ($\Delta R^2 = .097$, *p* = .122), and the modal explained in total 35.47% of the variances in the dependent variable, *F* (8, 51) = 3.504, *p* = .003. Among these predictors, number of strokes (*p* = .021) and character frequency (*p* = .002) were identified as significant predictors.

In summary, hierarchical regression analyses indicated that phonetic compound character's neighborhood size (NS) functioned as a significant predictor for L1 Chinese speakers' accuracy data but not for their RT data or for L2 Chinese learners' accuracy and RT data. Consistency was not a significant factor for participants' RT or accuracy.

Interim Discussion about Experiment 1(a)

Results revealed that the main effects of NS and consistency were significant, which were in accordance with the hypotheses and previous studies. For the main effect of NS, smaller NS yielded higher accuracy rate whereas larger NS resulted in lower accuracy. This indicated that the NS effect was inhibitory, and this conclusion was in accordance with Li et al. (2011) and Chang et al. (2016). The difference was that Li et al. (2011) and Chang et al. (2016) used naming tasks whereas this dissertation adopted LD task and showed that the inhibitory NS effect could be detected using LD task as well. The results also revealed that the consistency effect was facilitatory: consistent characters yielded higher accuracy. This was in accordance with Kim et al. (2016) and Lin & Collins (2012)'s results. Again, Kim et al. (2016) and Lin & Collins (2012) used naming tasks. But the results of the present study suggested that LD task could also yield facilitatory consistency effect.

A significant interaction between the NS and consistency effect was found. The consistency effect was significant and facilitatory when the NS was small. Consistency characters yielded shorter RT and higher accuracy for small-NS characters, but not for large-NS characters. Li et al. (2011) and Chang et al. (2016) also found significant NS by consistency interaction. However, the post-hoc analyses revealed different results. Li et al. (2011) suggested a significantly inhibitory NS effect when reading inconsistent characters. Chang et al. (2016) revealed a significantly facilitatory NS effect for consistent characters and a significantly inhibitory NS effect for inconsistent characters. Both studies agreed that the NS effect was inhibitory when reading inconsistent characters, but this result was not captured by the present study. This may be because the present study used a different task (LD) compared to the two studies.

Another significant two-way interaction was between groups and consistency. The consistency effect was facilitatory and significant for L2 Chinese learners, but not for L1 Chinese speakers. This result was similar to that of Kim et al. (2016) and Lin & Collins (2012) as they also suggested that the consistency effect was facilitatory for L2 Chinese learners. Regardless of using LD or naming tasks, L2 Chinese learners have consistently demonstrated consistency effect. This implied that consistency was an important indicator for L2 learners to extract phonological information from script despite opaque orthography-to-phonology mapping in Chinese. It also suggested that phonological activation played an important role in L2 learners' recognition of Chinese characters.

A significant three-way interaction between NS, consistency, and groups was found. Post-hoc analyses suggested that the consistency was facilitatory when L2 Chinese learners read small-NS characters, the consistency effect was significant and facilitatory because higher accuracy rate was yielded. This finding has not been found in literature because no studies have investigated the NS x consistency interaction among L2 Chinese speakers before. This result was an extension of Kim et al. (2016)'s and Lin & Collins (2012)'s results as they did not indicate how the consistency effect they found was modulated by the NS.

However, such consistency effect was not found among large-NS characters. One possible explanation was that L2 Chinese speakers have not developed the sensitivity to NS as expected. Rather, they were more sensitive to consistency and replied on it for phonological information's extraction.

Experiment 1(b)

Participants

The same group of participants who participated in Experiment 1(a) finished Experiment 1(b).

Design

Experiment 1(b) uses a 2 (NS) x 2 (Consistency degree) x 2 (Groups) factorial design. Each factor contained two categories. NS had large NS and small NS. Consistency degree contained higher- and low-consistency semantic-phonetic compound characters. Groups included L1 Chinese speakers and L2 Chinese learners. NS and consistency degree were the within-subject factors whereas groups served as the between-subject factor. Participants finished a lexical decision task.

Materials

A total of 60 semantic-phonetic compound characters were selected as the real characters. Another 60 pseudo-characters were created by combining one semantic and phonetic radical. All inclusion criteria were the same as those of Experiment 1(a) (please refer to Table 2.1) except criterion 9. In Experiment 1(b), all real characters were irregular semantic-phonetic compounds instead of regular ones. Another exception is about criterion 6, which stated that all included stimuli should only have one pronunciation (i.e., stimuli should not be heteronyms in Chinese (多音字)). The following two characters were exceptions: 哄 whose pronunciations can be /*hong1*/, /*hong3*/, or /*hong4*/ and the character 咽 which can be pronounced as either /*yan1*/ or /*yan4*/. Because each of the characters can be pronounced differently only in tones instead of in syllables, they were still considered acceptable to be included in this experiment's stimuli. All stimuli of Experiment 1(b) were listed in Appendix B. Features of real characters were summarized in Table 2.9.

For the real Characters, the large-NS condition and the small-NS condition were significantly different in the number of NS ($p < .001$). The high- and low-consistency conditions were significantly different in the type-consistency value ($p < .001$). Other factors, including number of strokes, character frequency, semantic radical NS, semantic radical familiarity, phonetic radical frequency, and neighborhood frequency sum were balanced across the four conditions. Other features, including number of strokes, character frequency, semantic radical neighborhood size, semantic radical familiarity, phonetic radical frequency, neighborhood frequency sum, number of homophone (without considering tones), number of homophone

Table 2.9

Means (Standard Deviations) and Ranges of Real Characters of Experiment 1(b)

	Large NS		Small NS		
	High Consistency (n = 15)	Low Consistency (n = 15)	High Consistency (n = 15)	Low Consistency (n = 15)	*p*
NS	6.60 (1.35) 5 - 9	7.13 (2.20) 5 - 14	3.33 (0.49) 3 - 4	4.0 (0.00) 4 - 4	between large- and small NS: t (33.03) = 9.34, $p < .001$
Type Consistency value	0.47 (0.07) 0.40 - 0.60	0.23 (0.05) 0.17 - 0.29	0.44 (0.16) 0.33 - 0.75	0.25 (0.00) 0.25 - 0.25	between high- and low consistency: t (34.57) = 9.37, $p < .001$
Token Consistency value	0.25 (0.13) 0.05 - 0.44	0.19 (0.18) 0.008 - 0.53	0.26 (0.19) 0.06 - 0.71	0.18 (0.17) 0.04 - 0.57	F (3, 56) = .95, p = .424
Number of Strokes	10.07 (2.46) 6 - 15	10.13 (2.61) 7 - 14	11.07 (2.87) 6 - 17	9.93 (2.09) 6 - 13	F (3, 56) = .63, p = .598
Frequency (Per million characters)	41.07 (49.57) 3.8 - 188.85	60.33 (105.09) 5.2 - 410.95	50.20 (47.32) 5.0 - 164.2	86.00 (118.29) 9.3 - 464.9	F (3, 56) = .76, p = .521
Semantic radical NS	40.93 (35.88) 4 - 119	45.87 (47.44) 2 - 139	53.47 (39.33) 10 - 139	52.40 (37.78) 10 - 119	F (3, 56) = .32, p = .812
Semantic radical familiarity	3.46 (0.22) 3.02 - 3.76	3.18 (0.53) 1.86 - 3.73	3.46 (0.28) 2.68 - 3.76	3.54 (0.16) 3.24 - 3.76	F (3, 56) = 3.50, p = .021[19]

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[19] Tukey HSD analyses demonstrated that this feature was significantly different between "small NS and low consistency" and "large NS and low consistency" conditions (p = .021).

Phonetic radical frequency	599.29 (966.86) 21 - 3813.05	426.24 (400.70) 11.9 - 1328	270.18 (290.60) 27.9 - 882.5	285.00 (562.23) 22 -2210.3	*F* (3, 56) = .94, *p* = .427
Neighborhood frequency sum	1149.59 (1447.95) 148.3 - 6060.3	1266.02 (1071.93) 145.7 - 3562.85	397.82 (321.73) 99.15 - 1056.1	539.23 (624.10) 180.5 - 2402.2	*F* (3, 56) = 3.01, *p* = .038[20]
Number of homophones (without considering tones)	10.13 (4.61) 5 - 23	13.00 (10.60) 2 - 43	9.27 (7.36) 1 - 31	13.13 (10.86) 1 - 34	*F* (3, 56) = .77, *p* = .518
Number of homophones (considering tones)	4.80 (2.81) 1 - 11	4.13 (2.77) 1 - 12	4.33 (3.87) 1 - 17	3.87 (2.70) 1 - 10	*F* (3, 56) = .25, *p* = .864
Number of meanings	2.20 (1.26) 1 - 5	1.73 (0.80) 1 - 3	1.87 (0.64) 1 - 3	2.27 (1.62) 1 - 6	*F* (3, 56) = .75, *p* = .525
Number of associated syllables	2.67 (0.72) 2 - 4	4.07 (1.33) 2 - 7	2.33 (0.49) 2 - 3	3.20 (0.56) 2 - 4	*F* (3, 56) = 12.01, *p* < .001[21]
Phonological neighbors	125.20 (59.54) 20 - 243	150.33 (79.33) 49 - 271	101.07 (57.92) 32 - 254	137.60 (68.85) 48 - 265	*F* (3, 56) = 1.48, *p* = .231
Percentage of stimuli that are the highest in frequency in a neighborhood	0/15 = 0.00%	0/15 = 0.00%	2/15 = 13.33%	2/15 = 13.33%	

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[20] However, Tukey HSK analyses showed no significant difference between any two conditions: "large NS and low consistency" vs. "large NS and high consistency" (*p* = .987); "small NS and high consistency" and "large NS and high consistency" (*p* = .156); "small NS and low consistency" vs. "large NS and high consistency" (*p* = .319); "small NS and high consistency" vs. "large NS and low consistency" (*p* = .078); "small NS and low consistency" vs. "large NS and low consistency" (*p* = .179); "small NS and low consistency" vs. "small NS and high consistency" (*p* = .978).

[21] Tukey HSD analyses demonstrated that this feature was significantly different between "large NS and low consistency" and "large NS and high consistency" (*p* <. 001), between "small NS and high consistency" and "large NS and low consistency" (*p* < .001), between "small NS and low consistency" and "large NS and low consistency" (*p* = .034), and between "small NS and low consistency" and "small NS and high consistency" (*p* = .034).

Table 2.10

Means (Standard Deviations) and Ranges of Real- and Pseudo-Characters of Experiment 1(b)

	Real Characters (n = 60)	Pseudo-characters (n = 60)	*p*
NS	5.27 (2.08) 3 - 14	5.32 (2.46) 3 - 14	*t* (114.86) = .12, *p* = .905
Number of strokes	10.30 (2.50) 6 - 17	9.82 (2.59) 6 - 17	*t* (117.84) = -1.04, *p* = .301
Semantic radical NS	48.17 (39.65) 2 - 139	44.57 (26.86) 15 - 139	*t* (103.73) = -.58, *p* = .562
Semantic familiarity	3.41 (0.35) 1.86 - 3.76	3.45 (0.21) 2.92 - 3.73	*t* (98.24) = .78, *p* = .436
Phonetic radical frequency	395.18 (610.62) 11.9 - 3813.05	606.65 (840.20) 7.2 - 4244.85	*t* (107.73) = 1.58, *p* = .118
Neighborhood frequency sum	838.17 (1015.06) 99.15 - 6060.3	2010.87 (4969.50) 99.15 - 38354.05	*t* (63.92) = 1.79, *p* = .078
Number of associated syllables	3.07 (1.06) 2 - 7	3.12 (1.30) 2 - 7	*t* (113.12) = .23, *p* = .818

(considering tones), number of meaning, number of associated syllables, number of phonological neighbors were attempted to be balanced across the four conditions. However, semantic radical familiarity was not perfectly balanced (*p* = .021). In addition, number of associated syllables (p < .001) and neighborhood frequency sum (*p* = .038) were not perfectly matched across the four experimental conditions, but that makes sense because (1) low-consistency characters tended to be from a neighborhood that had a greater number of associated syllables; (2) large NS tended to have larger neighborhood frequency sum because it had more characters than small NS.

In addition to real characters' features, those of pseudo-characters were demonstrated in Table 2.10. NS, number of strokes, semantic radical familiarity, phonetic radical frequency, and neighborhood frequency sum were balanced between real characters and pseudo-characters.

Procedures

The procedures of Experiment 1(b) were the same as those of Experiment 1(a). Participants finished a lexical decision task.

Results of Experiment 1(b)

Experiment 1(b) adopted a 2 (Neighborhood size) x 2 (Consistency degree) x 2 (Groups) repeated measures mixed factorial design. Participants' RTs and accuracy data were the dependent variables (DVs). ANOVAs, correlation analyses, and hierarchical regression analyses were conducted based on trimmed and log-transformed RT data and accuracy data. Data was analyzed using *RStudio*.

All items yielded an accuracy higher than 70%. The accuracy rate for all items ranged from 72.73% to 100%. As a result, all items' data were included in the analyses.

Table 2.11

Descriptive Statistics of Experiment 1(b)'s Results (Means and Standard Deviations in Parentheses))

RT (ms)	Large NS		Small NS	
	High Consistency	Low Consistency	High Consistency	Low Consistency
L1 speakers	614.050 (73.142)	614.050 (73.142)	596.225 (77.318)	595.892 (61.960)
L2 learners	794.744 (100.768)	756.008 (90.807)	753.857 (140.678)	747.725 (97.602)
Accuracy (%)	**Large NS**		**Small NS**	
	High Consistency	Low Consistency	High Consistency	Low Consistency
L1 speakers	96.781 (4.584)	97.470 (3.744)	94.712 (6.517)	95.632 (5.711)
L2 learners	80.889 (15.300)	84.445 (11.454)	77.777 (16.651)	82.223 (12.765)

Table 2.12

Bivariate Correlation Matrix of Experiment 1(b)

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. RT (all participants)	1.00													
2. RT (L1 speakers)	.92***	1.00												
3. RT (L2 learners)	.81***	.53***	1.00											
4. Accuracy (all participants)	-.37**	-.43***	-.32*	1.00										
5. Accuracy (L1 speakers)	-.27*	-.26*	-.21	.70***	1.00									
6. Accuracy (L2 learners)	-.31*	-.39**	-.28*	.88***	.27*	1.00								
7. NS	.27*	.34**	.04	.16	.18	.10	1.00							
8. Consistency (type)	.12	.08	.19	-.24	-.22	-.18	.00	1.00						
9. Consistency (token)	-.06	-.11	-.07	.25	-.01	.34**	.21	.18	1.00					
10. Frequency	-.21	-.34**	-.11	.41**	.17	.44***	-.07	-.21	.21	1.00				
11. Phonetic radical frequency	-.13	-.04	-.21	.12	.20	.02	.18	.11	-.09	.19	1.00			
12. Neighborhood frequency	-.10	-.01	-.24	.18	.19	.11	.45***	.00	.05	.32*	.88***	1.00		
13. Number of strokes	.13	.11	.08	-.05	-.27*	.11	-.06	.03	.14	-.19	-.15	-.17	1.00	
14. Semantic radical NS	.02	.06	.00	-.19	-.06	-.21	-.18	.07	.02	.06	-.09	-.13	-.14	1.00

* *p* < .05. ** *p* < .01. *** *p* < .001

Data Trimming

Data trimming was performed prior to data analysis. Similar to the data trimming procedures of Experiment 1(a), incorrect responses' RT data was excluded from data analysis. Additionally, RT data points out of the 300ms - 1,500ms range were not included in data analysis. This led to a deletion of 119 data points from 2,580 data points, accounting for 4.61% of the entire dataset. Specifically, 41 data points were removed from L1 Chinese speakers' responses, and another 78 data points were eliminated from L2 Chinese learners' responses. Table 2.11 demonstrates descriptive statistics after data trimming

Correlation Analyses

Similar to Experiment 1(a), Pearson's correlation coefficients were obtained based on participants' logarithmic RT and accuracy data as well as character's features, including NS type consistency, token consistency, frequency, phonetic radical's frequency, neighborhood frequency, number of strokes, semantic radical NS, and semantic radical familiarity. Results were displayed in Table 2.12.

Results suggested that a phonetic compound character's NS was significantly correlated to all participants' RT ($r = .27$, $p < .05$) and especially, to L1 Chinese speakers' RT ($r = .34$, $p < .01$). However, NS was not significantly correlated to L2 Chinese learners' RT ($r = .04$, $p > .05$). Also, NS was not significantly correlated to participants' accuracy data.

Similar to results of experiment 1(a), a phonetic compound character's type consistency value was not significantly correlated to any of the dependent variables. However, token consistency value was significantly correlated to L2 Chinese learners' accuracy ($r = .34$, $p < .01$).

In addition, character frequency was significantly correlated to L1 Chinese speakers' RT ($r = -.34$, $p < .01$), all participants' accuracy ($r = .41$, $p < .01$), and L2 Chinese learners' accuracy ($r = .44$, $p < .001$).

Lastly, a character's stroke number was significantly correlated to L1 Chinese speakers' accuracy data ($r = -.27$, $p < .05$). However, it was not significantly correlated to L2 Chinese learners' accuracy data.

ANOVA Results

Experiment 1(b) used a 2 (NS) x 2 (Consistency degree) x 2 (L1/L2 group) three-way ANOVA test on log-transformed RT data and log-transformed accuracy data. Results were reported based on by-subject (F_1) analyses and by-item analyses (F_2).

Main Effects. Analyses on log-transformed RT data revealed a significant main effect of L1/L2 groups, F_1 (1, 41) = 38.905, $p < .001$, $\eta^2_p = .41$; F_2 (1, 56) = 264.274, $p < .001$, $\eta^2_p = .54$. In addition, analyses suggested a significant main effect of NS, F_1 (1, 41) = 9.537, $p = .004$, $\eta^2_p = .03$; but not in by-item analysis, F_2 (1, 56) = 1.560, $p = .217$, $\eta^2_p = .02$. The main effect of consistency degree was not significant, F_1 (1, 41) = .169, $p = .683$, $\eta^2_p < .0001$; F_2 (1, 56) = .470, $p = .496$, $\eta^2_p = .006$.

Analyses on logarithmic accuracy data revealed significant main effect of group, F_1 (1, 42) = 34.524, $p < .0001$, $\eta^2_p = .37$; F_2 (1, 56) = 59.387, $p < .0001$, $\eta^2_p = .31$. In addition, analyses suggested significant main effect of NS, F_1 (1, 42) = 7.720, $p = .008$, $\eta^2_p = .01$; but not in by-item analysis, F_2 (1, 56) = 1.094, $p = .300$, $\eta^2_p = .01$. Lastly, the main effect of consistency was significant as well, F_1 (1, 42) = 6.332, $p = .016$, $\eta^2_p = .01$; but not significant in by-item analysis, F_2 (1, 56) = 1.157, $p = .287$, $\eta^2_p = .01$.

Two-way Interactions. Log-transformed RT data revealed no significant two-way interactions. The NS by consistency degree interaction was not significant, F_1 (1, 41) = .364, p = .550, η^2_p < .00001; F_2 (1, 56) = .423, p = .518, η^2_p = .006. The L1/L2 groups by NS interaction was not significant as well, F_1 (1, 41) = .037, p = .848, η^2_p < .0001; F_2 (1, 56) = .196, p = .660, η^2_p = .0009. Lastly, the L1/L2 groups by consistency degree interaction was not significant, F_1 (1, 41) = 2.128, p = .152, η^2_p = .005; F_2 (1, 56) = 2.270, p = .138, η^2_p = .010.

According to analysis on the logarithmic accuracy data, there were no significant two-way interactions. The NS by consistency degree interaction was not significant, F_1 (1, 42) = .124, p = .727, η^2_p = .0002; F_2 (1, 56) = .014, p = .906, η^2_p = .0001. Secondly, the NS by L1/L2 group interaction was not significant as well, F_1 (1, 42) = .310, p = .581, η^2_p = .0006; F_2 (1, 56) = .059, p = .809, η^2_p = .0005. Lastly, the consistency degree by L1/L2 group interaction was not significant, F_1 (1, 42) = 3.097, p = .086, η^2_p = .009; F_2 (1, 56) = .707, p = .404, η^2_p = .005.

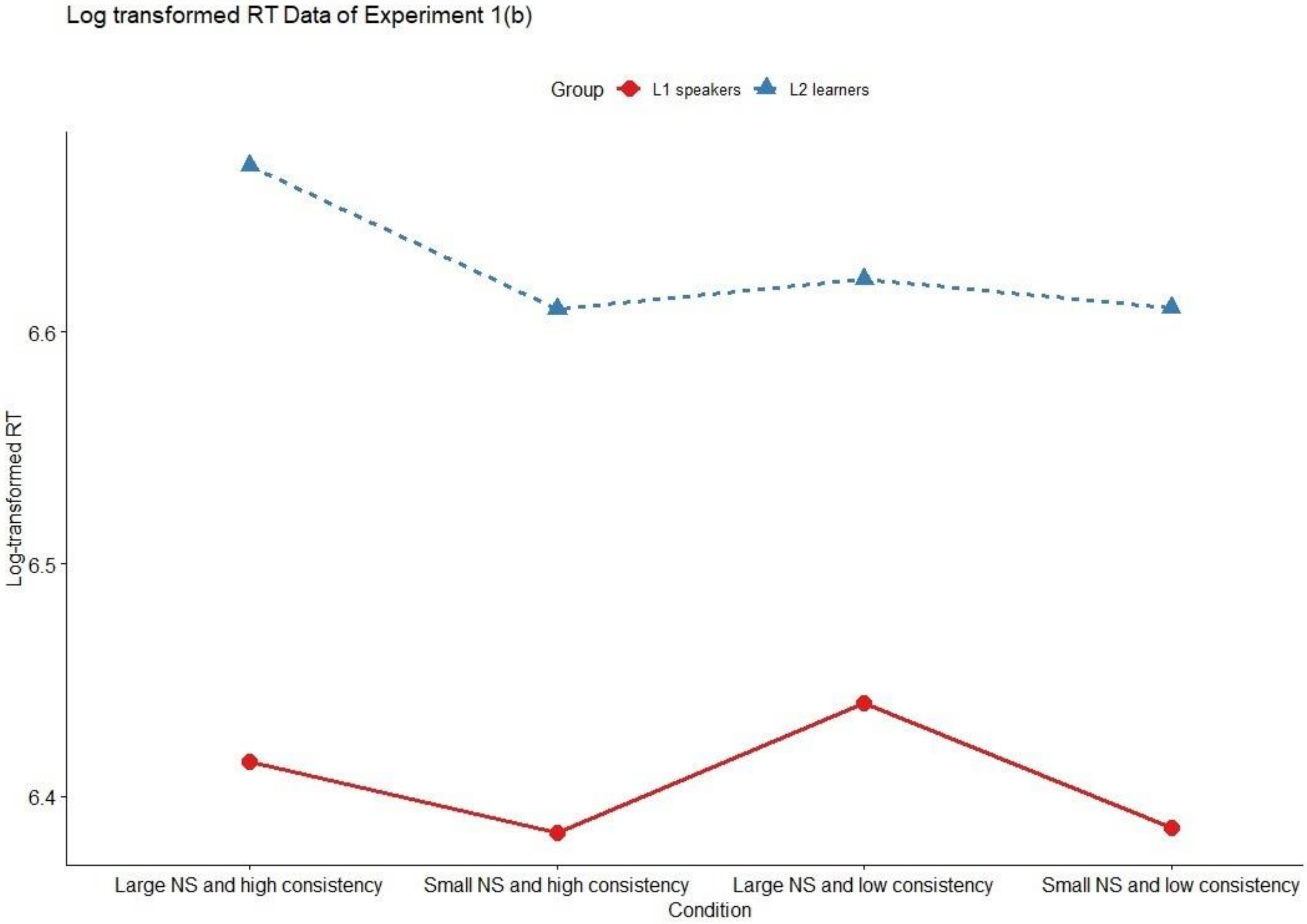
Three-way Interaction. There was no significant three-way interaction according to the analyses on the logarithmic RT data, F_1 (1, 41) = 2.723, p = .107, η^2_p = .005; F_2 (1, 56) = .043, p = .837, η^2_p = .0002. Logarithmic accuracy data revealed no significant three-way interaction, F_1 (1, 42) = .048, p = .828, η^2_p < .0001; F_2 (1, 56) = .005, p = .942, η^2_p < .0001.

Post-hoc Analyses on RT Data (Tukey HSD). Firstly, regarding the NS by consistency degree two-way interaction, post-hoc analyses showed no meaningful comparisons. As a result, no results were reported here.

Secondly, with regards to the NS by L1/L2 group two-way interaction, post-hoc comparisons showed a significant group effect. To be more specific, L1 Chinese speakers responded to large- NS characters significantly faster than L2 Chinese learners did, by-subject analysis p < .0001, by-item analysis p < .0001. Also, L1 Chinese speakers demonstrated significantly shorter RT when responding to small-NS characters than L2 Chinese learners did, by-subject analysis $p < .0001$, by-item analysis $p < .0001$. No other meaningful post-hoc comparisons were found.

Figure 2.7

Log-transformed RT Data of Experiment 1(b)



Thirdly, about the consistency degree by L1/L2 group two-way interaction, post-hoc comparisons demonstrated a significant group effect as well. L1 Chinese speakers responded to high-consistency characters significantly faster than L2 Chinese learners did, by-subject analysis $p < .0001$, by-item analysis $p < .0001$. In addition, L1 Chinese speakers responded to low-consistency characters significantly faster than L2 Chinese learners did as well, by-subject analysis $p < .0001$, by-item analysis $p < .0001$. No other meaningful post-hoc comparisons were detected.

Lastly, post-hoc analyses on the three-way interaction suggested a significant group effect as well. L1 Chinese speakers had significantly shorter RT in the following conditions than L2 Chinese learners: “Large NS and high consistency”, by-subject analysis $p < .0001$, by-item analysis $p < .0001$; “large NS and low consistency”, by-subject analysis $p < .001$, by-item analysis $p < .0001$; “small NS and high consistency”, by-subject analysis $p < .0001$, by-item analysis $p < .0001$; “small NS and low consistency”, by-subject analysis $p < .0001$, by-item analysis $p < .0001$. No other meaningful comparisons were found.

Post-hoc Analyses on Accuracy Data (Tukey HSD). Firstly, post-hoc analyses were conducted to investigate the NS by consistency degree two-way interaction. No meaningful comparisons were detected.

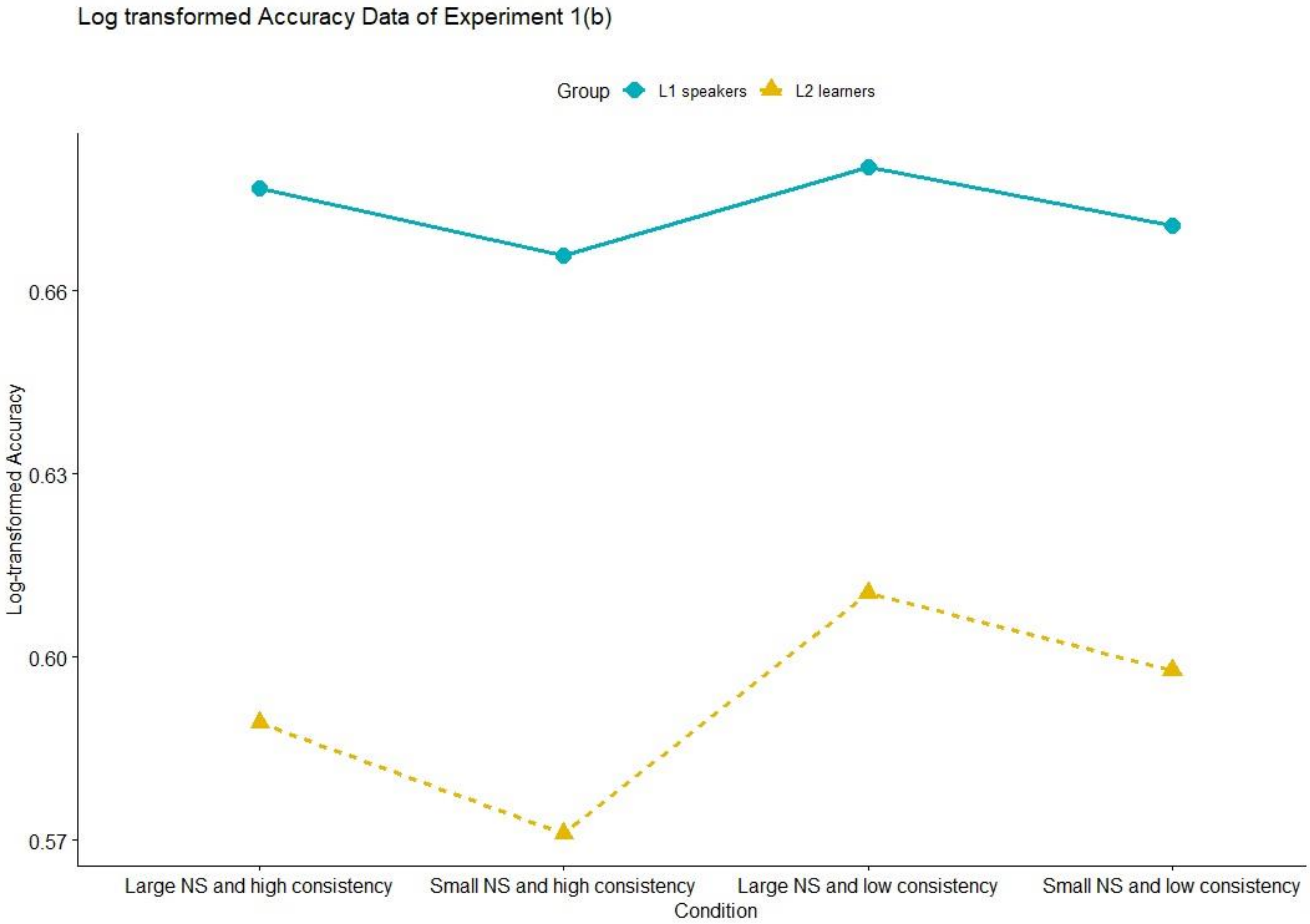
Secondly, post-hoc analyses were performed on the NS by L1/L2 group two-way interaction. A significant group effect was suggested. To be more specific, L1 Chinese speakers achieved significant accuracy than L2 Chinese learners when reading large-NS characters, by-subject analysis $p < .0001$, by-item analysis $p < .0001$. In addition, L1 Chinese speakers demonstrated significantly more accurate responses to small-NS characters than L2 Chinese learners did, by-subject analysis $p < .0001$, by-item analysis $p < .0001$. No other meaningful comparisons were found.

Thirdly, post-hoc analyses were carried out on the consistency degree by L1/L2 group two-way interaction. Again, the results indicated a significant group effect. L1 Chinese speakers made significantly more accurate responses when reading high-consistency characters than L2

Chinese learners did, by-subject analysis $p < .0001$, by-item analysis $p < .0001$. In addition, L1 Chinese speakers showed significantly higher accuracy rate when responding to low-consistency characters than L2 Chinese learners did, by-subject analysis $p < .0001$, by-item analysis $p < .0001$. No other meaningful comparisons were found.

Figure 2.8

Log-transformed Accuracy Data of Experiment 1(b)



Lastly, with regards to the NS x consistency degree x L1/L2 group three-way interaction, post-hoc comparisons suggested significant group effects as well. L1 Chinese speakers achieved significantly higher accuracy than L2 Chinese learners in the following conditions: "large NS and high consistency", by-subject analysis $p < .0001$, by-item analysis, $p = .005$; "large NS and low consistency", by-subject analysis $p < .001$, by-item analysis, $p = .048$; "small NS and high consistency", by-subject analysis $p < .0001$, by-item analysis, $p = .002$; "small NS and low consistency", by-subject analysis $p < .001$, by-item analysis, $p = .031$. Again, no other meaningful comparisons were detected.

Hierarchical Regression Analyses

Similar to Experiment 1(a), a series of hierarchical regression analyses were conducted on participants' log-transformed RT and accuracy data. Consistency value was first entered into the model, followed by the entry of NS. Lastly, the other orthographic features, including number of strokes, character's frequency, semantic radical's NS, phonetic radical's frequency, neighborhood frequency, and token consistency were entered into the modal (see Table 2.13).

For all participant's log-transformed RT, adding character frequency in the first step did not explain significant variances, $F(1, 58) = 2.766$, $p = .102$, $R^2 = .046$. After entering NS, type-, and token-consistency together into the model in the second step did not significantly improve the model ($\Delta R^2 = .034$, $p = .589$), and the model only predicted 7.91% of the variances in the dependent variable, $F(4, 55) = 1.181$, $p = .330$. After entering the other orthographic features into the model in the third step, these predictors could not significantly improve the model ($\Delta R^2 = .039$, $p = .692$), and the model could not significantly explain the variances in all participants' log-transformed RT, $F(8, 51) = .852$, $p = .562$, $R^2 = .118$.

For L1 speaker's log-transformed RT, adding character frequency significantly explained 11.34% of variances in the dependent variable, $F(1, 58) = 7.422$, $p = .009$, $R^2 = .113$. However, adding NS, type-, and token-consistency into the model in the second step did not make significant contribution to the model ($\Delta R^2 = .030$, $p = .608$), and the model could not explain significant proportions of variances, F (4, 55) = 2.297, $p = .071$, $R^2 = .143$, but character frequency remained a significant predictor ($p = .026$). Lastly, entering the other orthographic features did not significantly improve the model ($\Delta R^2 = .037$, $p = .687$), and the model in total explained 17.97% of the variance in L1 Chinese speaker's log-transformed RT, F (8, 51) = 1.396, $p = .221$. However, in the final model, character frequency was still a significant predictor ($p = .031$).

For L2 Chinese learner's log-transformed RT, adding character frequency in the first step did not explain significant variances, F (1, 58) = .686, $p = .411$, $R^2 = .012$. Adding NS, type-, and token-consistency into the model in the second step did not significantly improve the model ($\Delta R^2 = .044$, $p = .451$), and the model only explained 5.62% of the variances, F (4, 55) = 0.818, $p = .519$. Lastly, adding the other orthographic features into the model in the third step did not significantly improve the model ($\Delta R^2 = .039$, $p = .221$), and the model did not explain significant variances, F (8, 51) = 1.165, $p = .338$, $R^2 = .155$.

With regards to all participants' log-transformed accuracy data, adding character frequency in the first step explained significant variances in the dependent variable, F (1, 58) = 11.99, $p = .001$, $R^2 = .171$. Adding NS, type-, and token-consistency into the model in the second step significantly improved the model ($\Delta R^2 = .110$, $p = .047$), and the model explained significant proportions of variances, F (4, 55) = 5.371, $p = .001$, $R^2 = .281$. Frequency remained a significant predictor ($p = .006$). Lastly, adding the other orthographic features into the model in

Table 2.13

Hierarchical Regression Analyses of Experiment 1(b)

Predictors	**Log RT Data (All Participants)**				**Log RT Data (L1 Speakers)**				**Log RT Data (L2 Learners)**			
	R^2	ΔR^2	β	*Sig.*	R^2	ΔR^2	β	*Sig.*	R^2	ΔR^2	β	*Sig.*
Step 1	.046				.113**				.012			
1. Frequency			-.000	.102			-.000	.009**			-.000	.411
Step 2	.079	.034			.143	.030			.056	.044		
1. Frequency			.000	.225			.000	.026*			.000	.788
2. NS			-.035	.211			-.039	.186			-.029	.476
3. Consistency (type)			.065	.527			.022	.837			.209	.166
4. Consistency (token)			-.028	.750			-.033	.720			-.089	.484
Step 3	.118	.039			.180	.037			.155	.098		
1. Frequency			.000	.481			.000	.031*			.000	.430
2. NS			-.041	.229			-.026	.471			-.075	.116
3. Consistency (type)			.099	.369			.046	.694			.247	.113
4. Consistency (token)			-.072	.458			-.076	.452			-.120	.377
5. Number of strokes			.005	.395			.005	.460			.005	.592
6. Semantic radical NS			.000	.724			.000	.368			.000	.818
7. Phonetic radical frequency			.000	.438			.000	.314			.000	.951
8. Neighborhood frequency			.000	.736			.000	.270			.000	.284

* $p < .05$. ** $p < .01$. *** $p < .001$

Table 2.13 (continued)

Hierarchical Regression Analyses of Experiment 1(b)

	Log Accuracy Data (All Participants)				**Log Accuracy Data (L1 Speakers)**				**Log Accuracy Data (L2 Learners)**			
Predictors	R^2	ΔR^2	*β*	*Sig.*	R^2	ΔR^2	*β*	*Sig.*	R^2	ΔR^2	*β*	*Sig.*
Step 1	.171**				.029				.190***			
1. Frequency			.000	.001**			.000	.193			.000	.0005***
Step 2	.281**	.110*			.112	.083			.291***	.102		
1. Frequency			.000	.006**			.000	.252			.000	.005**
2. NS			-.014	.081			-.011	.092			-.021	.268
3. Consistency (type)			-.053	.081			-.034	.161			-.093	.188
4. Consistency (token)			.044	.090			-.002	.916			.144	.019*
Step 3	.342**	.062			.213	.100			.368**	.077		
1. Frequency			.000	.005**			.000	.427			.000	.001**
2. NS			-.019	.051			-.013	.096			-.032	.152
3. Consistency (type)			-.061	.055			-.048	.057			-.087	.234
4. Consistency (token)			.057	.041*			.017	.431			.142	.029*
5. Number of strokes			.000	.840			-.002	.076			.004	.284
6. Semantic radical NS			.000	.114			.000	.610			.000	.071
7. Phonetic radical frequency			.000	.136			.000	.097			.000	.459
8. Neighborhood frequency			.000	.137			.000	.183			.000	.319

* $p < .05$. ** $p < .01$. *** $p < .001$

the third step did not significantly improve the model (Δ R^2 = .062, p = .325), but the model could still explain significant proportions of the variances in participants' log-transformed accuracy, F (8, 51) = 3.320, p = .004, R^2 = .342. In addition, character frequency (p = .005) and token consistency (p = .041) were significant predictors. NS (p = .051) and type-consistency (p = .055) had a trend toward significant predictors.

Regarding L1 speakers' log-transformed accuracy, adding character frequency into the model in the first step could not explain significant variances, F (1, 58) = 1.732, p = .193, R^2 = .029. Adding NS, type-, and token-consistency into the model in the second step did not significantly improve the model (Δ R^2 = .083, p = .159), and the model explained 11.24% of the variances in the dependent variable, F (4, 55) = 1.742, p = .154. Lastly, adding the other orthographic features into the model in the third step only explain 10.01% additional variances (p = 0.184), and the entire model explained 21.25% variances of the dependent variable, F (8, 51) =1.720, p = .116.

About L2 Chinese learner's log-transformed accuracy, adding character frequency consistency in the first step made the model explain significant variances, F (1, 58) = 13.58, p < .001, R^2 = .031. In the second step, adding NS, type-, and token-consistency did not significantly improve the model (Δ R^2 = .102, p = .053), but the model explained significant variances in the dependent variable, F (4, 55) = 5.652, p < .001, R^2 = .291. In the third step, adding the other orthographic features did not significantly improved the model (Δ R^2 = .077, p = .201), and the entire model could explain 36.83% of the variances in L2 Chinese learners' log-transformed accuracy, F (8, 51) = 3.717, p = .002. In addition, character frequency and token consistency were identified as significantly predictors (p = .001 and p = .029 respectively).

Interim Discussion about Experiment 1(b)

Experiment 1(b) required participants to read irregular semantic-phonetic compounds, whose pronunciations were different from those of their phonetic radicals. In this setting, the main effect of NS was still significant and inhibitory, as large-NS characters yielded longer RTs. Again, the consistency effect was significant and facilitatory. It suggested that the NS and consistency effects were significant regardless of reading regular or irregular characters.

No other interactions were found in Experiment 1(b), suggesting that when reading irregular characters, the interactions between consistency and NS was not significant for either L1 speakers or L2 learners. Since the characters were irregular, their phonetic radicals were not reliable for phonological information's extractions. It was assumed that L2 learners would reply more on other factors to extract phonological information, such as consistency. This assumption was proved as the hierarchical regression analyses suggested that token consistency was a significant predictor of L2 learners' accuracy. Again, it may suggest that consistency was an important and useful indicator of phonology when regularity was not reliable for L2 learners.

However, the NS effect was not significant for the L2 learners. One possible explanation was that the NS was not large enough to reach a significant level. On average, the NS of the large-NS stimuli of Experiment 1(b) was 6.6 and 7.13 for the high- and low-consistency conditions respectively. They were smaller than the large-NS condition used in Li et al. (2011) and that in Change et al. (2016). In Li et al. (2011), the average NS of the large-NS condition was 13 (p. 37). In Chang et al. (2016), the number was 9.83 and 11.27 for the consistent and inconsistent conditions respectively (p. 7). As a result, they used larger NS than the present study, which could be an explanation for the result that there was a lack of significant consistency by NS interaction for either L1 speakers or L2 learners in the present study.

Chapter Summary

Chapter 2 explored the NS effect and its interaction with the consistency effect on L1 Chines speakers' and L2 Chinese leaners' recognition of single semantic-phonetic compound characters by conducting two experiments. Experiment 1(a) used regular semantic-phonetic compound characters whereas Experiment 1(b) used irregular ones.

In experiment 1(a), ANOVA tests on RT suggested: (1) significant main effect of group; (2) significant NS x consistency interaction; (3) significant consistency effect when reading small-NS characters; (4) significant consistency effect when L1 speakers read small-NS characters. ANOVA tests on accuracy revealed: (1) significant main effect of group, NS, and consistency; (2) significant NS x consistency interaction; (3) significant consistency x group interactions; (4) significant NS x consistency x group interaction; (5) consistency effect was significant when reading small-NS characters; (6) consistency effect was significant for L2 learners; (7) consistency effect was significant for L2 learners when they read small-NS characters. In addition, correlation analyses indicated: (1) NS was significantly but negatively correlated to L1 speaker's accuracy; (2) Token consistency was significantly but also negatively correlated to L1 speakers' RT; (3) NS and consistency were not significantly correlated to L2 learners' performance. Lastly, hierarchical regression analyses suggested: (1) consistency and NS explained significant variances in L1 speakers' accuracy; (2) consistency and NS did not explain significant variances in L2 Chiense learners' RT or accuracy.

In Experiment 1(b), ANOVA tests on RT suggested: (1) significant main effect of group; (2) significant main effect of NS; (3) no significant 2-way or 3-way interactions. ANOVA test on accuracy revealed: (1) significant main effect of group; (2) significant main effect of NS; (3) significant main effect of consistency degree. (4) no significant 2-way or 3-way interactions. Additionally, correlation analyses suggested: (1) NS was significantly and positively correlated to all participants' RT and to L1 speakers' RT; (2) token consistency degree was significantly and positively correlated to L2 learners' accuracy. Lastly, hierarchical regression analyses revealed: (1) consistency and NS did not explain significant variances in L1 speakers' and L2 leaners' RT or accuracy; (2) token consistency degree was a significant predictor of L2 leaners' accuracy.

Generally speaking, the NS effect was found inhibitory whereas the consistency was facilitatory. The findings were in agreement with previous studies. However, the NS effect was not consistently found. One possible explanation was that the NS of selected large-NS stimuli was not large enough to yield significant NS effects.

Chapter 3

Study 2: The Effect of Neighborhood Size and Consistency on Word Recognition by L2 Chinese Learners and L1 Chinese Speakers

Chapter 3 focused on how a semantic-phonetic compound character's NS and consistency affect the reading of a two-character Chinese word that contains this semantic-phonetic compound character and another character that is not a semantic-phonetic compound character (e.g., 跑(/*pao3*/, to run) + 步(/*bu4*/, steps) = 跑步(/*pao3 bu4*/, to run or jog, running or jogging)). Literature review covered two-character word reading. Methodology and results of experiment 2 were reported as well.

Literature Review

A two-character word refers to the Chinese words consisting of two morphemes or two characters (Huang et al., 2006; Leong & Cheng, 2003; Reichle & Yu, 2018;Tan & Perfetti, 1998; Tan & Perfetti, 1999; Tsai et al., 2006). Two-character words play an important part in the modern Chinese language.

Importance of Two-character Words

Tan and Perfetti (1998) indicated that in a 1,130,000-word corpus, two-character words had a proportion of 64% while single-character word only accounted for 34% (Leong & Cheng, 2003; Tan & Perfetti, 1999). Tsai et al. (2006) noticed that more than 70% of the contemporary Chinese vocabulary were two- and three-character words. In addition, other studies reported that in a one-million-word corpus, 65% of the words were two-character words (Huang & Liu, 1978; Liu et al., 1975 as cited in Leong & Cheng (2003)). Huang et al. (2006) informed that more than 80% of Chinese vocabulary consisted of two Chinese characters. Based on the Modern Chinese Frequency Dictionary (1986 edition), Reichle and Yu (2018) estimated that one-character words accounted for 20% of the total vocabulary, two-character words 70% and three- or more-character words 10%. Despite the different data reported in different studies, it is commonly recognized that two-character words take approximately 60% to 70% of the total Chinese words whereas one-character words have a smaller proportion.

Phonological Activation of Two-character Words' Reading

Because of their importance, two-character words have been studied extensively in research of Chinese word recognition and reading. For example, a line of research explored phonological activation in the process of reading two-character words. Tan and Perfetti (1997) learned that a two-character word's phonology is activated at the word level instead of character level (cited in Tan & Perfetti (1998)). In addition, Tan and Perfetti (1999) found that the phonological representations of a constituent character of a two-character word were activated in the process of reading regardless of the constituent character's position (i.e., 1st or 2nd constituent character). They further proposed a two-phase model for reading two-character Chinese words, which consisted of the first phase where common activation of the phonological information of a constituent character happened and a second phase where context decided the correct phonology that is needed.

Huang et al. (2006) found that the first constituent character of a two-character word had more contributions and a more important role in visual word recognition than its second counterpart. In summary, previous studies learned that two-character words reading required phonological activation at both whole-word level and constituent-character level.

The Consistency and Neighborhood Size Effects at Word Level

Other research concerning two-character words' reading focused on consistency and NS effects. However, such research studied the character-level consistency and word-level NS effects.

Character-level consistency is a completely different concept from the radical-level consistency (the latter one is the focus of this dissertation), and the two concepts have no connections with each other. Character-level consistency indicates if a constituent character of a two-character word are heteronyms in Chinese (多音字) or not (e.g., 便 can be read as *bian* or *pian*) (Leong & Cheng, 2003; Tan & Perfetti, 1999). Leong and Cheng (2003) found that an inconsistent constituent character (i.e., a heteronym) on the right position of a two-character word produced facilitation on naming and that an inconsistent character was favored in lexical decision tasks, due to the difference in definition of consistency. However, Leong and Cheng (2003)'s conclusion cannot inform how radical-level consistency plays a role in reading two-character Chinese words by both L1 users and L2 learners.

Word-level neighborhood size (NS) has a different definition compared to the radical-level NS and the two concepts are not related to each other as well. Word-level NS refers to the total number of two-character words that share the same constituent characters (Huang et al., 2006; Li et al., 2015; Tsai et al., 2006; Wang & Zhang, 2011). For example, for the target word 移民, the first component character (i.e., the character on the left: 移) constitutes the following words in the HSK vocabulary list: 移动 and 移民, while the second component character (i.e., the character on the right: 民) can form the following HSK words: 渔民, 公民, 居民, 农民, and 移民. As a result, the target word has a word-level NS of 6, including the target word itself.

Tsai and colleagues (2006) found that neighboring two-character words that share the first constituent character are activated at the same time when a target word was presented, and that a two-character word with large NS produced facilitations in lexical decision by L1 Chinese users. Huang et al. (2006) suggested a similar facilitative effect of the first-character neighborhood size, and they further concluded that the first constituent character in a two-character word had a more important role than the second constituent character and that high-frequency neighboring words sharing the first constituent character with the target words exerted inhibitory influences on lexical decision among L1 Chinese users. However, these conclusions are not able to indicate how character-level NS (i.e., semantic-phonetic compounds sharing the same phonetic radicals) influences visual word recognition of two-character Chinese words by L1 Chinese speakers and L2 Chinese learners.

Radical-level Features and Two-character Words' Reading

To the author's knowledge, only two studies explored the phonetic-radical-related features (i.e., radical-level regularity, consistency, and NS) in reading two-character Chinese words. Li (2002) used a 2 (grades: 2nd and 5th graders) x 2 (one- and two-character words) x 3 (high-, medium-, low-regularity) mixed factorial design to investigate the regularity effect among L1 Chinese children, but this study did not match or investigate stimuli's consistency and NS.

To the author's knowledge, Nguyen (2016) is the first and only one study that explored the neighborhood size effect and the consistency effect on L1 Chinese speakers' reading of both single Chinese characters and two-character Chinese words. However, Nguyen (2016) did not match stimuli's regularity, and for this reason, the present dissertation would not use Nguyen (2016)'s design. Instead, the experimental design of this dissertation has taken the regularity effect into consideration. To avoid any confounding regularity effect, the material of this study only included two-character words containing irregular semantic-phonetic compound characters.

In summary, despite the fact that reading two-character Chinese words has been largely investigated and that the effects of character-level consistency and neighborhood size (i.e., the major factors of interest of this dissertation) have been extensively studied in single-character word reading (as reviewed in Chapter 2), it remained unknown as to how character-level consistency and neighborhood size play their roles in L1 Chinese speakers' and L2 Chinese learners' visual word recognition of two-character Chinese words.

Research Gaps

Previous studies have explored how character-level phonological features affect the phonological activations and the reading process of two-character Chinese words. However, how radical-level features (i.e., consistency and NS) affect two-character Chinese words' reading has not been studied among L1 Chinese speakers or L2 Chinese learners. As a result, Study 2 investigated this problem.

Research Questions

Building upon the general research questions stated in Chapter 1, the following specific research questions were asked to guide Study 2:

Research Question 1: *What is the NS effect and its interaction with the consistency effect on L2 Chinese learners' recognition of two-character Chinese words that contain semantic-phonetic compound characters*?

Research Question 2: *What are the differences between L1 speakers and L2 learners in reading two-character Chinese words that contain semantic-phonetic compound characters*?

To answer these research questions, participants were invited to finish Experiment 2 consisting of a lexical decision task. Details were provided below.

Methodology

Participants

The same group of participants who participated in Experiment 1(a) and Experiment 1(b) finished Experiment 2.

Design

The design learned from Tan and Perfetti (1999)'s design of their Experiment 2, in which they used a lexical decision task and employed a 2 (heteronym or not) x 2 (target character's position: left/right) two-way factorial design to examine the influence of single constituent character's phonological features (i.e., being heteronym or not) on recognizing two-character Chinese words. Tan and Perfetti (1999) found that participants took longer time responding to words containing heteronym characters and that constituent character's phonological activation is position independent. It means that locating on the left or right side does not affect access to target characters' phonology retrievals. Tan and Perfetti (1999) argued that readers were sensitive to character-level phonology while reading two-character words.

Tan and Perfetti (1999)'s study provided strong support and served as an example regarding how single component character's features affect two-character words' reading and how such effect can be tested. As a result, this dissertation's Study 2 learned from their design in this way: The heteronym factor (i.e., target character being a heteronym or not) in Tan and Perfetti (1999) was analogous to the consistency (Consistent and Inconsistent) and NS (Large and Small) factors of this dissertation because they represent phonological features of single component characters of two-character words. Therefore, this dissertation used a 2 (NS) x 2 (consistency) x 2 (groups) factorial design. NS and consistency degree were the within-subject factors whereas groups served as the between-subject factor. NS had two level: large NS vs. small NS. Consistency had two levels as well: high consistency vs. low consistency. Participants finished a lexical decision task.

To the best of the author's knowledge, no prior studies have used this design to explore single semantic-phonetic compound character's NS and consistency effects on reading two-character words. Thus, adopting this design is a unique characteristic of this dissertation.

Materials

A total of 64 two-character words were selected as the real words (e.g., 跑步). All real words consisted of one semantic-phonetic compound character (i.e., target character, e.g., 跑) and one non-semantic-phonetic compound character (non-target character, e.g., 步). Another 64 pseudo-words (e.g., 抚示) were created by combining one real semantic-phonetic compound character (e.g., 抚) and one real non-semantic-phonetic compound character (e.g., 示).

For the real words, each between-subject condition (i.e., large NS and high consistency, large NS and low consistency, small NS and high consistency, and small NS and low consistency) contained 16 words, among which 8 words had the semantic-phonetic compound character on the left (e.g., 词典) and another 8 words had the semantic-phonetic compound characters on the right (e.g., 美妙). The following table demonstrates the inclusion criteria for the materials of Experiment 2:

Table 3.1

Inclusion Criteria for the Stimuli of Experiment 2

	Number	Inclusion Criteria
	1	All real words must be selected from the HSK vocabulary list, which was officially published by *Hanban* in *International Curriculum for Chinese Language Education* (Confucius Institute Headquarters/Hanban, 2014).
	2	All real words must contain one semantic-phonetic compound character and one non-semantic-phonetic compound character.
	3	All semantic-phonetic compound characters must have a phonetic radical and a semantic radical.
	4	All semantic-phonetic compound characters were left-right structure (e.g., 泳) or left-right-like structures (e.g., 趟). Top-bottom (e.g., 究) structure and other types of structures (e.g., 辨, 问, 国) were not included.
	5	For all the semantic-phonetic compound characters, their semantic radicals were on the left, and their phonetic radicals were on the right.

Real words	6	No phonetic radicals were bound radicals. All real character’s phonetic radicals must be able to stand alone as characters and have their own pronunciations.
	7	All phonetic radicals must be a character that appeared in the HSK vocabulary list. If not, the semantic-phonetic compound characters that contain such phonetic radicals were not selected. For example, the phonetic radical (e.g., 艮) did not appear as a character in the HSK vocabulary list, so its semantic-phonetic compound character 根 was not selected as a stimulus.
	8	All semantic-phonetic compound characters must not be heteronyms in Chinese (多音字) that have more than one pronunciation (e.g., 便 can be pronounced as /*bian4*/ and /*pian2*/ and was not selected as a stimulus). One exception is 哄 whose pronunciations could be /hong1/, /hong3/, or /hong4/. Since these pronunciations are different from each other only in tones, but not in syllables, this character was still included in materials.
	9	All semantic-phonetic compound characters were irregular semantic-phonetic compounds.
	10	All non-semantic-phonetic compound characters (i.e., the non-target characters) must be selected from the HSK vocabulary list.
Pseudo-words	11	All pseudo-words must consist of a real semantic-phonetic compound character and a real non-semantic-phonetic compound character.
	12	The semantic-phonetic compound characters must be selected from the HSK vocabulary list and so must the non-semantic-phonetic compound characters.
	13	The semantic compound characters must also meet the inclusion criteria #3, #4, #5, #6, #7, #8, and #9 in this table.
	14	All pseudo-words were made sure that they do not exist in modern Chinese by using http://corpus.zhonghuayuwen.org/CnCindex.aspx . [22] This website allows researchers to enter a word, and it shows its frequency in a Chinese corpus. If the corpus shows no results about the word, it was considered that the word does not exist in modern Chinese.

All stimuli of Experiment 2 were listed in Appendix C. Features of real- and pseudo-words were summarized in Table 3.2.

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[22] Using information from this website entails citations of the following three publications per the developers’ request: Xiao (2010), Jin et al. (2005), and Xiao (2016). Detailed information of the three publications can be found in the “References” section.

Table 3.2

Means (Standard Deviations) and Ranges of Stimuli of Experiment 2

	Real Words (N = 64)					Pseudo-words (N =64)	Comparisons between real- and pseudo-words
	Large NS		Small NS				
	High Consistency (N =16)	Low Consistency (N =16)	High Consistency (N =16)	Low Consistency (N =16)	*p*		
Semantic-phonetic compound's NS	6.25 (1.18) 5 - 9	6.69 (1.66) 5 - 10	3.06 (0.85) 2 - 4	3.31 (0.48) 3 - 4	between large- and small NS: *t* (44.68) = 11.64, *p* < .001	4.66 (1.90) 2 - 10	*t* (125.72) = -.50, *p* = .619
Semantic-phonetic compound's type consistency	0.54 (0.10) 0.43 - 0.83	0.27 (0.06) 0.20 - 0.33	0.57 (0.10) 0.50 - 0.75	0.31 (0.04) 0.25 - 0.33	between high- and low consistency: *t* (46.75) = 13.80, *p* < .001	0.42 (0.16) 0.17 - 0.83	*t* (125.77) = .09, *p* = .930
Semantic-phonetic compound's token consistency	0.26 (0.12) 0.05 - 0.44	0.13 (0.13) 0.01 - 0.50	0.34 (0.19) 0.10 - 0.73	0.31 (0.28) 0.01 - 0.81	*F* (3, 60) = 3.80, *p* = .015	0.27 (0.21) 0.01 - 0.85	*t* (125.89) = .16, *p* = .875
Semantic-phonetic compound's frequency (per million characters)	221.70 (398.35) 8.4 - 1651.7	136.86 (189.46) 13.4 - 655.1	132.59 (171.17) 20.65 - 732.7	485.70 (782.61) 19.95- 2152	*F* (3, 60) = 2.11, *p* = .108	137.03 (238.35) 10.65 - 1651.7	*t* (93.48) = -1.63, *p* = .107
Semantic-phonetic compound's number of strokes	9.56 (2.45) 6 -14	10.13 (2.22) 6 -14	9.94 (1.98) 7 - 13	10.06 (2.41) 6 - 15	*F* (3, 60) = .20, *p* = .898	9.61 (2.60) 4 - 16	*t* (123.13) = -.73, *p* = .467

Frequency of the semantic-phonetic compound's phonetic radicals	792.98 (1171.36) 22.5 - 3813.05	532.61 (709.76) 8.8 - 2910.15	356.20 (300.18) 47.05 - 1055.2	647.33 (983.13) 14.85 - 3649.9	*F* (3, 60) = .75, *p* = .527	564.87 (788.18) 10.2 - 3813.05	*t* (125.26) = -.12, *p* = .902
Semantic-phonetic compound's semantic radical NS	50.50 (36.91) 5 - 118	45.50 (39.16) 3 - 139	58.25 (41.73) 15 - 139	57.81 (50.10) 10 - 139	*F* (3, 60) = .34, *p* = .798	56.53 (40.99) 2 - 139	*t* (125.97) = .48, *p* = .631
Semantic-phonetic compound's semantic radical familiarity	3.37 (0.41) 2.54 - 3.76	3.38 (0.37) 2.20 - 3.76	3.41 (0.17) 3.16 - 3.76	3.26 (0.38) 2.46 - 3.76	*F* (3, 60) = .61, *p* = .613	3.42 (0.37) 2.20 - 3.76	*t* (125.26) = .99, *p* = .325
Semantic-phonetic compound's neighborhood frequency sum	1455.76 (1614.03) 220.95 - 6060.3	1782.08 (1768.19) 148.3 - 7401.1	525.33 (349.63) 109.75 - 1170.65	1288.86 (1263.19) 115.3 - 4041.75	*F* (3, 60) = 2.44, *p* = .073	1105.79 (1470.94) 69.2 - 7401.1	*t* (125.78) = -.62, *p* = .538
Semantic-phonetic compound's number of homophones (without considering tones)	8.75 (2.79) 5 - 12	9.75 (3.80) 5 - 21	12.88 (12.03) 4 - 43	17.25 (12.24) 1 - 43	*F* (3, 60) = 2.95, *p* = .040[23]	10.06 (6.50) 2 - 34	*t* (112.72) = -1.48, *p* = .143
Semantic-phonetic compound's number of homophones (considering tones)	4.13 (1.59) 2 - 7	4.00 (1.93) 2 - 8	5.75 (4.17) 2 - 16	6.44 (4.80) 1 - 17	*F* (3, 60) = 2.00, *p* = .124	4.20 (2.78) 1 - 17	*t* (119.87) = -1.57, *p* = .120
Semantic-phonetic compound's number of meanings	2.19 (1.05) 1 - 5	3.00 (2.53) 1 - 8	2.25 (1.39) 1 - 5	3.00 (1.21) 2 - 6	*F* (3, 60) = 1.20, *p* = .318	2.41 (1.28) 1 - 8	*t* (118.46) = -.78, *p* = .440

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[23] Tukey HSD analyses demonstrated that this feature was significantly different between "small NS and low consistency" and "large NS and high consistency" conditions (*p* = .043).

Semantic-phonetic compound's number of associated syllables	2.50 (0.63) 2 - 4	3.94 (1.06) 2 - 6	2.13 (0.34) 2 - 3	2.69 (0.79) 2 - 4	F (3, 60) = 17.36, $p < .001$[24]	2.67 (0.80) 2 - 5	t (119.79) = -.88, p = .383
Semantic-phonetic compound's number of phonological neighbors	114.13 (41.55) 47 - 177	120.13 (67.72) 20 - 274	137.50 (69.67) 35 - 271	144.00 (61.26) 59 - 265	F (3, 60) = .85, p = .470	107.20 (50.29) 2 - 271	t (121.68) = -2.20, p = .030
Percentage of semantic-phonetic compounds that have the highest frequency in a neighborhood	0/16 =0.00%	1/16 = 6.25%	2/16 =12.5%	4/16 =25%		9/64 = 14.06%	
Semantic-phonetic compound's position	Left (N = 8) Right (N =8)	Left (N = 8) Right (N =8)	Left (N = 8) Right (N =8)	Left (N = 8) Right (N =8)	NA	Left (N =32) Right (N = 32)	
Non-target character's number of strokes	7.69 (3.96) 2 - 17	6.69 (2.65) 2 - 12	7.06 (2.57) 4 - 12	5.56 (1.75) 3 - 8	F (3, 60) = 1.58, p = .205	6.28 (2.05) 2 - 12	t (113.74) = -1.06, p = .292
Non-target character's frequency	1039.71 (1533.35) 41.25 - 6081.4	956.13 (964.57) 37 - 3103	1158.84 (1986.08) 54.9 - 8324.05	1158.13 (734.7) 33.05 - 2662.95	F (3, 60) = .08, p = .970	1134.18 (998.61) 173.5 - 7061.05	t (115.53) = .27, p = .791

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[24] Tukey HSD analyses demonstrated that this feature was significantly different between "large NS and low consistency" and "large NS and high consistency" ($p < .001$), between "small NS and high consistency" and "large NS and low consistency" ($p < .001$), and between "small NS and low consistency" and "large NS and low consistency" ($p < .001$).

Non-target character's number of meanings	3.94 (1.98) 1 - 8	4.75 (2.27) 1 - 10	4.75 (2.89) 1 - 11	5.56 (2.39) 1 - 9	*F* (3, 60) = 1.22, *p* = .311	5.19 (2.44) 1 - 11	*t* (125.99) = 1.02, *p* = .310
Non-target character's number of homophones (without considering tones)	12.88 (8.41) 3 - 30	10.63 (6.48) 2 - 26	15.44 (10.41) 3 - 39	7.88 (4.56) 2 - 14	*F* (3, 60) = 2.75, *p* = .051	12.75 (8.74) 1 - 39	*t* (125.26) = .70, *p* = .483
Non-target character's number of homophones (considering tones)	5.44 (4.32) 1 - 14	3.19 (2.56) 1 - 11	5.38 (4.47) 1 - 19	3.81 (3.47) 1 - 11	*F* (3, 60) = 1.43, *p* = .244	5.06 (4.25) 1 - 19	*t* (124.63) = .85, *p* = .395
Word-level NS	8.19 (5.64) 2 - 22	7.75 (7.13) 1 - 30	8.69 (5.19) 2 - 19	9.50 (6.03) 2 - 20	*F* (3, 60) = .25, *p* = .863	9.81 (4.27) 3 - 22	*t* (114.51) = 1.40, *p* = .164
Word-level NS of the first component character	3.75 (4.01) 1 - 16	4.38 (4.05) 1 - 14	5.19 (5.11) 1 - 18	4.94 (4.42) 1 - 17	*F* (3, 60) = .34, *p* = .800	4.78 (4.41) 0 - 20	*t* (125.98) = .28, *p* = .778
Word-level NS of the second component character	5.44 (4.57) 1 - 21	4.38 (5.29) 1 - 21	4.56 (4.32) 1 - 17	5.56 (4.86) 1 - 18	*F* (3, 60) = .26, *p* = .858	5.03 (4.67) 0 - 21	*t* (126) = .06, *p* = .955
Word frequency	149.94 (87.74) 15 - 354	183.06 (107.81) 67 - 383	156.44 (105.83) 8 - 481	724.06 (1398.06) 25 - 5572	*F* (3, 60) = 2.54, *p* = .065	NA	NA
Word's total number of strokes	17.25 (4.06) 10 - 23	16.81 (2.59) 13 - 22	17.00 (2.03) 14 - 22	15.63 (1.75) 13 - 20	*F* (3, 60) = 1.10, *p* = .358	15.89 (3.51) 8 - 22	*t* (119.43) = −1.40, *p* = .164
Absolute value of stroke number differences between the two characters	4.00 (3.69) 0 - 12	4.56 (2.76) 2 - 12	3.69 (3.32) 0 - 9	4.88 (3.30) 0 - 12	*F* (3, 60) = .43, *p* = .734	3.73 (2.59) 0 - 11	*t* (120.18) = −1.06, *p* = .294

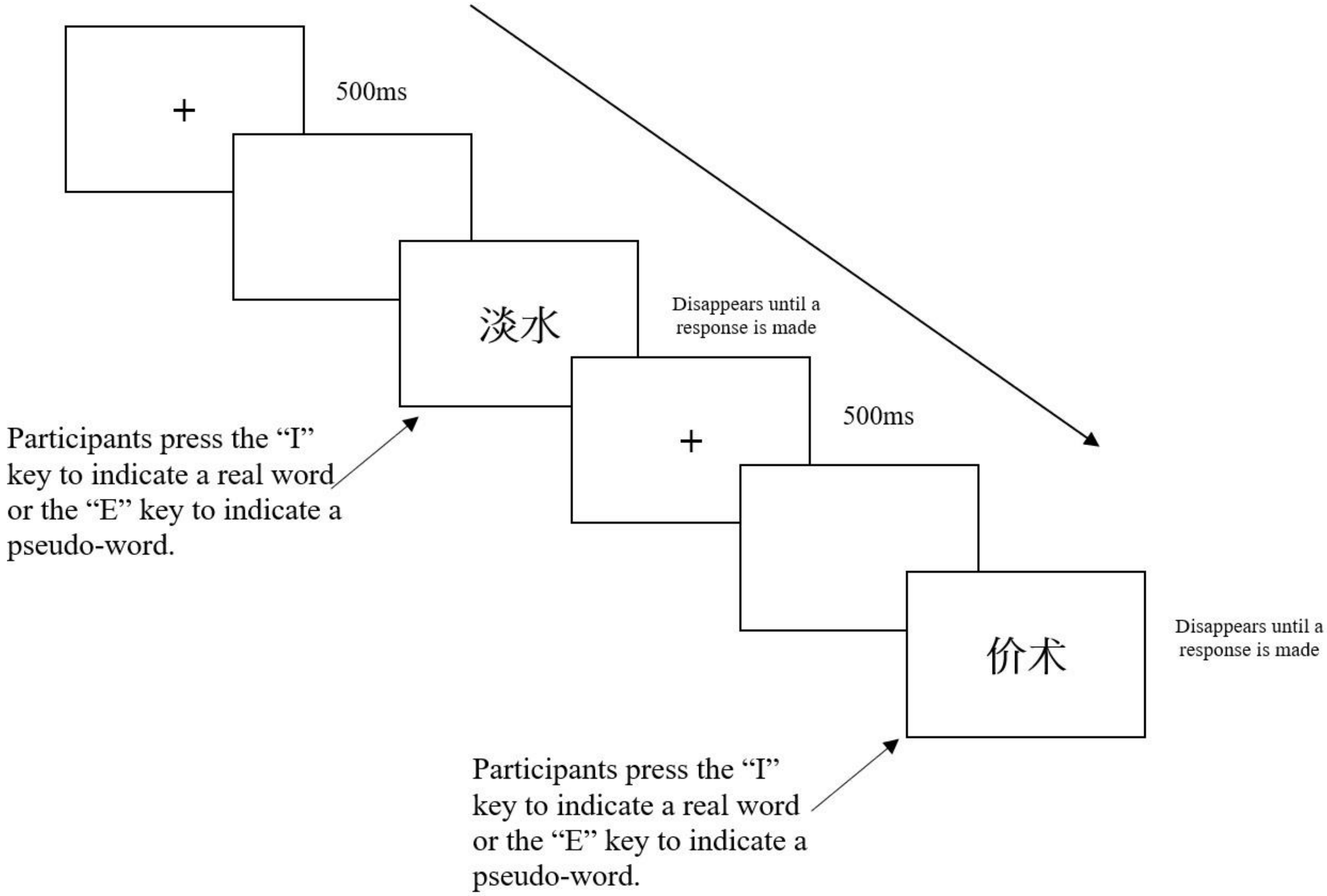
The large-NS condition and the small-NS condition were significantly different in terms of semantic-phonetic compound characters' NS ($p < .001$). The high- and low-consistency conditions were significantly different in terms of semantic-phonetic compound character's type consistency values. Other factors were balanced across the four conditions.

Procedure

The procedure of Experiment 2 was the same as that of Experiment 1(a) and 1(b). Participants finished a lexical decision task. Details regarding the experimental procedures were demonstrated in Figure 3.1.

Figure 3.1

Procedures of Experiment 2



Results of Experiment 2

Experiment 2 adopted a 2 (Neighborhood size) x 2 (consistency degree) x 2 (Groups) repeated measures mixed factorial design. Participants' RTs and accuracy data were the dependent variables (DVs). ANOVAs, correlation analyses, and hierarchical regression analyses were conducted on trimmed and natural logarithmic values of RT and accuracy data. Data analyses were conducted using *RStudio*.

All items yielded an accuracy rate higher than 70%. The accuracy rate for all items ranged from 72.73% to 100%. Thus, all items were included in data analyses.

Data Trimming

Before data analysis, data trimming was performed. The data trimming procedures of Experiment 2 were the same as those of Experiment 1(a) and 1(b). Firstly, RT data points that were associated with incorrect responses were excluded from data analysis. Secondly, RT data points there were shorter than 300 ms or those longer than 1,500ms were not included in data analysis. As a result, 51 data points were excluded from L1 Chinese speakers' data, and 149 data points were deleted from L2 Chinese learners' data. In total, 200 out of 2,688 data points were deleted (i.e., 7.44% of the total dataset). Table 3.3 shows descriptive statistics of Experiment 2 after data trimming.

Table 3.3

Descriptive Statistics of Experiment 2's Results (Means and Standard Deviations in Parentheses))

RT (ms)	Large NS		Small NS	
	High Consistency	Low Consistency	High Consistency	Low Consistency
L1 speakers	677.236 (86.168)	671.230 (68.510)	703.180 (86.807)	678.294 (71.178)

L2 learners	849.149 (156.649)	843.804 (187.930)	844.888 (154.405)	817.236 (109.682)
Accuracy (%)	Large NS		Small NS	
	High Consistency	Low Consistency	High Consistency	Low Consistency
L1 speakers	98.060 (3.774)	97.414 (4.264)	96.552 (4.601)	98.060 (3.384)
L2 learners	90.625 (7.251)	87.054 (11.357)	79.464 (18.086)	87.946 (13.307)

Correlation Analyses

To evaluate the relation between participants logarithmic RT, logarithmic accuracy, and the character-level as well as word-level features, correlation analyses were performed. In addition to characters' features addressed in Experiment 1(a) and 1(b), this time the correlation analyses also involved word-level features, including word NS (i.e., number of words sharing the same first- or second-component character with the target stimulus), word frequency, and number of strokes in a word. In addition, orthographic features of the non-target character of a stimulus, including its number of stroke and frequency, were included in the analysis. Results were demonstrated in Table 3.4.

According to the result, targeted phonetic compound character's NS were not significantly correlated to participants' RT or accuracy. Their type-consistency values were not significantly correlated to participants' RT or accuracy as well. However, token-consistency values were found significantly correlated to L2 Chinese learners' RT (r = -.31, p < .05).

Targeted phonetic compound character's frequency was significantly correlated to all participants' RT (r = -.27, p < .05) and L2 Chinese learners' RT (r = -.34, p < .01) but was not significantly correlated to L1 Chinese speakers RT or accuracy. It was not significantly correlated to L2 Chinese learners' accuracy as well. A non-targeted character's number of

Table 3.4

Bivariate Correlation Matrix of Experiment 2

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. RT (all participants)	1.00											
2. RT (L1 speakers)	.94***	1.00										
3. RT (L2 learners)	.68***	.42***	1.00									
4. Accuracy (all participants)	-.68***	-.69***	-.43***	1.00								
5. Accuracy (L1 speakers)	-.52***	-.48***	-.36**	.82***	1.00							
6. Accuracy (L2 learners)	-.66***	-.7***	-.39**	.93***	.55***	1.00						
7. NS	.00	-.03	.00	.07	-.01	.11	1.00					
8. Consistency (type)	.13	.13	.12	-.05	-.01	-.06	-.18	1.00				
9. Consistency (token)	-.24	-.18	-.31*	.13	.13	.10	-.27*	.21	1.00			
10. Frequency (target character)	-.27*	-.19	-.34**	.18	.13	.17	-.09	-.14	.59***	1.00		
11. Number of stroke (non-target)	.19	.15	.30*	-.23	-.12	-.25*	.11	.16	-.01	-.09	1.00	
12. Number of stroke (Word)	.13	.07	.29*	-.15	-.14	-.12	.11	.13	-.13	-.30*	.69***	1.00

* $p < .05$. ** $p < .01$. *** $p < .001$

strokes was found significantly correlated to L2 Chinese speaker's RT ($r = .30, p < .05$). It was also significantly correlated to L2 Chinese speakers' accuracy ($r = -.25, p < .05$). This finding seemed to indicate that as a non-targeted character had a larger number of strokes, L2 Chinese speakers' performance in the LD task was attenuated (i.e., longer RT and lower accuracy). The finding was surprising to the researcher because number of strokes of the targeted phonetic compound character was not found significantly correlated to participants' RT or accuracy. Lastly, the total number of strokes of a two-character word was significantly correlated L2 Chinese learners' RT ($r = .29, p < .05$).

ANOVA Results

Experiment 2 used a 2 (NS) x 2 (consistency degree) x 2 (L1/L2 group) three-way ANOVA test on the logarithmic RT data and logarithmic accuracy data. Both by-subject analyses (F_1) and by-item analyses (F_2) were conducted, and results were reported accordingly.

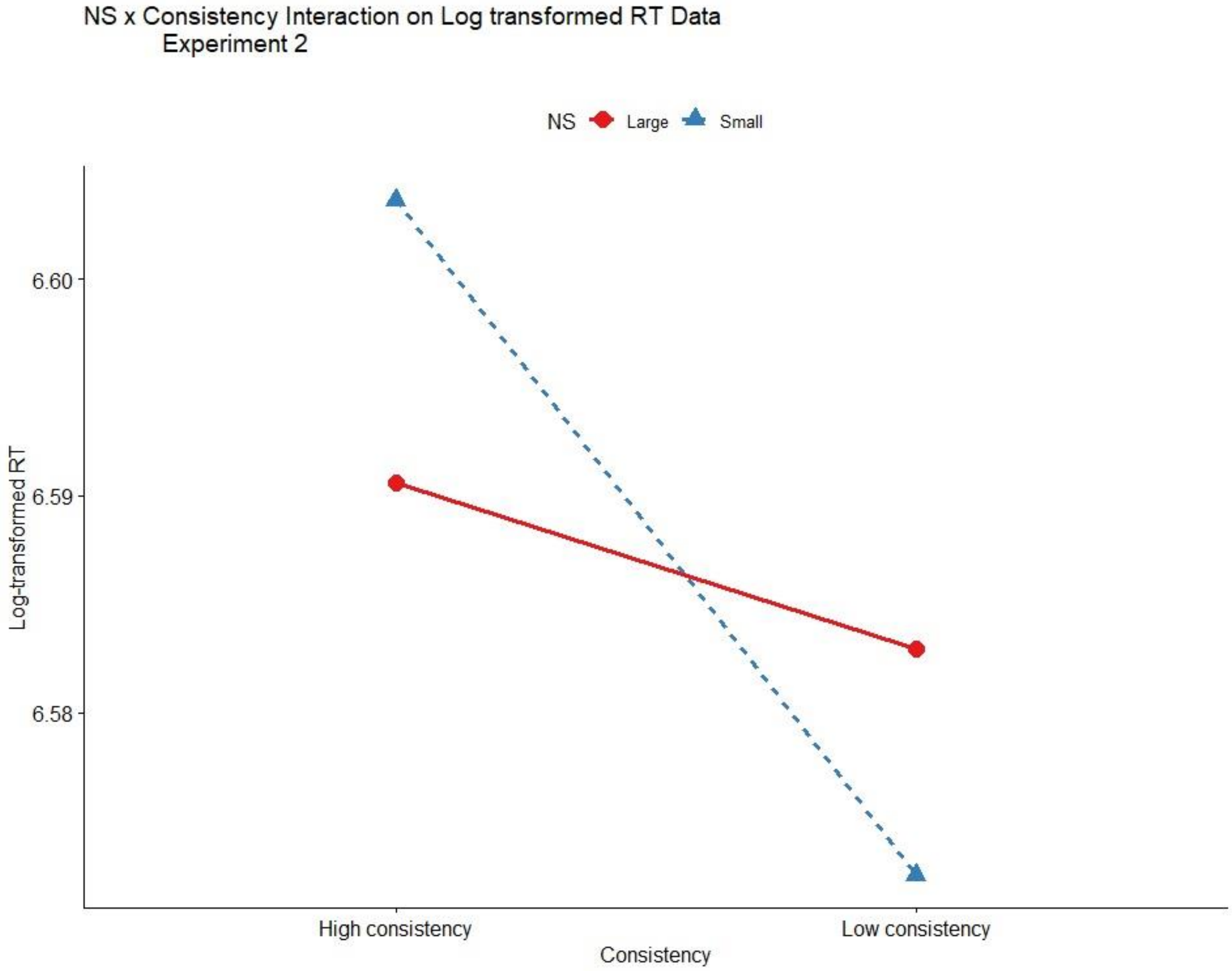
Main Effects. By-subject and by-item analyses suggested a significant main effect of L1/L2 group, indicating a significant difference in logarithmic RT between the two groups, F_1 (1, 37) = 62.027, $p < .001$, $\eta^2_p = .44$; F_2 (1, 60) = 284.110, $p < .001$, $\eta^2_p = .58$. The main effect of NS was not significant, F_1 (1, 37) = .743, $p = .394$, $\eta^2_p < .0001$; F_2 (1, 60) = .003, $p = .960$, $\eta^2_p < .0001$. Also, the main effect of consistency degree was not significant as well, F_1 (1, 37) = 4.020, $p = .052$, $\eta^2_p = .007$; F_2 (1, 60) = 1.947, $p = .168$, $\eta^2_p = .02$.

By-subject and by-item analyses on log-transformed accuracy data suggested a significant main effect of group, F_1 (1, 41) = 30.74, $p < .001$, $\eta^2_p = .29$; F_2 (1, 60) = 119.218, $p < .0001$, $\eta^2_p = .41$. Also, the main effect of NS was significant, F_1 (1, 41) = 7.38, $p = .010$, $\eta^2_p = .02$; but not significant based on by-item analysis, F_2 (1, 60) = 1.531, $p = .221$, $\eta^2_p = .02$. Lastly, the main effect of consistency degree was not significant, F_1 (1, 41) = 3.81, $p = .058$, η^2_p

= .005; F_2 (1, 60) = .536, p = .467, η^2_p =.006.

Figure 3.2

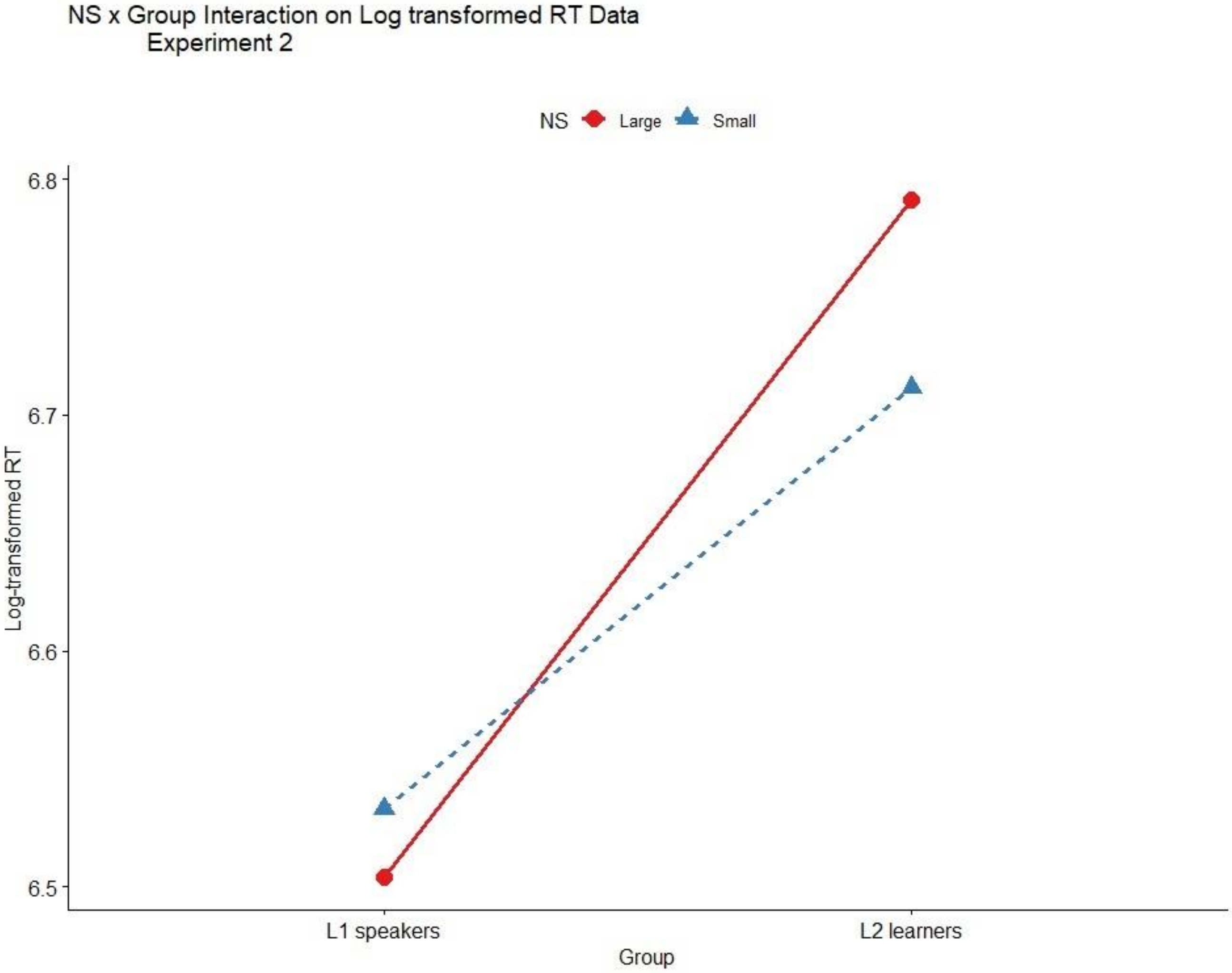
NS by Consistency Interaction (RT Data, Experiment 2)



Two-way Interactions. About the logarithmic RT data, ANOVA results suggested a significant NS by consistency degree interaction, F_1 (1, 37) = 4.863, p = .034, η^2_p = .003; but not significant according to the by-item analysis, F_2 (1, 60) = .931, p = .338, η^2_p = .01 (see Figure 3.2). In addition, results indicated a significant NS by L1/L2 groups interaction, F_1 (1, 37) = 9.264, p = .004, η^2_p = .04; F_2 (1, 60) = 4.306, p = .042, η^2_p = .02 (see Figure 3.3). The consistency degree by L1/L2 groups interaction was not significant, F_1 (1, 37) = .153, p = .698, η^2_p = .002; F_2 (1, 60) = .251, p = .618, η^2_p = .001.

Figure 3.3

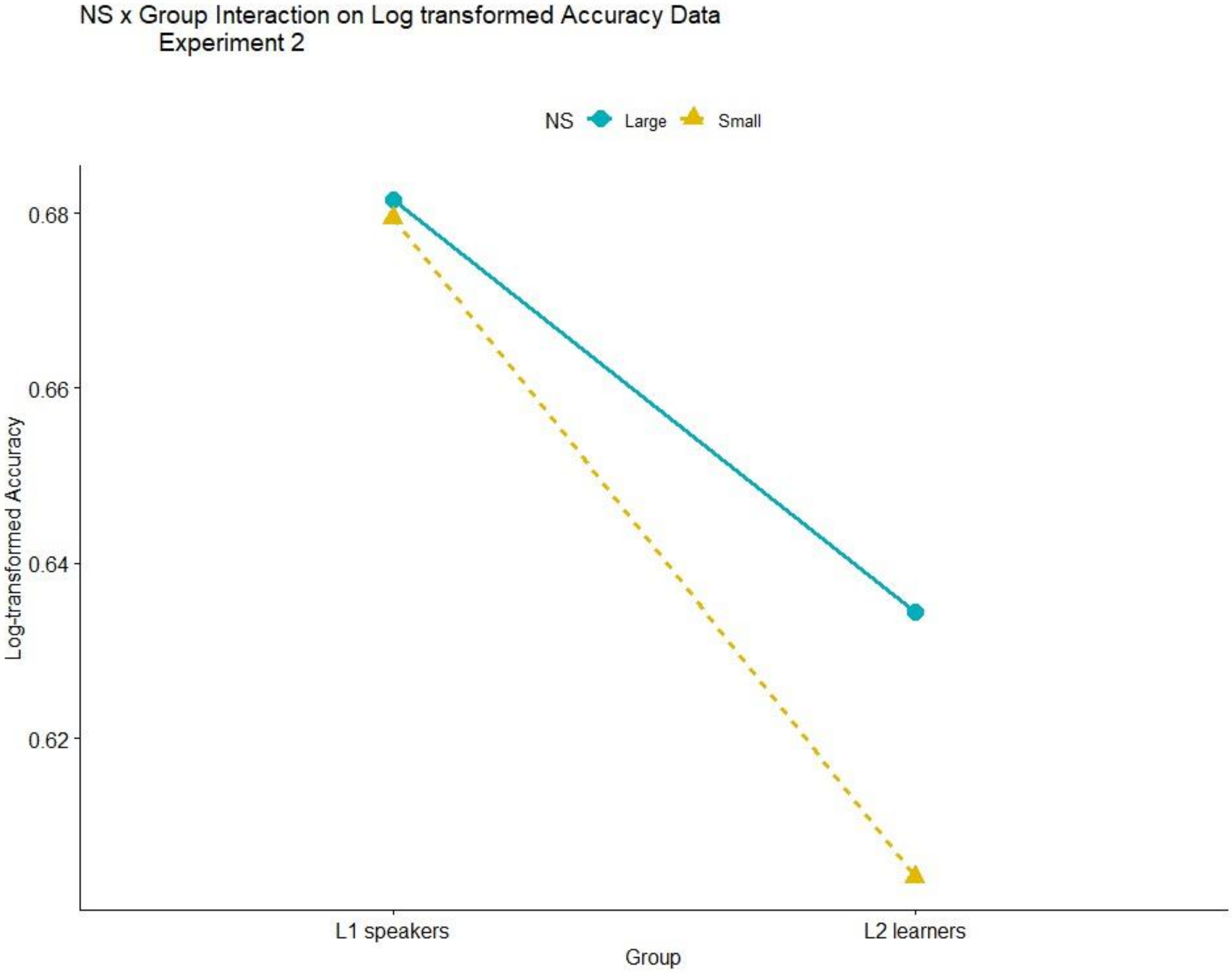
NS by Group Interaction (RT Data, Experiment 2)



Analyses on logarithmic accuracy data showed that the L1/L2 group by NS interaction was significant, F_1 (1, 41) = 5.81, p = .021, η^2_p = .03; but not significant based on by-item analysis, F_2 (1, 60) = 1.966, p = .166, η^2_p = .01 (see Figure 3.4). In addition, the NS by consistency degree interaction was significant as well, F_1 (1, 41) = 10.28, p = .003, η^2_p = .03; but not significant according to by-item analysis, F_2 (1, 60) = 3.030, p = .087, η^2_p = .03 (see Figure 3.5). Lastly, the L1/L2 group by consistency degree interaction was not significant, F_1 (1, 41) = 2.25, p = .141, η^2_p = .005; F_2 (1, 60) = .489, p = .487, η^2_p = .003.

Figure 3.4

NS by Group Interaction (Accuracy Data, Experiment 2)



Three-way Interaction. Analyses on log-transformed RT data suggested a non-significant three-way interaction, F_1 (1, 37) = 1.346, $p = .253$, $\eta^2_p = .0007$; F_2 (1, 60) = .245, $p = .623$, $\eta^2_p = .001$. However, analyses on log-transformed accuracy data suggested a significant interaction between NS, consistency degree, and L1/L2 group, F_1 (1, 41) = 5.81, $p = .020$, $\eta^2_p = .03$; but this three-way interaction was not significant referring to by-item analysis, F_2 (1, 60) = 2.735, $p = .103$, $\eta^2_p = .02$.

Post-hoc Analyses on RT Data (Tukey HSD). Post-hoc comparisons using Tukey HSD on participants' log-transformed RT data suggested the following meaningful comparisons. Firstly, post-hoc analyses on the NS by consistency degree interaction showed no meaningful comparisons.

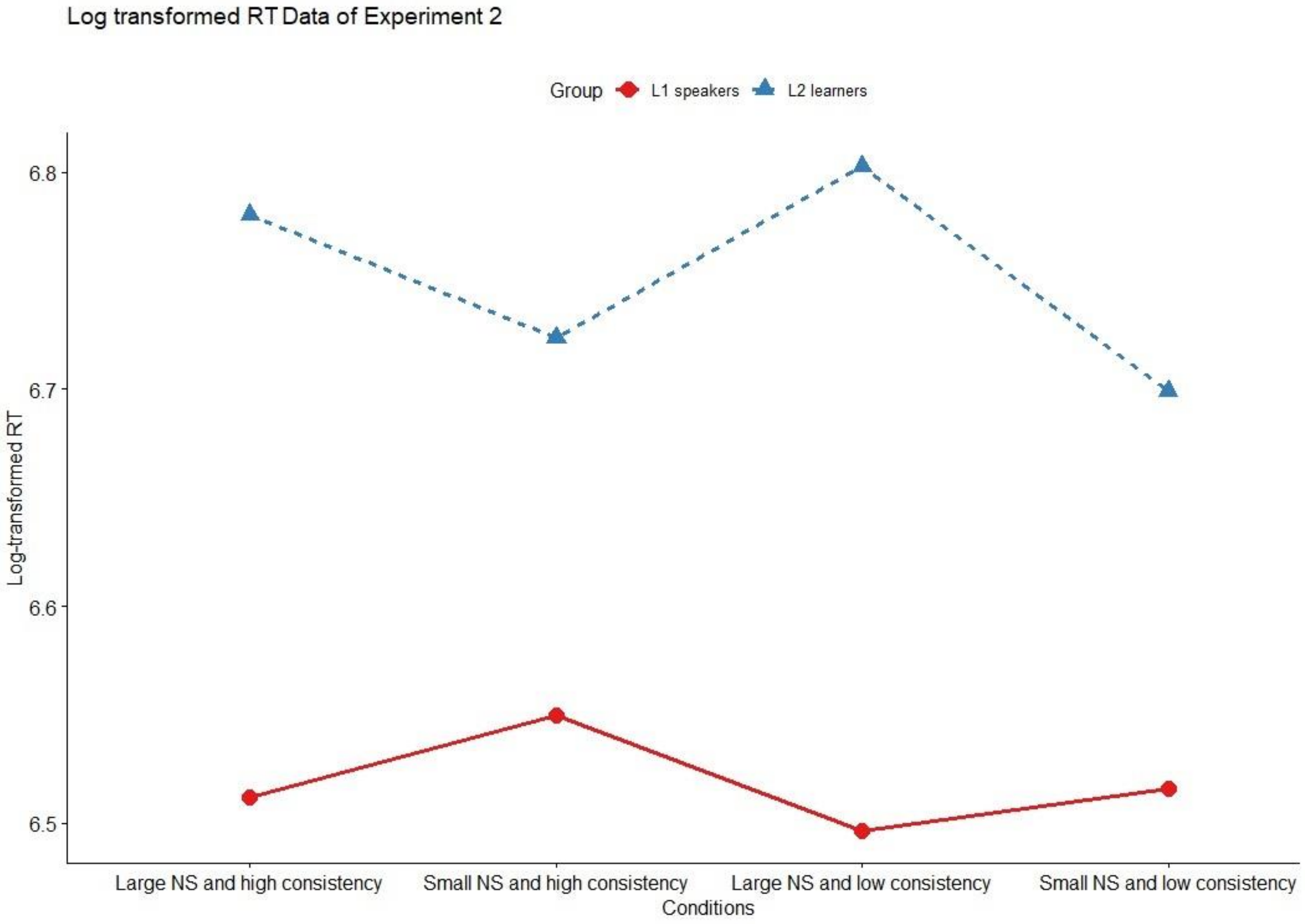
Secondly, regarding NS by L1/L2 group two-way interactions, Tukey HSD analysis revealed significant group effect as L1 Chinese speakers demonstrated significantly shorter RT in reading words containing large-NS characters than L2 learners, by-subject $p < .0001$, by-item $p < .0001$. In addition, L1 Chinese speakers had significantly shorter RT when reading words containing small-NS characters than L2 learners, by-subject $p < .0001$, by-item $p < .0001$. No other significant comparisons were found.

Thirdly, regarding consistency degree by L1/L2 group two-way interactions, Tukey HSD analysis revealed significant group effect as L1 Chinese speakers demonstrated significantly shorter RT when reading words containing high-consistency characters than L2 learners, by-subject $p < .0001$, by-item $p < .0001$. This significant group effect was also found when reading words containing low-consistency characters, by-subject $p < .0001$, by-item $p < .0001$. No other significant comparisons were found.

Thirdly, regarding the three-way interactions, Tukey HSD analyses on logarithmic RT data suggested that L1 Chinese speakers performed the LD tasks significantly faster than the L2 Chinese learners in all the four stimuli conditions: "large NS and high consistency" (by-subject analysis $p < .0001$; by-item analysis $p < .0001$), "large NS and low consistency" (by-subject analysis $p < .0001$; by-item analysis $p < .0001$), "small NS and high consistency" (by-subject analysis $p < .001$; by-item analysis $p < .0001$), "small NS and low consistency" (by-subject analysis $p < .001$; by-item analysis $p < .0001$). No other meaningful pairwise comparisons were found.

Figure 3.5

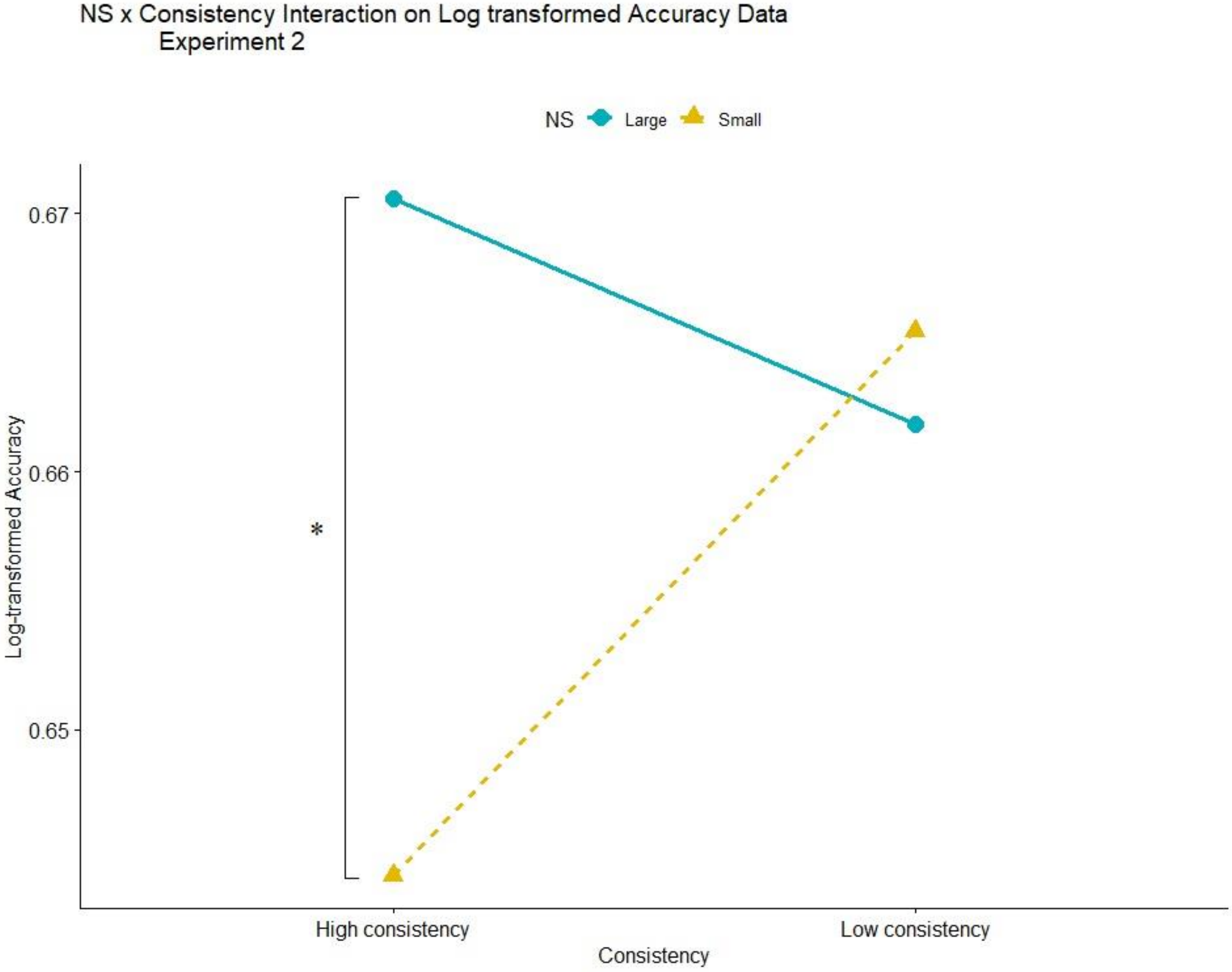
Log-transformed RT Data of Experiment 2



Post-hoc Analyses on Accuracy Data (Tukey HSD). Post-hoc comparisons using Tukey HSD on participants' log-transformed accuracy data suggested the following meaningful comparisons. First, regarding NS by consistency degree two-way interactions, Tukey HSD analysis showed a significant NS effect when reading two-character words containing high-consistency characters, by-subject p = .037, but not significant by-item p = .080. This NS effect was not found in reading two-character words containing low-consistency characters (see Figure 3.6).

Figure 3.6

NS by Consistency Interaction (Accuracy Data, Experiment 2)



* $p < .05$. ** $p < .01$. *** $p < .001$

Secondly, regarding the NS by L1/L2 group two-way interactions, Tukey HSD analysis revealed a significant group effect because L1 Chinese speakers achieved significantly higher accuracy in reading words containing large-NS characters than L2 learners, by-subject $p < .0001$, by-item $p < .0001$. Also, L1 Chinese speakers had significantly higher accuracy when reading words containing small-NS characters than L2 learners, by-subject $p < .0001$, by-item $p < .0001$.

Thirdly, regarding the consistency degree by L1/L2 group two-way interactions, Tukey HSD analysis revealed a significant group effect as L1 Chinese speakers demonstrated significantly higher accuracy when reading words containing high-consistency characters than L2 Chinese learners, by-subject $p < .0001$, by-item $p < .0001$. This significant group effect was also found when participants read words containing low-consistency characters, by-subject $p < .0001$, by-item $p < .0001$.

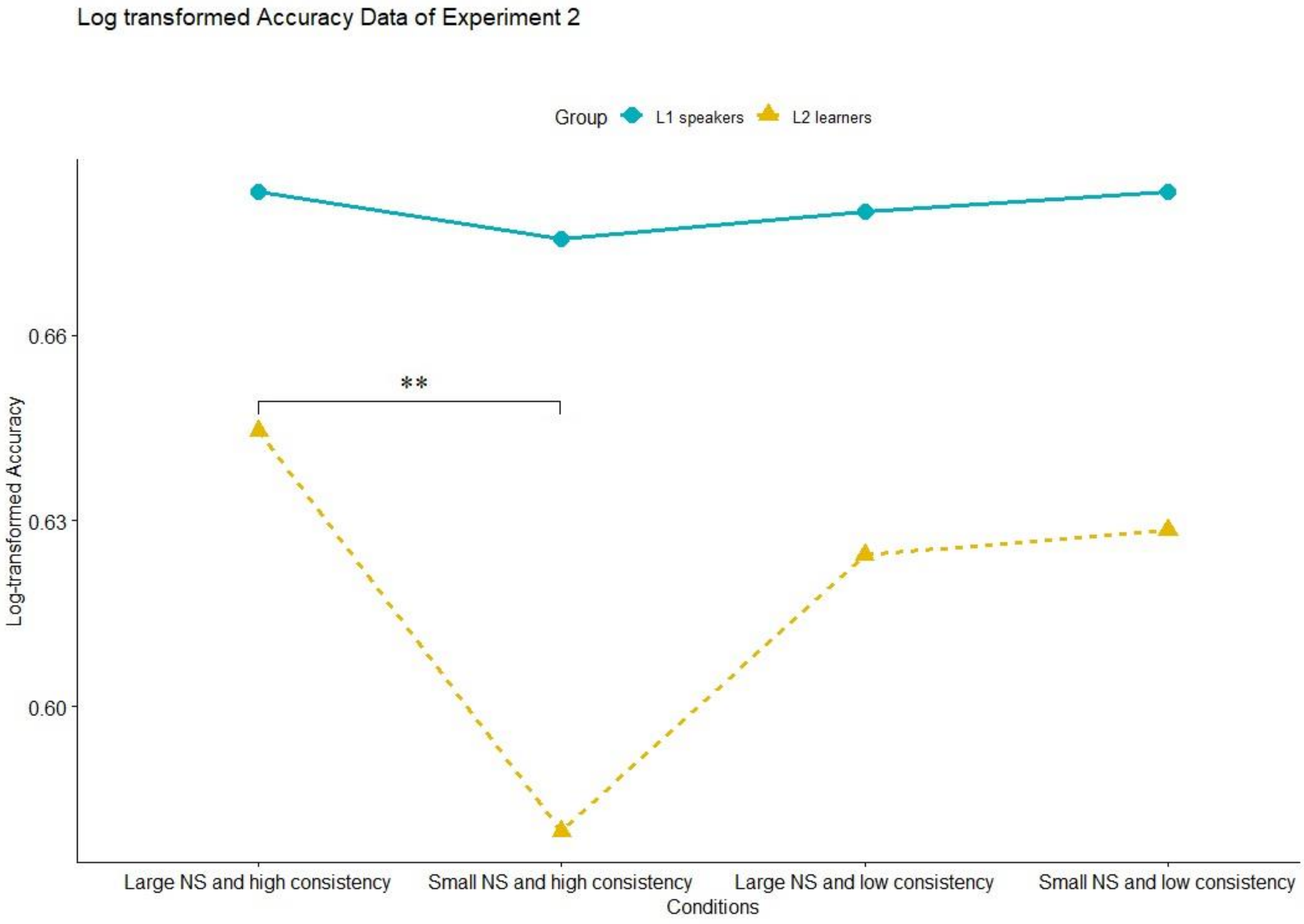
In addition, with regards to three-way interactions, Tukey HSD analysis indicated significant group effect. In other words, L1 Chinese speakers achieved significantly higher accuracy than L2 Chinese leaners in the following conditions, "large NS and high consistency" (by-item $p = .012$; but not significant according to by-subject analysis $p = .144$), "large NS and low consistency" (by-subject $p = .005$, by-item $p < .001$), "small NS and high consistency" (by-subject $p < .0001$, by-item $p < .0001$), and "small NS and low consistency" (by-subject $p = .006$, by-item $p = .002$).

Lastly and very interestingly, a significant facilitatory NS effect was found when L2 Chinese speakers read two-character words containing a high-consistency character, by-subject analysis $p = .005$, but not significant based on by-item analysis $p = .068$. To be more specific, L2 Chinese speakers' log-transformed accuracy in "large NS and high consistency" was significantly higher than that in "small NS and high consistency". Because the log-transformed accuracy was normally distributed in these two conditions and that the assumption of homogeneity of variance was met, it was considered that the result was reliable. It is worth noting that this facilitatory NS effect was not found when L2 Chinese learners read two-character words that contain a low-consistency character. Also, this facilitatory NS effect was not found in

L1 Chinese speaker's accuracy data (See Figure 3.7).

Figure 3.7

Log-transformed Accuracy Data of Experiment 2



* $p < .05$. ** $p < .01$. *** $p < .001$

Hierarchical Regression Analyses

Hierarchical regression analyses were performed to examine various factors' contributions in participants' RT and accuracy. Similar to Experiment 1(a) and 1(b), targeted phonetic compound characters' frequency was first entered into the model, followed by the entry of NS, type-, and token-consistency values, which were entered together into the model in step 2.

In step 3, targeted character's other orthographic features were entered. However, different from Experiment 1(a) and 1(b), a fourth-step predictor entry was carried out: word-level features, including word NS, word frequency, and number of strokes of a word. Dependent variables were the log-transformed RT and accuracy of all participants, those of L1 speakers only, and those of L2 leaners only. Results were presented in Table 3.5 (RT only) and Table 3.6 (accuracy only).

For all participants' log-transformed RT data, after adding target character's frequency as the 1st predictor, the model explained significant variances in the dependent variable, F (1, 62) = 4.877, p = .031, R^2 = .073. In step 2, adding target character's NS, type-, and token consistency did not significantly improve the model (ΔR^2 = .034, p = .530), and the model only explained 10.67% of the variances, F (4, 59) = 1.761, p = .149. In step 3, adding the other orthographic features into the model did not significantly improve the model as well (ΔR^2 = .093, p = .305), and the model explained 20.01% of the variances, F (9, 54) = 1.501, p = .171. Lastly, adding word-level features in step 4 did not significantly improve the model (ΔR^2 = .030, p = .580), and the model did not explain significant variances in the dependent variable, F (12, 51) = 1.270, p = .265, R^2 =.023.

For L1 speakers' RT data, adding target character's frequency in step 1 did not explain significant variances, F (1, 62) = 2.302, p = .134, R^2 = .036. Adding target character's NS, type-, and token-consistency into the model did not significantly improve the model (ΔR^2 = .030, p = .597), and the model only explained 6.54% of the variances, F (4, 59) = 1.031, p = .399. Adding other orthographic features at the 3rd step (ΔR^2 = .123, p = .181) and word-level features at the 4th step (ΔR^2 = .018, p = .763) did not make the model explain significant variances in the dependent variable, F (9, 54) = 1.394, p = .214, R^2 =.189 and F (12, 51) = 1.107, p = .375, R^2 =.207 respectively.

Table 3.5

Hierarchical Regression Analysis of Experiment 2 (RT Data Only)

	Log RT Data (All Participants)				**Log RT Data (L1 Speakers)**				**Log RT Data (L2 Learners)**			
Predictors	R^2	Δ R^2	β	*Sig.*	R^2	Δ R^2	β	*Sig.*	R^2	Δ R^2	β	*Sig.*
Step 1	.073*				.036				.114**			
1. Target character frequency			-.000	.031*			-.000	.134			-.000	.006**
Step 2	.107	.034			.065	.030			.156*	.042		
1. Target character frequency			.000	.440			.000	.695			.000	.286
2. NS			-.002	.747			-.003	.634			-.003	.666
3. Consistency (type)			.074	.260			.080	.294			.097	.278
4. Consistency (token)			-.080	.208			-.079	.287			-.136	.118
Step 3	.200	.093			.189	.123			.182	.026		
1. Target character frequency			.000	.823			.000	.642			.000	.206
2. NS			.002	.685			.003	.592			-.005	.546
3. Consistency (type)			.072	.301			.075	.345			.102	.300
4. Consistency (token)			-.096	.210			-.116	.189			-.119	.275
5. Number of strokes			-.006	.201			-.008	.155			-.004	.539
6. Semantic radical NS			.001	.076			.001	.070			.000	.614
7. Phonetic radical's frequency			.000	.572			.000	.384			.000	.677
8. Neighborhood frequency			.000	.519			.000	.206			.000	.444
9. Semantic radical familiarity			-.040	.264			-.051	.217			-.009	.865
Step 4	.230	.030			.207	.018			.258	.077		
1. Target character frequency			.000	.914			0.000	.612			.000	.401
2. NS			.001	.801			0.003	.697			-.006	.417
3. Consistency (type)			.058	.411			0.063	.440			.067	.489
4. Consistency (token)			-.098	.210			-0.119	.189			-.117	.277
5. Number of strokes			-.009	.099			-0.010	.101			-.009	.220
6. Semantic radical NS			.001	.055			0.001	.057			.000	.431
7. Phonetic radical's frequency			.000	.563			0.000	.404			.000	.855
8. Neighborhood frequency			.000	.511			0.000	.213			.000	.495
9. Semantic radical familiarity			-.042	.252			-0.053	.210			-.012	.809
10. Word NS			.001	.505			0.001	.628			.001	.694
11. Word frequency			.000	.732			0.000	.694			.000	.763
12. Word stroke number			.005	.214			0.004	.351			.012	.027*

* $p < .05$. ** $p < .01$. *** $p < .001$

For L2 learners' RT data, after entering target character's consistency, the model explained significant variances in the dependent variable F (1, 62) = 7.995, $p = .006$, $R^2 = .114$. Adding target character's NS, type-, and token-consistency in step 2 (Δ $R^2 = .042$, $p = .421$) did not make the model explain significant variances, but the model could still explain significant variances, F (4,59) = .479, $p = .038$, $R^2 = .156$. Adding the other orthographic features (Δ R^2

= .026, p = .878) in the 3rd step and adding word-level features ($\Delta R^2 = .077$, p = .166) in the 4th step did not make the model explain significant variances, F (9, 54) = 1.331, p = .243, R^2 =.182 and F (12, 51) = 1.481, p = .162, R^2 = .258 respectively. However, in the final model, the number of strokes of a complete word served as a significant predictor (p = .027).

With regards to all participants' accuracy data, after adding target character's frequency into the model in the step 1, the model did not explain significant variances in the dependent variable, F (1, 62) = 2.020, p = .160, R^2 = .032. In step 2, adding target character's NS, type-, and token-consistency together ($\Delta R^2 = .011$, p = .867) did not help the model explain significant variances in the dependent variable, F (4, 59) = .662, p = .621, R^2 = .043. In step 3, adding the other orthographic features ($\Delta R^2 = .076$, p = .449) did not significantly improve the model, F (9, 54) = .808, p = .611, R^2 =.119. Lastly, in step 4, adding word-level features ($\Delta R^2 = .080$, p = .181) did not significantly improve the model, F (12, 51) = 1.051, p = .419, R^2 =.198. However, the final model suggested that targeted characters' number of strokes served as a significant predictor (p = .043).

Regarding L1 Chinese speakers' accuracy, after adding target character's frequency into the model in step 1, the model did not explain significant variances, F (1, 62) = 1.102, p = .298, R^2 = .017. In step 2, adding NS, type-, and token-consistency together into the model (ΔR^2 = .006, p = .955) did not significantly improve the model, F (4, 59) = .347, p = .845, R^2 = .023. In step 3, adding the other orthographic features ($\Delta R^2 = .044$, p = .760) did not make the model explain significant variances in the dependent variable, F (9, 54) = .428, p = .914, R^2 =.067. Lastly, adding word-level features ($\Delta R^2 = .076$, p = .227) did not explain significant additional variances, and the model explained 14.22% of the variances in L1 Chinese speakers' accuracy, F (12, 51) = .704, p = .740.

Table 3.6

Hierarchical Regression Analysis of Experiment 2 (Accuracy Data Only)

	Log Accuracy Data (All Participants)				**Log Accuracy Data (L1 Speakers)**				**Log Accuracy Data (L2 Learners)**			
Predictors	R^2	ΔR^2	β	*Sig.*	R^2	ΔR^2	β	*Sig.*	R^2	ΔR^2	β	*Sig.*
Step 1	.032				.017				.029			
1. Target character frequency			.000	.160			.000	.298			.000	.176
Step 2	.043	.011			.023	.006			.046	.017		
1. Target character frequency			.000	.441			.000	.669			.000	.398
2. NS			.002	.460			.000	.856			.004	.328
3. Consistency (type)			-.006	.843			-.002	.907			-.012	.849
4. Consistency (token)			.014	.614			.010	.571			.021	.726
Step 3	.119	.076			.067	.044			.152	.106		
1. Target character frequency			.000	.904			.000	.945			.000	.894
2. NS			.000	.911			.000	.820			.002	.728
3. Consistency (type)			.000	.992			.000	.987			.001	.988
4. Consistency (token)			.029	.387			.012	.585			.064	.364
5. Number of strokes			.003	.158			.000	.999			.009	.038*
6. Semantic radical NS			.000	.523			.000	.328			.000	.780
7. Phonetic radical's frequency			.000	.571			.000	.630			.000	.617
8. Neighborhood frequency			.000	.223			.000	.582			.000	.154
9. Semantic radical familiarity			-.001	.933			-.001	.925			-.003	.936
Step 4	.198	.080			.142	.076			.216	.064		
1. Target character frequency			.000	.594			.000	.942			.000	.461
2. NS			.001	.662			.000	.999			.003	.502
3. Consistency (type)			.008	.795			.004	.852			.017	.785
4. Consistency (token)			.034	.307			.015	.523			.076	.285
5. Number of strokes			.005	.043*			.001	.400			.012	.017*
6. Semantic radical NS			.000	.347			.000	.214			.000	.591
7. Phonetic radical's frequency			.000	.651			.000	.728			.000	.680
8. Neighborhood frequency			.000	.229			.000	.601			.000	.160
9. Semantic radical familiarity			.001	.950			.000	.982			.003	.929
10. Word NS			-.001	.310			-.001	.130			-.001	.628
11. Word frequency			.000	.199			.000	.451			.000	.163
12. Word stroke number			-.003	.093			-.002	.163			-.005	.127

* $p < .05$. ** $p < .01$. *** $p < .001$

Lastly, concerning about L2 Chinese learners' accuracy, after entering target character's frequency in step 1, the model did not explain significant variances, F (1, 62) = 1.872 p = .176, R^2 = .029. In step 2, adding target character's NS, type-, and token-consistency together into the model (ΔR^2 = .017, p = .773) did not significantly improve the model, F (4, 59) = .719, p = .583,

R^2 = .046. In step 3, adding the other orthographic features into the model (ΔR^2 = .106, *p* = .250) did not significantly improve the model as well, *F* (9, 54) = 1.075, *p* = .396, R^2 =.152. In step 3, targeted character's strokes number was a significant contributor (*p* = .038). Lastly, in step 4, adding word-level features did not significantly improve the model (ΔR^2 = .064, *p* = .256), and the model explained 21.61% of the variances in L2 Chinese learners' accuracy data, *F* (12, 51) = 1.172, *p* = .328. Targeted character's strokes number remained as a significant contributor (*p* = .017).

In summary, semantic-phonetic compound characters' consistency and NS were not significant predictors of participants' RT and accuracy in reading two-character Chinese words.

Interim Discussion

Results revealed a significant NS effect for reading two-character Chinese words. This finding has not been reported in previous studies. This indicated that radical-level features could not only affect the recognition of single characters (as reported in Chapter 2) but could also play an important role in recognizing two-character word. However, the direction of the NS effect was not as expected. The NS effect was assumed to be inhibitory, but the results in the present study showed that larger NS yielded higher accuracy.

One possible explanation was that the context has changed. To be more specific, most previous studies explored the NS effect by using single-character words as stimuli, but this study used two-character words. A two-character word has two constituent characters, both of which contribute their phonological and semantic values to the whole word. In other words, the non-targeted character provided a context for the readers to narrow down the range of semantic-phonetic compound characters that have been activated due to sharing the same phonetic radical at the radical level as the targeted character. The more semantic-phonetic compounds were activated, the easier participants recognized the targeted character.

This facilitatory NS effect was significant when participants were reading high-consistency characters relative, but not significant when reading low-consistency ones. This is because high-consistency characters have more “friends” than “enemies” in their neighborhood and high-consistency characters tend to possess the dominant syllable in the neighborhood, which was easier for participants to extract phonological information of the targeted semantic-phonetic compounds. As a result, both the easier access to phonology and the semantic context provided by the non-targeted-character contributed to the more accurate recognition of the two-character words. And the larger the NS a semantic-phonetic compound was, the more accurately participants could respond to it because the semantic clue provided by the non-target character could help participants select the right targeted character among a group of characters that have been activated.

Lastly, it was interesting to find that the facilitatory NS effect was significant when L2 learners read two-character words that contained a high-consistency character. It showed that L2 learners needed to rely more on radical-level features for phonological information’s extraction and that they were sensitive to the radical-level features even reading two-character words.

Chapter Summary

Study 2 focused on the semantic-phonetic compound characters’ NS effect and its interaction with consistency on L1 Chinese speakers’ and L2 Chinese learners’ recognition of two-character Chinese words. A lexical decision task was administered. ANOVA tests on RT showed: (1) significant main effect of group effect; (2) significant NS x consistency degree interaction; (3) significant NS x group interaction. ANOVA tests on accuracy demonstrated: (1)

significant main effect of group; (2) significant main effect of NS; (3) significant NS x group interaction; (4) significant NS x consistency degree interaction; (5) significant NS x consistency degree x group interaction; (6) NS effect was significant when reading high-consistency characters; (7) NS effect was facilitatory and significant for L2 learners read words containing high-consistency characters. Furthermore, correlation analyses revealed: token consistency degree was significantly and negatively correlated to L2 Chinese learners' RT. Lastly, hierarchical regression analyses implied: consistency and NS did not explain significant variances in L1 speakers' and L2 leaners' RT or accuracy.

Discussion focused on why the NS effect turned out to be facilitatory, instead of inhibitory, especially when L2 learners read words containing high-consistency semantic-phonetic compounds. It was hypothesized that the semantic clues provided by the non-targeted characters and the high consistency both contributed to more accurate responses, especially when the targeted character had large NS.

Chapter 4

General Discussion

How Did the Data Answer the Research Questions?

Two general research questions were asked in Chapter 1 to guide this dissertation. The first research question concerned about the NS effect on L2 Chinese learners' recognition of semantic-phonetic compound characters. To answer this research question, Study 1 invited seventeen L2 Chinese learners (n = 17) to complete two lexical decision (LD) tasks. Results of Experiment 1(a) showed that when L2 Chinese learners read regular semantic-phonetic compound characters, the NS effect modulated L2 Chinese learners' consistency effect. To be more specific, this dissertation extended Kim et al. (2016)'s and Lin & Collins (2012)'s conclusions. Kim et al. (2016) and Lin & Collins (2012) yielded a facilitatory consistency effect, but they did not explore how it interacted with the NS effect. The data of this dissertation showed that the facilitatory consistency effect was significant when L2 Chinese learners read small-NS characters but not significant when reading large-NS characters. Even though this dissertation did not detect significant NS effect for L2 Chinese learners, this finding was still considered useful for researchers to understand how NS and consistency interacted.

The second general research question asked about the NS effect on L2 Chinese learners' recognition of two-character Chinese words that contain one semantic-phonetic compound character and one non-semantic-phonetic compound character. The same group of participants finished Experiment 2, and the data answered this research question. A significant NS effect was detected when L2 Chinese learners read two-character words that contain a high-consistency character, and this NS effect was facilitatory. In addition, this NS effect was not found when L2 learners read two-character words that contain a low-consistency character.

In summary, the research purpose of exploring the NS effect on L2 Chinese learners' reading of characters and words have been met by the data. Also, the main research questions have been responded to by the data. The NS effect was not significant when L2 Chinese learners read single characters but could modulate the consistency effect. However, the NS effect was significant when L2 Chinese learners read two-character Chinese words.

A Discussion on the Hypotheses

Based on the Lexical Constituency Model and previous studies, this dissertation proposed two hypotheses in Chapter 1. They hypothesized that the NS effect would be significant and inhibitory for L2 learners to read single characters and two-character words respectively. The data and results did not show any evidence that the two hypotheses were met.

For the first hypothesis, the NS effect was not significant for L2 Chinese learners. One potential explanation was that L2 learners' mental lexicon did not have enough number of characters sharing the same phonetic radicals to reach a significant level. To be more specific, L1 Chinese speakers know more Chinese characters than L2 learners did and thus, L1 speakers' mental lexicon contained larger NS than L2 leaners. Previous studies detecting significant NS effect among L1 speakers reported much larger NS of semantic phonetic compound characters relative to L2 learners, which was discussed in Chapter 2. Here, more details were provided. The following table shows how previous studies defined large- and small NS.

As can be seen from this table, previous studies defined L1 Chinese speakers' large NS as the neighborhood containing more than 10 characters, which was much larger than the definition of L2 Chinese learners' large NS in the present dissertation. Why? This is because L2 Chinese leaners may not know as many characters as L1 speaker did, so it is impractical to directly adopt previous studies' definition of large NS in the present dissertation. To make sure that the present dissertation can measure L2 Chinese learners' mental lexicon, the present dissertation only defined a neighborhood based on the L2 Chinese curriculum, which had much small range of characters. According to Kim & Shin (2015a), among all semantic-phonetic compound characters that appeared in the L2 Chinese curriculum, only nine (n = 9) neighborhoods had 10 or more characters. In other words, if the present dissertation adopted the definition of large NS used in previous studies, there would not be sufficient number of stimuli. That is why the present dissertation used smaller NS for "large NS". As a result, this could account for the result that no significant NS was detected in Study 1.

Table 4.1

Ranges of Large and Small Neighborhood Size in Previous Studies

Studies	Focused Group	Large NS	Small NS
Li et al. (2011)	L1 speakers	10 - 16	2 - 8
Chang et al. (2016)	L1 speakers	average 9.83 - 11.27	average 3.47 - 3.6
Zhao et al. (2012)	L1 speakers	10 - 23	2 - 7
Jiang & Zhang (2014)	L1 speakers	> 10	< 5
Zhao et al. (2011)	L1 speakers	≥ 11	≤ 9
Present study (Exp1a)	L2 learners	average 5.4 - 5.67	average 3.13 - 3.27
Present study (Exp1b)	L2 learners	average 6.6 - 7.13	average 3.33 - 4.0
Present study (Exp 2)	L2 learners	average 6.25 - 6.69	average 3.06 - 3.31

As for the second hypothesis, according to the Lexical Constituency Model, when a learner reads a single character that shares the same phonetic radical with many other characters (i.e., neighbors), the activation at the character level was localized so that all activated neighbors compete with each other. This competing process results in prolonged reaction time and lower accuracy, which in turn, attenuates the process of recognizing the whole word. However, the results did not support this hypothesis because the NS effect was significant but turned out to be facilitatory. It has been discussed in Chapter 3 that the context of reading single characters and that of reading two-character words are different. There is no confirmed theory or framework that can explain the facilitatory NS effect found in this study.

One possible explanation is that: When reading a two-character word, each constituent character provides contexts to the recognition of the whole word. The non-target character (e.g., 步) provides its semantic and phonological context so that the recognition of the targeted semantic phonetic compound character (e.g., 跑) was facilitated. The phonetic radical (e.g., 包) activated multiple characters in L2 learners' mental lexicon at the character level (i.e., 包, 胞, 雹, 饱, 抱, 袍, 跑, 炮, 泡). The semantic and phonological context/clue/hint provided by 步 (/bu4/, steps) can help readers decide that 跑 (*/pao3/*, to run) is the right character as its semantic radical is "足" (foot-related) and that its meaning is related to 步 (/bu4/, steps). In this situation, the competition between neighbors at the character level (i.e., 包, 胞, 雹, 饱, 抱, 袍, 跑, 炮, 泡) may have disappeared. Rather, the relation between these characters may have become facilitatory. However, this explanation needs more empirical supports in the future.

This Dissertation and Previous Studies

When comparing the present dissertation's results to those in previous studies, two major conclusions can be reached. Firstly, with regards to the consistency effect, this study agreed with most of the previous studies exploring the consistency effect on both L1 and L2 reading. Lee et al. (2005) revealed facilitatory consistency effects when L1 Chinese readers named regular characters as well as irregular characters. Lin & Collins (2012) revealed similar results for L2 Chinese learners. Kim et al. (2016) suggested facilitatory consistency effect when L2 Chinese learners learn to read low-frequency characters. The present study also suggested facilitatory consistency effect when L2 Chinese learners did lexical decision tasks on regular and small-NS characters. In addition, the present study indicated that token consistency degree was positively correlated to L2 Chinese learners' accuracy in lexical decision tasks, which again showed that consistency degree served as an important and beneficial source for L2 learners to extract phonological information from orthography, regardless in naming tasks or lexical decision tasks.

However, the present study's result about the consistency effect was different from that of Yum et al. (2016), in which the authors found an inhibitory consistency effect. Yum et al. (2016) invited eighteen L2 Chinese learners whose L1 was English to finish a delayed naming task and a lexical decision task on semantic phonetic compounds. Their results showed that participants used significantly longer time responding to consistent semantic phonetic compounds than inconsistent one, suggesting an inhibitory consistency effect. The authors explained that their participants' Chinese proficiency was equal to the Grade 4 level of primary school students, and their awareness of consistency had not developed to the extent of adult Chinese speakers. As a result, Yum et al. (2016) did not yield the consistency effect as reported in Kim et al. (2016) and Lin & Collins (2012). Additionally, their selection of experimental stimuli might provide some explanations. The authors did not balance stimuli's NS across conditions: There was a significant difference in stimuli's phonetic-radical-based NS between the high- and low-consistency conditions (as reported in Yum et al. (2016, p. 344, Table 2)). The low-consistency stimuli had significantly larger phonetic radical NS than the high-consistency ones. The imperfect selection of stimuli made their results about the consistency effects become unreliable.

Secondly, regarding the NS effect, the present study yielded similar conclusions to those in previous studies, especially the ones exploring the NS effect among L1 Chinese speakers. First of all, the present study found that the NS effect was negative for L1 speakers, which was in accordance with Chang et al. (2016), Li et al. (2011), and Li et al. (2020). In the present study, it was found that the main effect of NS has consistently been significant in both Experiment 1(a) and 1(b). Second, this study found that NS was significantly and negatively correlated to L1 Chinese speakers' accuracy in Experiment 1(a) and that NS was significantly and positively correlated to L1 Chinese speaker's RT in Experiment 1(b), which again suggested an inhibitory NS effect on L1 speakers.

This Dissertation and the Research Gaps

This dissertation filled the first research gap that the NS effect has not been studied on L2 Chinese learners' reading of semantic phonetic compound characters. This dissertation suggested that the NS effect was not as significant among L2 learners as among L1 speakers.

This study also filled the second research gap that the NS effect has not been explored on reading two-character words. This dissertation suggested that a semantic phonetic compound character's NS feature plays an important role in reading two-character words, especially for L2 Chinese learners.

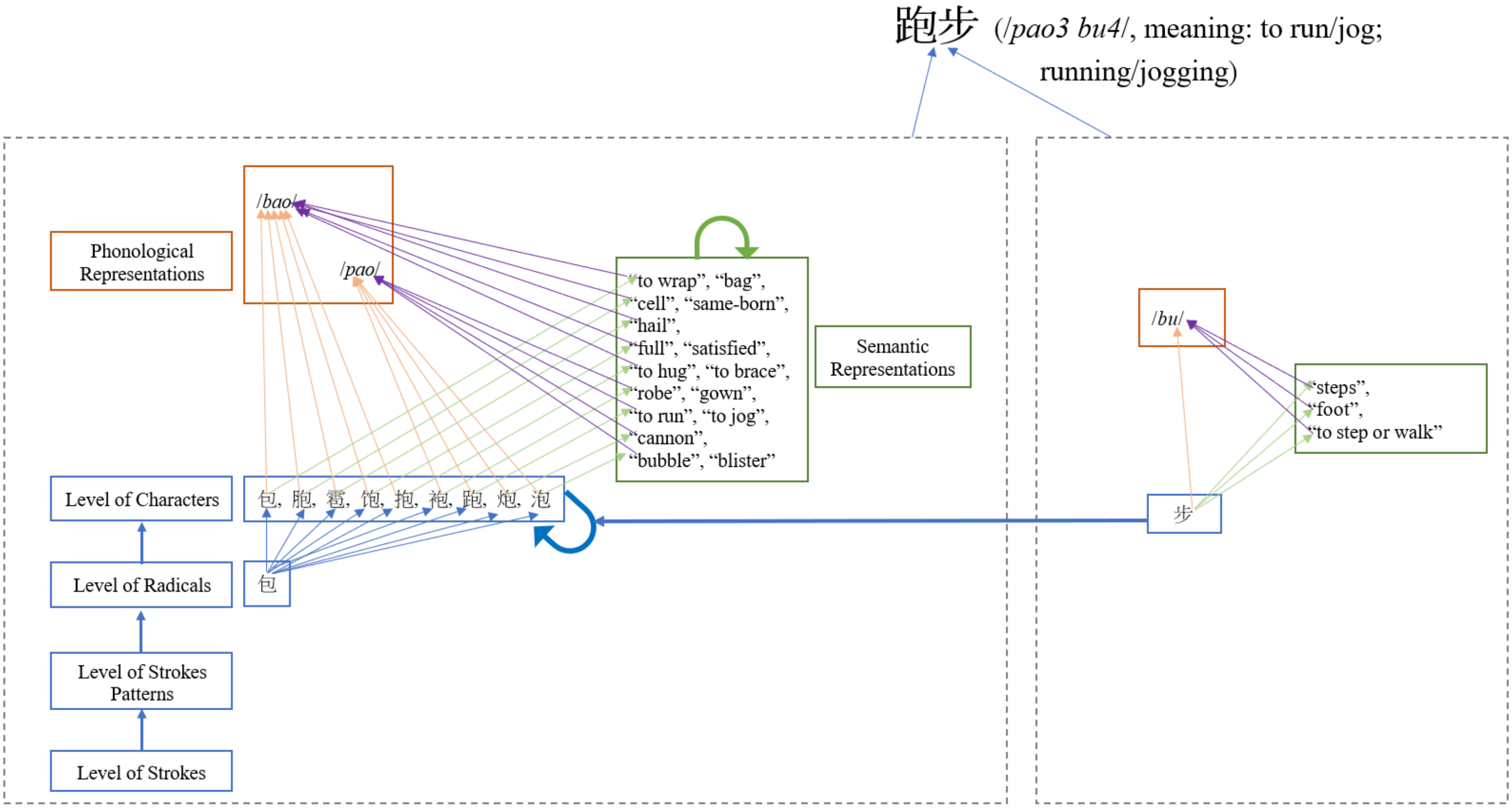
Theoretical Implications

Theoretical implications were discussed from two perspectives: single characters reading and two-character words reading. With regards to single characters reading, results of this dissertation suggested that the Lexical Constituency Model could explain the NS effect. As stated in Chapter 1, characters at the orthographic level had "localized representations" (Perfetti et al., 2005, p. 49), and activated characters compete with and had "negative connections" with each other at this level (p. 49). The larger number of characters that a radical activates, the more inhibitions are expected at this level, resulting in negative NS effects. The results of this dissertation, especially those of Study 1, provided empirical evidence for this model's assumption, as the NS effect was found negative when participants read regular (Experiment

1(a)) and irregular (Experiment 1(b)) semantic phonetic compound characters. However, the model seemed not able to explain why NS effect was absent among L2 learners.

Figure 4.1

Proposed Model for Reading Two-Character Words for L2 Chinese Learners



As for reading two-character words, this dissertation proposed the following model (Figure 4.1) based on the Lexical Constituency Model (Perfetti & Liu, 2006; Perfetti et al., 2005). Firstly, this proposed model agrees with the LCM that radical-level representations play important roles in the whole word recognition process and that the recognition of each constituent character requires correct recognition of their orthographic, phonological, and semantic information. Secondly, the proposed model considers that one constituent character (e.g., 步) provides important semantic and phonological clues, which made the process of recognizing another constituent character (e.g., 跑) become easier than when there are no such clues. Thirdly, the proposed model suggests that activation starts from the radical-level representation and sends activation to the orthographic level; however, the inter-level connection between activated characters at the orthographic level becomes facilitatory rather than inhibitory because of the clues provided by another constituent character. Lastly, as a result, the NS effect becomes facilitatory instead of negative.

Pedagogical Implications

It is an instructor's responsibility to come up with useful linguistic clues and efficient learning methods that can benefit learners' learning and use of learned as well as new words. And this dissertation's conclusion about phonetic radical neighborhood size, in certain ways, satisfied their needs. This study implied that a semantic-phonetic compound character's NS played a facilitatory role in L2 learners' reading of two-character words, and this facilitatory role was significant when the characters have a high consistency degree. Based on this conclusion, L2 Chinese educators may emphasize the importance of NS and consistency and boost L2 learners' awareness of them while learning new words, especially for learners of higher proficiency. This is because as learners' proficiency level goes higher, they acquire more characters and a learned phonetic radical's neighborhood tends to be larger. At this stage, if L2 Chinese instructors can purposefully help L2 learners understand what NS and consistency are and how the information about them can be facilitatory, L2 leaners' learning efficiency can be improved significantly. Especially, if L2 Chinese instructors can make a list of all words containing the semantic-phonetic compound characters from the same neighborhood (such as the one in Figure 4.2) and help learners understand their orthographic, phonological, and semantic differences as well as their correct usage, the learners would feel that radicals could be a useful linguistic source for not only memorizing and writing words but also for recognizing and reading words. In this way, this dissertation responded to the real-world problem stated in the "Problem Statement" section in Chapter 1 that complicated and unique orthographic, phonological, and semantic features of Chinese characters impose difficulties for L2 Chinese learners. The present dissertation echoed with previous studies and reemphasized the importance of radicals, especially the phonetic radicals, in Chinese pedagogy.

For example, because the "small NS and high consistency" characters yielded more errors when L2 Chinese learners read two-character words, L2 Chinese instructors should focus more on such words and provide more training opportunities for learners. Instructors can create a learning material or PowerPoint slide like Figure 4.2 to compile words that learners tend to have difficulties recognizing accurately. In Figure 4.2, this instructor compiled all words that have the phonetic radical 则(*/ze2/*) (selected from Kim & Shin (2015a; 2015b). This phonetic radical has a small NS (i.e., NS = 4), and three members of the neighborhood (测, 侧, 厕, all */ce4/*) have a high consistency degree (i.e., 0.75 = 3 ÷ 4). According to Study 2's results, the words containing such characters (left to the dashed line in Figure 4.2) may yield more errors by L2 learners. Instructors may need to draw learners' attention to these words and provide detailed lectures about these words. Particularly, instructors at the HSK level 6 or equivalent proficiency level can compile and collect these words to create learning materials because these words are from different proficiency levels. When learners have reached the highest level (i.e., HSK 6) this method can efficiently help them review previous learned words, strengthen the memory and knowledge of new words, and make effective comparisons between these words to avoid confusions and mistakes. It is also suggested that instructors not only list words but also the characters and phonetic radicals explicitly to make learners become aware of the relations between different levels of orthographic representations. Lastly, instructors are encouraged to create in-class activities, exam questions, or homework tasks like Figure 4.3 to train learners.

Figure 4.2

An Example of How Instructors Can Design Pedagogical Materials

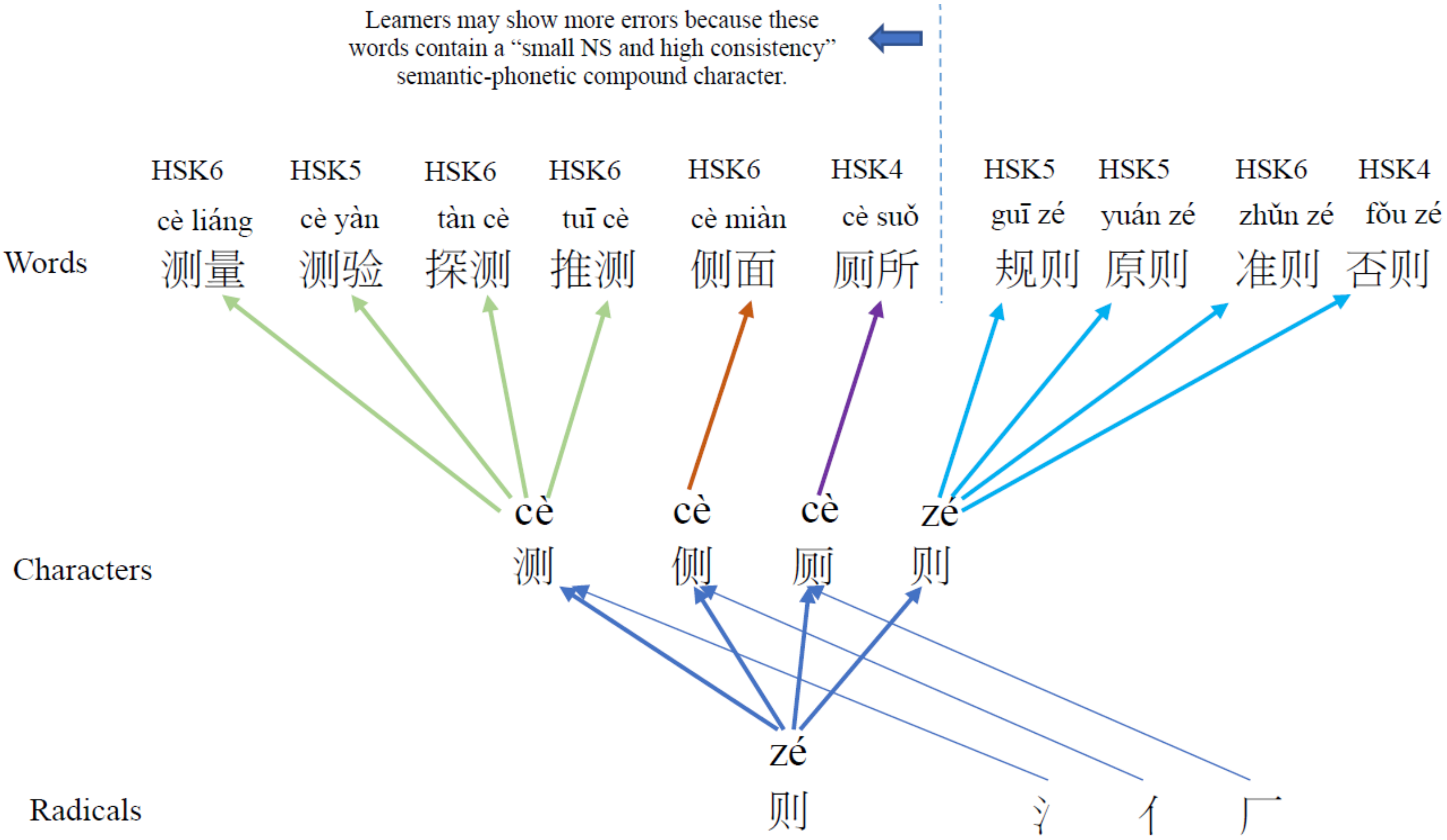
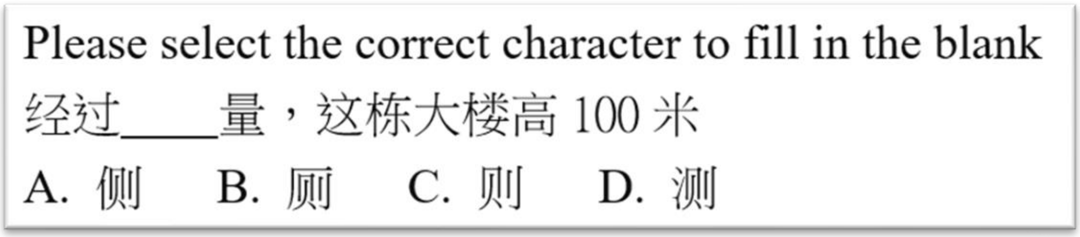


Figure 4.3

An Example Question that Can Be Used to Train Learners



Please select the correct character to fill in the blank

经过____量，这栋大楼高 100 米

A. 侧　B. 厕　C. 则　D. 测

Methodological Implications

This section mainly discusses the measurements of stimuli for L2 Chinese learners. How can researchers accurately gauge the features of characters from the perspectives of L2 learners? Is it appropriate to use L1 speakers' measurement of characters/words features directly on L2 learners? A very controversial issue is about words/characters' frequency. L1 speakers' exposure to certain words and characters can be measured by the frequency index, but this index is based on L1 users' conversations, newspapers, publications, and other aspects of language use. L2 learners' exposure to a certain word or a character is difficult to gauge. As a result, Lin & Collins (2012) used "curriculum-based character familiarity" (p. 1752) as an alternative measurement of L2 Chinese learners' exposure to words and characters, rather than the words and characters' frequency based on L1 Chinese speaker's language use. One the one hand, this may make sure that the measurement of frequency was more accurate because L2 learners may not be exposed to words and characters as frequently as L1 users. On the other hand, this method had drawbacks: (1) it was not easy to make sure that all participants have used the same textbook; (2) it still could not help researchers know L2 learners' exposure to words and characters outside of the textbook and classrooms.

The controversy over frequency has also imposed a question for the present study: How should researchers measure a character's NS and consistency for L2 learners? If L2 learners only know and understand the characters from the L2 Chinese curriculum, then L2-leaners-based NS would be smaller than that of L1 speakers. Why? Take the neighborhood of 马 for instance: For L1 speakers, this neighborhood had 11 members (NS = 11), including 马(*/ma3/*), 妈(*/ma1/*), 犸(*/ma3/*), 玛(*/ma3/*), 码(*/ma3/*), 骂(*/ma4/*), 蚂(*/ma3/* or */ma4/*), 吗(*/ma/*), 冯(*/feng4/*), 笃(*/du3/*), and 闯(*/chuang4/*); however, for L2 speakers, this neighborhood has only 5 members (NS = 5) based on the HSK words list: 马(/*ma3*/), 吗(/*ma*/), 妈(/*ma1*/), 码(/*ma3*/), and 骂(/*ma4*/). In addition to the differences in NS, consistency varied as well. For L2 Chinese speakers, this neighborhood is a consistent one as all members are pronounced the same, and each member has a type-consistency value as 1.00. However, for L1 Chinese speakers, this neighborhood is inconsistent, and the type-consistency value of the /*ma*/ syllable is lowered from 1.00 to 0.73.

In this light, this dissertation considered that using L1-speakers-based measurements of NS and consistency was not proper or accurate to test the NS and consistency effects among L2 Chinese learners. Thus, this dissertation adopted indices of NS and consistency based on L2 curriculum (Kim & Shin, 2015(a), 2015(b)). However, there were two drawbacks. Firstly, as discussed above, the "large NS" condition may not be large enough to detect a significant NS effect. Secondly, it is still unclear what the true NS is in L2 learners' mental lexicon as they may still have been exposed to characters and words outside of the L2 Chinese curriculum.

It is of great importance to solve these two issues. And this requires further discussions and more empirical studies in the future.

Limitations

This dissertation had the following limitations. First of all, the sample size was not big enough, especially the sample size of L2 Chinese learners' group. It was difficult to find L2 Chinese learners and invite them to this research during the COVID-19 pandemic. The author's original plan was going back to China and visiting different universities to recruit participants. However, due to the pandemic, this plan could not be implemented. The author could only stay in the U.S. and recruit participants online. As a result, the data collection was not effective, and the sample size was small.

Secondly, this dissertation could not control for L2 Chinese leaners' L1 backgrounds.

Specifically, this dissertation originally planned to separate L2 Chinese learners into several groups based on their first languages, including Korean- and English-speaking Chinese learners. However, due to the small sample size, this plan was not practical. As a result, this dissertation failed to explore the L1-L2 crosslinguistic effects on Chinese learners' reading.

The third limitation is about online data collection. To comply with University of Cincinnati's COVID-19 safety regulations, face-to-fact data collection was restricted and was not practiced for this dissertation. Consequently, the researcher could not monitor participants' process of completing the experiments. To be more specific, the researcher was not able to make sure if participants' distance to screen, screen sizes, participants' sitting postures, environments (e.g., noise and other interrupting factors) and other aspects have satisfied psycholinguistic experiments' requirements and expectations.

The fourth limitation is about the homogeneity of participants, especially about L2 participants' locations and learning experiences. Most of them had the experiences of learning Chinese in China, but due to the COVID-19 pandemic many of them have returned to their home countries. As a result, at the time of data collection, they were in different locations around the world. Their learning experiences varied as well. Some of them has only learned Chinese in China for one year and then continued learning in their home countries. Some have been living in China in the past years. These differences failed to ensure the participants' homogeneity.

The fifth limitation is about the tasks used in this study. The original plan was that naming tasks would also be involved and that participants' performances in the lexical decision tasks and those in the naming tasks would be compared. However, due to the online data collection, this plan was not able to be practiced. The lack of naming data made this dissertation become unable to provide a comprehensive and deep understanding about the NS effect on L2 Chinese learners' reading.

The last limitation is about the data analysis methods used in this dissertation. When analyzing participants' RT and accuracy data, both by-subject (F1) and by-item (F2) analyses were conducted. However, recent research has pointed out the problems that separate F1 and F2 analyses have brought. For example, Pae et al. (2020) indicated that such analyses "tend to inflate a Type I error or overestimate parameters" (p. 2400), which in turn could lead to misinterpretation of data analysis results. Pae et al. (2020) suggested other statistical techniques, such as "a two-level cross-classified model" and "a two-level hierarchical linear model" (pp. 2400-2401).

Future Studies

This dissertation indicates the following future research directions about the same or similar topics. Firstly, future studies exploring the NS effect on L2 Chinese learners' reading of Chinese characters and words should enlarge the sample size, control for learners' L1 backgrounds, and make sure that participants have homogeneity. Also, future studies may consider avoiding online data collections for psycholinguistic studies.

Secondly, future studies exploring the NS effect may also need to consider using other reading tasks, such as naming tasks. Exploring the NS effect on L2 learners' naming and comparing the results of naming to those of lexical decision can enrich the meaningfulness of a research and can provide a deeper understanding about the NS effect on L2 Chinese learners' reading.

Thirdly, future studies may continue exploring the NS effect on two-character words' reading, as this is a major research gap in the field. In this dissertation, only two-character words containing one semantic-phonetic compound and one non-semantic-phonetic compound were used as the stimuli. In the future, studies may consider investigating two-character words containing two semantic-phonetic compound characters (e.g., 镇静, 敏捷, etc.) and explore how each constituent character's regularity, consistency, and NS influence the reading and recognition of the whole word.

Lastly, future studies may adopt various research methods to explore this topic, such as qualitative research methods and mixed methods research (MMR). This dissertation only used quantitative methods to understand the statistical differences between different stimuli conditions (e.g., large vs. small NS). However, how L2 learners think of the role of phonetic radicals and their neighborhoods qualitatively is also important to help researchers obtain a comprehensive understanding about the issue. Merging quantitative and qualitative findings may also provide new insights for researchers to answer the problems about NS and consistency.

Chapter 5

Conclusions

This dissertation invited thirty-five L1 Chinese speakers and seventeen L2 Chinese learners to finish two studies. The first study used two lexical decision task and asked participants to judge if the demonstrated semantic-phonetic compound character was real characters. A 2 (Neighborhood size (NS)) x 2 (consistency) x 2 (groups) design was adopted. Results showed significant NS effect and consistency effect. Also, results suggested significant consistency effect when L2 Chinese speakers read small-NS characters. In the second study, participants finished a lexical decision task on two-character words containing one semantic-phonetic compound and a non-semantic-phonetic compound. The same design was adopted as Study 1. Results showed significant NS effect when L2 Chinese learners read high-consistency characters.

This study had the following implications. Theoretically, this dissertation proposed a word recognition model for two-character word, which argues that the connections between activated characters at the orthographic level should be facilitatory instead of inhibitory. Methodologically, this dissertation asked questions regarding stimuli selections in second language research. Pedagogically, this dissertation suggested that L2 Chinese instructors compile words containing “small NS and high consistency” characters and train learners about them. This study had the limitations of small sample size, restricted face-to-face data collection, and limited tasks. Futures studies should enlarge the sample size, consider more reading tasks, and use multiple research methods, such as qualitative methods and mixed methods research.

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Appendix A

Stimuli of Experiment 1(a)

Stimuli number 1 to 60 are real characters; Stimuli number 61 to 120 are pseudo-characters.

Number	Stimuli	NS	Type Consist-ency	Condition	Frequency (per million)	Number of Stokes	Phonetic radical
1	注	6	1.00	Large NS and consistent	312.7	8	主
2	征	6	1.00	Large NS and consistent	214.5	8	正
3	呻	6	1.00	Large NS and consistent	5.8	8	申
4	咐	5	1.00	Large NS and consistent	15.5	8	付
5	饥	5	1.00	Large NS and consistent	24.6	5	几
6	构	5	1.00	Large NS and consistent	437.35	8	勾
7	讶	5	1.00	Large NS and consistent	12.3	6	牙
8	值	5	1.00	Large NS and consistent	329.2	10	直
9	湖	5	1.00	Large NS and consistent	114.8	12	胡
10	踩	5	1.00	Large NS and consistent	14.95	15	采
11	吗	5	1.00	Large NS and consistent	335	6	马
12	伸	6	1.00	Large NS and consistent	104.35	7	申
13	证	6	1.00	Large NS and consistent	408.05	7	正
14	柱	6	1.00	Large NS and consistent	52.8	9	主
15	肌	5	1.00	Large NS and consistent	50.7	6	几
16	睁	5	0.6	Large NS and inconsistent	29.95	11	争
17	职	6	0.67	Large NS and inconsistent	251.05	11	只
18	犹	6	0.67	Large NS and inconsistent	47.9	7	尤
19	舱	7	0.57	Large NS and inconsistent	24.8	10	仓
20	趣	5	0.6	Large NS and inconsistent	121.5	15	取
21	纹	5	0.6	Large NS and inconsistent	38.25	7	文
22	蹬	5	0.6	Large NS and inconsistent	6.8	19	登
23	护	6	0.33	Large NS and inconsistent	232.45	7	户
24	贩	6	0.67	Large NS and inconsistent	19.15	8	反
25	饼	6	0.33	Large NS and inconsistent	20.85	9	并
26	址	6	0.33	Large NS and inconsistent	18.8	7	止
27	帜	6	0.67	Large NS and inconsistent	11.25	8	只

Number	Stimuli	NS	Type Consist-ency	Condition	Frequency (per million)	Number of Stokes	Phonetic radical
28	绣	5	0.6	Large NS and inconsistent	18.15	10	秀
29	递	5	0.6	Large NS and inconsistent	59.3	10	弟
30	编	6	0.5	Large NS and inconsistent	135.35	12	扁
31	熄	3	1.00	Small NS and consistent	11.05	14	息
32	冻	3	1.00	Small NS and consistent	42.35	7	东
33	议	3	1.00	Small NS and consistent	294.15	5	义
34	忆	4	1.00	Small NS and consistent	68.9	4	乙
35	糖	3	1.00	Small NS and consistent	58.1	16	唐
36	肤	3	1.00	Small NS and consistent	36.95	8	夫
37	跨	3	1.00	Small NS and consistent	34.35	13	夸
38	按	3	1.00	Small NS and consistent	319.8	9	安
39	馆	3	1.00	Small NS and consistent	89.7	11	官
40	键	3	1.00	Small NS and consistent	65.85	13	建
41	档	3	1.00	Small NS and consistent	19.6	10	当
42	唱	4	1.00	Small NS and consistent	134.15	11	昌
43	镜	3	1.00	Small NS and consistent	127.55	16	竟
44	慌	3	1.00	Small NS and consistent	44.75	12	荒
45	讽	3	1.00	Small NS and consistent	14.65	6	风
46	舰	3	0.67	Small NS and inconsistent	26.5	10	见
47	叨	3	0.67	Small NS and inconsistent	9.8	5	刀
48	倦	3	0.67	Small NS and inconsistent	17.1	10	卷
49	扣	3	0.67	Small NS and inconsistent	38.5	6	口
50	揍	3	0.67	Small NS and inconsistent	3.85	12	奏
51	洲	3	0.67	Small NS and inconsistent	168.05	9	州
52	诫	3	0.67	Small NS and inconsistent	6.2	9	戒
53	粒	3	0.67	Small NS and inconsistent	90.9	11	立
54	逗	3	0.67	Small NS and inconsistent	12.55	10	豆
55	控	3	0.67	Small NS and inconsistent	134	11	空
56	描	3	0.67	Small NS and inconsistent	97.75	12	苗
57	阶	4	0.5	Small NS and inconsistent	626.75	6	介
58	殃	4	0.5	Small NS and inconsistent	2.7	9	央
59	碌	4	0.5	Small NS and inconsistent	16.65	13	录
60	狈	4	0.5	Small NS and inconsistent	5.25	7	贝

Number	Stimuli	NS	Number of Stokes	Phonetic radical	Number	Stimuli	NS	Number of Stokes	Phonetic radical
61	⿰讠付	5	7	付	91	⿰口丈	3	6	丈
62	⿰纟几	5	5	几	92	⿰氵才	3	6	才
63	⿰讠勾	5	6	勾	93	⿰扌义	3	6	义
64	⿰纟牙	5	7	牙	94	⿰纟劳	3	10	劳
65	⿰纟直	5	11	直	95	⿰月原	3	14	原
66	⿰忄胡	5	12	胡	96	⿰讠唐	3	12	唐
67	⿰石采	5	13	采	97	⿰氵代	3	8	代
68	⿰土马	5	6	马	98	⿰口竟	3	14	竟
69	⿰巾主	6	8	主	99	⿰亻息	3	12	息
70	⿰犭正	6	8	正	100	⿰扌风	3	7	风
71	⿰⻊申	6	12	申	101	⿰氵旨	3	9	旨
72	⿰阝主	6	7	主	102	⿰扌荒	3	12	荒
73	⿰纟正	6	8	正	103	⿰纟昌	4	11	昌
74	⿰讠申	6	7	申	104	⿰纟乙	4	4	乙
75	⿰讠直	5	10	直	105	⿰纟利	3	10	利
76	⿰讠门	5	5	门	106	⿰土先	4	9	先
77	⿰贝巨	5	9	巨	107	⿰贝出	4	9	出
78	⿰口户	6	7	户	108	⿰木勿	4	8	勿
79	⿰彳斩	5	10	斩	109	⿰土司	4	8	司
80	⿰讠弟	5	9	弟	110	⿰讠黑	4	14	黑
81	⿰月文	5	8	文	111	⿰贝多	4	10	多
82	⿰纟果	5	11	果	112	⿰贝央	4	8	央
83	⿰讠巴	6	6	巴	113	⿰日奇	4	12	奇
84	⿰贝旁	6	14	旁	114	⿰氵害	4	13	害
85	⿰纟反	6	7	反	115	⿰讠录	4	10	录
86	⿰目只	6	9	只	116	⿰氵两	3	10	两
87	⿰讠余	6	9	余	117	⿰亻州	3	8	州
88	⿰纟巴	6	7	巴	118	⿰口师	3	9	师
89	⿰纟支	6	7	支	119	⿰亻奏	3	11	奏
90	⿺辶己	7	6	己	120	⿰亻或	3	10	或

Appendix B

Stimuli of Experiment 1(b)

Stimuli number 1 to 60 are real characters; Stimuli number 61 to 120 are pseudo-characters.

Number	Stimuli	NS	Type Consist-ency	Condition	Frequency (per million)	Number of Stokes	Phonetic radical
1	谅	7	0.58	Large NS and high consistency	16.85	10	京
2	忙	8	0.5	Large NS and high consistency	188.85	6	亡
3	骗	6	0.5	Large NS and high consistency	38.55	12	扁
4	姓	6	0.5	Large NS and high consistency	72.2	8	生
5	玩	7	0.43	Large NS and high consistency	96.75	8	元
6	炮	9	0.44	Large NS and high consistency	72.05	9	包
7	晾	7	0.57	Large NS and high consistency	3.8	12	京
8	踌	6	0.5	Large NS and high consistency	4.55	14	寿
9	畔	7	0.43	Large NS and high consistency	11.3	10	半
10	炒	7	0.43	Large NS and high consistency	12.05	8	少
11	袍	9	0.44	Large NS and high consistency	12.9	9	包
12	哄	5	0.6	Large NS and high consistency	18.9	9	共
13	澄	5	0.4	Large NS and high consistency	12.4	15	登
14	咽	5	0.4	Large NS and high consistency	24.6	9	因
15	脾	5	0.4	Large NS and high consistency	30.25	12	卑
16	睛	8	0.25	Large NS and low consistency	152	13	青
17	积	6	0.17	Large NS and low consistency	410.95	10	只
18	措	8	0.25	Large NS and low consistency	86.6	11	昔
19	吟	5	0.2	Large NS and low consistency	19.45	7	今
20	嫌	6	0.17	Large NS and low consistency	20.4	13	兼
21	抢	7	0.29	Large NS and low consistency	73.7	7	仓
22	枯	7	0.29	Large NS and low consistency	30.8	7	古
23	妒	6	0.17	Large NS and low consistency	7.05	7	户
24	酿	7	0.29	Large NS and low consistency	12.6	14	良
25	睹	14	0.29	Large NS and low consistency	7.5	13	者
26	徘	9	0.22	Large NS and low consistency	6.55	11	非
27	歧	6	0.17	Large NS and low consistency	18.4	8	支

Number	Stimuli	NS	Type Consist-ency	Condition	Frequency (per million)	Number of Stokes	Phonetic radical
28	尴	5	0.2	Large NS and low consistency	5.2	13	监
29	侮	6	0.17	Large NS and low consistency	12.25	9	每
30	秒	7	0.29	Large NS and low consistency	41.55	9	少
31	扭	4	0.5	Small NS and high consistency	42.25	7	丑
32	械	3	0.33	Small NS and high consistency	87.45	11	戒
33	域	3	0.33	Small NS and high consistency	145.7	11	或
34	辖	4	0.5	Small NS and high consistency	24.35	14	害
35	媒	4	0.5	Small NS and high consistency	20.65	12	某
36	讼	4	0.75	Small NS and high consistency	17.55	6	公
37	瞧	3	0.33	Small NS and high consistency	53.3	17	焦
38	促	3	0.33	Small NS and high consistency	164.2	9	足
39	猾	3	0.67	Small NS and high consistency	5	12	骨
40	衬	3	0.33	Small NS and high consistency	20.55	7	寸
41	棒	3	0.33	Small NS and high consistency	29.4	12	奉
42	凑	3	0.33	Small NS and high consistency	25.55	11	奏
43	滩	4	0.75	Small NS and high consistency	34	13	难
44	棍	3	0.33	Small NS and high consistency	21.6	12	昆
45	腔	3	0.33	Small NS and high consistency	61.4	12	空
46	价	4	0.25	Small NS and low consistency	464.9	6	介
47	洗	4	0.25	Small NS and low consistency	83.5	9	先
48	睡	4	0.25	Small NS and low consistency	128.75	13	垂
49	移	4	0.25	Small NS and low consistency	181.7	11	多
50	椅	4	0.25	Small NS and low consistency	36.8	12	奇
51	绿	4	0.25	Small NS and low consistency	139.45	11	录
52	淡	4	0.25	Small NS and low consistency	78.75	11	炎
53	软	4	0.25	Small NS and low consistency	73.65	8	欠
54	袜	4	0.25	Small NS and low consistency	9.3	9	末
55	贬	4	0.25	Small NS and low consistency	11.7	8	乏
56	唾	4	0.25	Small NS and low consistency	10.05	11	垂
57	坝	4	0.25	Small NS and low consistency	16.45	7	贝
58	椒	4	0.25	Small NS and low consistency	10.15	12	叔
59	砍	4	0.25	Small NS and low consistency	23.15	9	欠
60	慨	4	0.25	Small NS and low consistency	21.75	12	既

Number	Stimuli	NS	Number of Stokes	Phonetic radical	Number	Stimuli	NS	Number of Stokes	Phonetic radical
61	⿰⻊莫	10	17	莫	91	⿺辶番	3	15	番
62	⿰钅扁	6	14	扁	92	⿰纟童	3	15	童
63	⿺辶兼	6	13	兼	93	⿰月咸	4	13	咸
64	⿰贝昔	8	12	昔	94	⿰钅奉	3	13	奉
65	⿰讠监	5	12	监	95	⿰日贵	3	13	贵
66	⿰饣青	8	11	青	96	⿰纟甚	4	12	甚
67	⿰贝肖	12	11	肖	97	⿰亻害	4	12	害
68	⿰日并	6	10	并	98	⿰纟某	4	12	某
69	⿰纟寿	6	10	寿	99	⿰车炎	4	12	炎
70	⿰女各	8	9	各	100	⿰扌责	3	11	责
71	⿰纟共	5	9	共	101	⿰木足	3	11	足
72	⿰纟寺	6	9	寺	102	⿰贝告	4	11	告
73	⿰日由	6	9	由	103	⿰女空	3	11	空
74	⿰纟羊	9	9	羊	104	⿰纟坐	3	10	坐
75	⿰贝中	7	8	中	105	⿰钅世	3	10	世
76	⿰阝舌	7	8	舌	106	⿰贝西	4	10	西
77	⿰纟古	7	8	古	107	⿰日多	4	10	多
78	⿰扌生	6	8	生	108	⿰贝失	4	9	失
79	⿰车者	14	12	者	109	⿰阝求	3	9	求
80	⿰阝半	7	7	半	110	⿰忄那	3	9	那
81	⿰土尤	6	7	尤	111	⿰讠里	4	9	里
82	⿰女反	6	7	反	112	⿰讠列	3	8	列
83	⿰贝高	5	14	高	113	⿰讠至	3	8	至
84	⿰讠予	6	6	予	114	⿰纟必	3	8	必
85	⿰讠今	5	6	今	115	⿰讠光	3	8	光
86	⿰讠仓	7	6	仓	116	⿰阝先	4	8	先
87	⿰扌亡	8	6	亡	117	⿰火见	3	8	见
88	⿰贝非	9	12	非	118	⿰火从	4	8	从
89	⿺辶勺	6	6	勺	119	⿰讠尔	3	7	尔
90	⿰贝丁	10	6	丁	120	⿰月千	3	7	千

Appendix C

Stimuli of Experiment 2

Stimuli number 1 to 64 are real words; Stimuli number 65 to 128 are pseudo-words.

Number	Stimuli (targeted characters are bold and underlined)	Targeted character's phonetic radical	Targeted character's NS	Targeted character's type consistency	Targeted character's condition	Targeted character's frequency (per million)	Targeted character's number of strokes	Non-targeted character's frequency (per million)	Non-targeted character's number of strokes
1	**跑**步	包	9	0.44	Large NS and high consistency	195.95	12	543.6	7
2	**偏**见	扁	6	0.5	Large NS and high consistency	109.1	11	937.7	4
3	**玩**具	元	6	0.5	Large NS and high consistency	96.75	8	649.4	8
4	**钞**票	少	7	0.43	Large NS and high consistency	8.4	9	70.45	11
5	**洪**水	共	5	0.6	Large NS and high consistency	69.35	9	1393.9	4
6	**何**必	可	5	0.6	Large NS and high consistency	433	7	702.45	5
7	**魅**力	未	5	0.6	Large NS and high consistency	11.35	14	1605.4	2
8	**偏**差	扁	6	0.5	Large NS and high consistency	109.1	11	264.45	9
9	肩**膀**	旁	6	0.83	Large NS and high consistency	42.5	14	61.8	8
10	匆**忙**	亡	8	0.5	Large NS and high consistency	188.85	6	41.25	5
11	着**凉**	京	6	0.5	Large NS and high consistency	59.45	10	2783.3	11
12	原**谅**	京	6	0.5	Large NS and high consistency	16.85	10	1016.75	10
13	黄**河**	可	5	0.6	Large NS and high consistency	306.6	8	303.2	11
14	荒**凉**	京	6	0.5	Large NS and high consistency	59.45	10	72.1	9
15	繁**忙**	亡	8	0.5	Large NS and high consistency	188.85	6	108.15	17
16	人**性**	生	6	0.5	Large NS and high consistency	1651.7	8	6081.4	2
17	**精**力	青	8	0.25	Large NS and low consistency	475.7	14	1605.4	2

Number	Stimuli (targeted characters are bold and underlined)	Targeted character's phonetic radical	Targeted character's NS	Targeted character's type consistency	Targeted character's condition	Targeted character's frequency (per million)	Targeted character's number of strokes	Non-targeted character's frequency (per million)	Non-targeted character's number of strokes
18	**排**斥	非	9	0.22	Large NS and low consistency	278	11	37	5
19	**破**产	皮	10	0.3	Large NS and low consistency	270.05	10	2122.45	6
20	**倘**若	尚	9	0.33	Large NS and low consistency	17.7	10	164.25	8
21	**坦**率	旦	5	0.2	Large NS and low consistency	68.4	8	263.9	11
22	**柜**台	巨	5	0.2	Large NS and low consistency	30.15	8	318.3	5
23	**浑**身	军	5	0.2	Large NS and low consistency	34.8	9	865.1	7
24	**慎**重	真	5	0.2	Large NS and low consistency	24.95	13	1299.35	9
25	名**牌**	卑	5	0.2	Large NS and low consistency	73.85	12	577.05	6
26	出**路**	各	8	0.25	Large NS and low consistency	655.1	13	3103	5
27	用**途**	余	6	0.33	Large NS and low consistency	116.55	10	2643.3	5
28	丝**绸**	周	6	0.33	Large NS and low consistency	13.4	11	129.05	5
29	无**耻**	止	6	0.33	Large NS and low consistency	17.25	10	1148.15	4
30	美**妙**	少	7	0.29	Large NS and low consistency	61.95	7	724.45	9
31	喜**悦**	兑	7	0.29	Large NS and low consistency	29.5	10	227.5	12
32	奔**驰**	也	6	0.33	Large NS and low consistency	22.45	6	69.9	8
33	**侧**面	则	4	0.75	Small NS and high consistency	85.7	8	1932.15	9
34	**峡**谷	夹	4	0.75	Small NS and high consistency	21.9	9	92.2	7
35	**秘**书	必	3	0.67	Small NS and high consistency	94.8	10	496.35	4
36	**押**金	甲	3	0.67	Small NS and high consistency	22.1	8	598.2	8
37	**词**典	司	4	0.5	Small NS and high consistency	226.3	7	127.7	8
38	**媒**介	某	4	0.5	Small NS and high consistency	20.65	12	176.45	4

Number	Stimuli (targeted characters are bold and underlined)	Targeted character's phonetic radical	Targeted character's NS	Targeted character's type consistency	Targeted character's condition	Targeted character's frequency (per million)	Targeted character's number of strokes	Non-targeted character's frequency (per million)	Non-targeted character's number of strokes
39	**握**手	屋	2	0.5	Small NS and high consistency	162.65	12	966.25	4
40	**迹**象	亦	2	0.5	Small NS and high consistency	82.35	9	1130.6	11
41	光**滑**	骨	3	0.67	Small NS and high consistency	60.05	12	732.1	6
42	气**概**	既	4	0.5	Small NS and high consistency	196.9	13	1116.35	4
43	不**堪**	甚	4	0.5	Small NS and high consistency	24.45	12	8324.05	4
44	奥**秘**	必	3	0.67	Small NS and high consistency	94.8	10	54.9	12
45	事**迹**	亦	2	0.5	Small NS and high consistency	82.35	9	1522.6	8
46	总**统**	充	2	0.5	Small NS and high consistency	732.7	9	696.7	9
47	采**纳**	内	2	0.5	Small NS and high consistency	115.45	7	338.2	8
48	坚**硬**	更	3	0.5	Small NS and high consistency	98.35	12	236.7	7
49	**移**民	多	4	0.25	Small NS and low consistency	181.7	11	1644.65	5
50	**淡**水	炎	4	0.25	Small NS and low consistency	78.75	11	1393.9	4
51	**进**步	井	4	0.25	Small NS and low consistency	1803.45	7	543.6	7
52	**拟**定	以	4	0.25	Small NS and low consistency	40	7	1773.7	8
53	**减**少	咸	4	0.25	Small NS and low consistency	190.5	11	819.25	4
54	**挽**回	免	3	0.33	Small NS and low consistency	19.95	10	806.1	6
55	**凑**合	奏	3	0.33	Small NS and low consistency	25.55	11	1169.55	6
56	**现**成	见	3	0.33	Small NS and low consistency	2152	8	2662.95	6
57	应**酬**	州	3	0.33	Small NS and low consistency	24.35	13	1153.65	7
58	区**域**	或	3	0.33	Small NS and low consistency	145.7	11	692.9	4
59	广**播**	番	3	0.33	Small NS and low consistency	117.1	15	432.3	3

Number	Stimuli (targeted characters are bold and underlined)	Targeted character's phonetic radical	Targeted character's NS	Targeted character's type consistency	Targeted character's condition	Targeted character's frequency (per million)	Targeted character's number of strokes	Non-targeted character's frequency (per million)	Non-targeted character's number of strokes
60	口**腔**	空	3	0.33	Small NS and low consistency	61.4	12	716.9	3
61	表**现**	见	3	0.33	Small NS and low consistency	2152	8	1142.05	8
62	或**许**	午	3	0.33	Small NS and low consistency	545.85	6	882.5	8
63	成**绩**	责	3	0.33	Small NS and low consistency	68.7	11	2662.95	6
64	仓**促**	足	3	0.33	Small NS and low consistency	164.2	9	33.05	4
65	**榜**布	旁	6	0.83	Large NS and high consistency	15.9	14	380.5	5
66	**狼**步	良	7	0.57	Large NS and high consistency	31.9	10	543.6	7
67	**玩**产	元	7	0.43	Large NS and high consistency	96.75	8	2122.45	6
68	**偏**身	扁	6	0.5	Large NS and high consistency	109.1	11	865.1	7
69	**谅**害	京	6	0.5	Large NS and high consistency	16.85	10	243.65	10
70	**棵**而	果	5	0.6	Large NS and high consistency	32.95	12	2470.9	6
71	**河**言	可	5	0.6	Large NS and high consistency	306.6	8	478.2	7
72	**烘**止	共	5	0.6	Large NS and high consistency	10.65	10	228	4
73	平**哄**	共	5	0.6	Large NS and high consistency	18.9	9	934.75	5
74	本**忙**	亡	8	0.5	Large NS and high consistency	188.85	6	1587	5
75	单**凉**	京	6	0.5	Large NS and high consistency	59.45	10	487.7	8
76	充**性**	生	6	0.5	Large NS and high consistency	1651.7	8	270.65	6
77	电**泡**	包	9	0.44	Large NS and high consistency	57.45	8	903.85	5
78	争**膀**	旁	6	0.83	Large NS and high consistency	42.5	14	534.85	6
79	回**浪**	良	7	0.57	Large NS and high consistency	107.15	10	806.1	6
80	展**昧**	未	5	0.6	Large NS and high consistency	11.05	9	1112	10

Number	Stimuli (targeted characters are bold and underlined)	Targeted character’s phonetic radical	Targeted character’s NS	Targeted character’s type consistency	Targeted character’s condition	Targeted character’s frequency (per million)	Targeted character’s number of strokes	Non-targeted character’s frequency (per million)	Non-targeted character’s number of strokes
81	**枪**果	仓	7	0.29	Large NS and low consistency	117.85	8	928.65	8
82	**海**成	每	6	0.17	Large NS and low consistency	801.1	10	2662.95	6
83	**池**力	也	6	0.33	Large NS and low consistency	25.95	6	1605.4	2
84	**透**员	秀	5	0.2	Large NS and low consistency	130.8	10	745.05	7
85	**波**方	皮	10	0.2	Large NS and low consistency	213	8	2061.1	4
86	**抢**色	仓	7	0.29	Large NS and low consistency	73.7	7	660.1	6
87	**精**非	青	8	0.25	Large NS and low consistency	475.7	14	440.7	8
88	**填**必	真	5	0.2	Large NS and low consistency	39.6	13	702.45	5
89	变**绸**	周	6	0.33	Large NS and low consistency	13.4	11	1018.4	8
90	手**娘**	良	7	0.29	Large NS and low consistency	204.4	10	966.25	4
91	采**慎**	真	5	0.2	Large NS and low consistency	24.95	13	338.2	8
92	参**耻**	止	6	0.33	Large NS and low consistency	17.25	10	309.75	8
93	承**酿**	良	7	0.29	Large NS and low consistency	12.6	14	186.95	8
94	复**脾**	卑	5	0.2	Large NS and low consistency	73.85	12	399.3	9
95	风**驰**	也	6	0.33	Large NS and low consistency	22.45	6	585.85	3
96	表**渐**	斩	5	0.2	Large NS and low consistency	197.1	11	1142.05	8
97	**懒**立	赖	3	0.67	Small NS and high consistency	20.05	16	892.3	5
98	**秘**象	必	3	0.67	Small NS and high consistency	94.8	10	1130.6	11
99	**媒**向	某	4	0.5	Small NS and high consistency	20.65	12	1074	6
100	**抚**示	无	2	0.5	Small NS and high consistency	35.25	7	352.9	5
101	**谈**告	炎	4	0.5	Small NS and high consistency	272.65	10	325.7	7

Number	Stimuli (targeted characters are bold and underlined)	Targeted character's phonetic radical	Targeted character's NS	Targeted character's type consistency	Targeted character's condition	Targeted character's frequency (per million)	Targeted character's number of strokes	Non-targeted character's frequency (per million)	Non-targeted character's number of strokes
102	**暗**局	音	2	0.5	Small NS and high consistency	127.6	13	285.15	7
103	**讼**前	公	4	0.75	Small NS and high consistency	17.55	6	1421	9
104	**况**事	兄	2	0.5	Small NS and high consistency	447.85	7	1522.6	8
105	光**松**	公	4	0.75	Small NS and high consistency	142.6	8	732.1	6
106	比**院**	完	2	0.5	Small NS and high consistency	321.65	9	931.4	4
107	从**煤**	某	4	0.5	Small NS and high consistency	70.2	13	1639.8	4
108	后**眠**	民	2	0.5	Small NS and high consistency	32.9	10	2132.15	6
109	出**淀**	定	2	0.5	Small NS and high consistency	25.2	11	3103	5
110	反**掘**	屈	2	0.5	Small NS and high consistency	30.5	11	915.4	4
111	原**脚**	却	2	0.5	Small NS and high consistency	207.95	11	1016.75	10
112	关**纽**	丑	4	0.5	Small NS and high consistency	23.55	7	1194.15	6
113	**短**业	豆	3	0.33	Small NS and low consistency	188.5	12	1517.65	5
114	**价**术	介	4	0.25	Small NS and low consistency	464.9	6	764.8	5
115	**泄**自	世	3	0.33	Small NS and low consistency	25.95	8	2170.6	6
116	**棍**具	昆	3	0.33	Small NS and low consistency	21.6	12	649.4	8
117	**彻**面	切	3	0.33	Small NS and low consistency	93.95	7	1932.15	9
118	**轨**民	九	4	0.25	Small NS and low consistency	47.6	6	1644.65	5
119	**衬**然	寸	3	0.33	Small NS and low consistency	20.55	8	1840.1	12
120	**纤**有	千	3	0.33	Small NS and low consistency	37.4	6	7061.05	6
121	丰**洞**	同	4	0.25	Small NS and low consistency	98.2	9	173.5	4
122	气**仇**	九	4	0.25	Small NS and low consistency	29.95	4	1116.35	4

Number	Stimuli (targeted characters are bold and underlined)	Targeted character's phonetic radical	Targeted character's NS	Targeted character's type consistency	Targeted character's condition	Targeted character's frequency (per million)	Targeted character's number of strokes	Non-targeted character's frequency (per million)	Non-targeted character's number of strokes
123	合**械**	戒	3	0.33	Small NS and low consistency	87.45	11	1169.55	6
124	其**诉**	斥	3	0.33	Small NS and low consistency	171.05	7	1392.1	8
125	水**棒**	奉	3	0.33	Small NS and low consistency	29.4	12	1393.9	4
126	火**域**	或	3	0.33	Small NS and low consistency	145.7	11	382.75	4
127	公**耗**	毛	3	0.33	Small NS and low consistency	74.25	10	839.45	4
128	无**训**	川	3	0.33	Small NS and low consistency	141.25	5	1148.15	4

Appendix D

Consent Form

UNIVERSITY OF CINCINNATI SOCIAL, BEHAVIORAL, AND EDUCATIONAL CONSENT TO PARTICIPATE IN A RESEARCH STUDY

STUDY TITLE: *The orthographic regularity, consistency and neighborhood size effects in reading Chinese as L1 and L2*	
PRINCIPAL INVESTIGATOR NAME: ***Xiao Luo***	**PHONE NUMBER (24-hour Emergency Contact)** ***+1(513)305-5856***
FACULTY ADVISOR (if PI is student): ***Hye K. Pae, Ph.D.***	**DEPARTMENT:** **College of Education, Criminal Justice, and Human Services**

KEY INFORMATION

Purpose of the Study:	*The purpose of this research is to understand how learners of Chinese language read Chinese characters and words and what characteristics of the Chinese writing system play important roles in the reading process.*
Length of the Study:	*Each individual participant will finish experiments within approximately 30 minutes to 45 minutes.* *The whole research project will last for approximately one year to finish.*
Risks:	*No known risks.*
Benefits of the Study:	*There is no direct benefit because of being in this study. However, being in this study may help researchers and educators of Chinese as a second language to understand how learners learn and read Chinese characters and words.*
Alternative procedures:	*Not Applicable.*

INTRODUCTION

You are being asked to take part in a research study. Please read this paper carefully and ask questions about anything that you do not understand.

This research is funded by the CECH 2019-2020 Graduate Student and Faculty Research Mentoring Grant 2by College of Education, Criminal Justice and Human Services of the University of Cincinnati.

WHO IS DOING THIS RESEARCH STUDY?

The person in charge of this research study is Xiao Luo of the School of Education at the University of Cincinnati (UC) School of Education. He is being guided in this research by Dr. Hye K. Pae.

WHAT IS THE PURPOSE OF THIS RESEARCH STUDY?

The purpose of this research is to understand how learners of Chinese language read Chinese characters and words and what characteristics of the Chinese writing system play important roles in the reading process.

WHO WILL BE IN THIS RESEARCH STUDY?

About 150 people will take part in this study. You may be in this study if you:

- have normal or corrected-to-normal vision
- 18 years of age or older
- learners of Mandarin as a second/foreign language OR learners of Cantonese as a second/foreign language OR native Chinese speakers
- can speak and/or understand English as a first/second/foreign language

WHAT WILL YOU BE ASKED TO DO IN THIS RESEARCH STUDY, AND HOW LONG WILL IT TAKE?

You will be asked to complete computerized reading tasks (i.e. naming tasks and/or lexical decision tasks), a language history questionnaire, and/or character pronunciation knowledge tests, and/or some other surveys. It will take about 30 minutes to 45 minutes. The research will take place in a university classroom/library/office room OR you can take the tests online at your own home. Your names, contacts and other identifiable information will only be collected for the purpose of this research. When a paper is published from this study, your data will not be reported individually but will be arrogated with other participants' data. Your personal data will NOT be disclosed to a third party.

ARE THERE ANY RISKS TO BEING IN THIS RESEARCH STUDY?

It is not expected that you will be exposed to any risk by being in this research study.

ARE THERE ANY BENEFITS FROM BEING IN THIS RESEARCH STUDY?

You will probably not get any benefit from being in this study. However, your participation in this study may help researchers and educators of Chinese as a second language understand how learners learn and read Chinese characters.

WHAT WILL YOU GET BECAUSE OF BEING IN THIS RESEARCH STUDY?

You will be paid a gift card or cash worth of 50 RMB (equivalent to 7USD) for your time and travel. You will be paid once you successfully finish all tasks.

DO YOU HAVE CHOICES ABOUT TAKING PART IN THIS RESEARCH STUDY?

If you do not want to take part in this research study you may simply not participate and let the PI know that you do not want to take part in the research via email or by phone calls or notify the PI in person.

HOW WILL YOUR RESEARCH INFORMATION BE KEPT CONFIDENTIAL?

Information about you will be kept private by using a study ID number instead of the participant's name on the research forms, limiting access to research data to researcher, and keeping research data on a password-protected computer.

Your information will be kept in a locked cabinet in the researcher's office for 5 years. After that it will be destroyed by disposing of all paper documents.

Participant's identity and his/her research data are not disclosed beyond the research team:

1. LOCATION: The questionnaire data will be stored in a locked cabinet in the principal researcher's office. Signed consent document and master lists of participant names and ID numbers will be stored in a separate, locked cabinet in the researcher's office. The computer files will be password-protected.

2. HOW LONG:
   a. Identifiers such as name will be deleted as soon as possible. Birth date, M-number, and other types of identifiable information will not be collected.
   b. Hard copies of signed consent documents will be kept at Dr. Hye Pae's office for five years after the study is closed.
   c. Raw data will be kept in the PI's laptop for ten years after the study is closed.

3. HOW DATA WILL BE DISCARDED:
   a. removing participant's name from all research data
   b. deleting computerized records
   c. shredding paper research files

4. USE OF IDENTIFIERS
   The data from this research study may be published; but you will <u>not</u> be identified by name.

   Agents of the University of Cincinnati may inspect study records for audit or quality assurance purposes.

Information that could identify you will be removed from the study data. The study data will not be used or shared for future research studies. The researcher cannot promise that information sent by the internet or email will be private.

WHAT ARE YOUR LEGAL RIGHTS IN THIS RESEARCH STUDY?

Nothing in this consent form waives any legal rights you may have. This consent form also does not release the investigator, the College of Education, Criminal Justice, and Human Services of the University of Cincinnati, the institution, or its agents from liability for negligence.

WHAT IF YOU HAVE QUESTIONS ABOUT THIS RESEARCH STUDY?

If you have any questions or concerns about this research study, you should contact Xiao Luo at luoxo@mail.uc.edu or (513) 305-5856. Or, you may contact Dr. Hye K. Pae at hye.pae@uc.edu.

The UC Institutional Review Board reviews all research projects that involve human participants to be sure the rights and welfare of participants are protected.

If you have questions about your rights as a participant, complaints and/or suggestions about the study, you may contact the UC IRB at (513) 558-5259. Or, you may call the UC Research Compliance Hotline at (800) 889-1547, or email the IRB office at irb@ucmail.uc.edu.

DO YOU HAVE TO TAKE PART IN THIS RESEARCH STUDY?

No one has to be in this research study. Refusing to take part will NOT cause any penalty or loss of benefits that you would otherwise have. You may skip any questions that you don't want to answer.

You may start and then change your mind and stop at any time. To stop being in the study, you should contact the principal investigator (Mr. Xiao Luo) at luoxo@mail.uc.edu or (513) 305-5856. You can also notify him of your withdrawal in person.

Agreement:

I have read this information and have received answers to any questions I asked. I give my consent to participate in this research study. I will receive a copy of this signed and dated consent form to keep.

Participant Name (please print) ____

Participant Signature ____ Date _______

Signature of Person Obtaining Consent _____________________________ Date _______

Appendix E

Participant Demographic Information and Language History Information Form

1. Age: ( )

2. Gender: ( )

3. HSK scores: ( )

4. What is your native language(s): ( )

5. What other languages do you speak? ( )

6. Since what year did you start learning Chinese regardless of locality? ( )

7. Since what age did you start learning Chinese regardless of locality? ( )

8. For how long have you been in this country (China)? ( ) (in months)

9. Rate your own Chinese proficiency below

(1 means minimal proficiency level, 10 means native-like)

Speaking	1	2	3	4	5	6	7	8	9	10
Listening	1	2	3	4	5	6	7	8	9	10
Reading	1	2	3	4	5	6	7	8	9	10
Writing	1	2	3	4	5	6	7	8	9	10

Curriculum Vitae

罗骁
Luo, Xiao (Peter)
(DOB: February 08, 1991)
School of Education
University of Cincinnati
Cincinnati, Ohio 45220, U.S.A.
Email: luoxo@mail.uc.edu

EDUCATION

- **University of Cincinnati**, Ohio, U.S.A., 2021
  Ph.D. in Educational Studies, GPA: 3.95/4.0
  - Concentration: Second Language Studies
  - Dissertation: *The Effect of Orthographic Neighborhood Size and Consistency on Character and Word Reading by Learners of Chinese as a Second Language and Native Chinese Speakers*.
  - Committee: Drs. Hye K. Pae (Chair); Haiyang Ai; Tina Stanton-Chapman; Fengyang Ma

- **The Hong Kong Polytechnic University**, Hong Kong S.A.R., China, 2015
  M.A. (with Distinction) in Teaching Chinese as a Foreign Language, GPA: 3.75/4.0

- **Shenzhen University**, Guangdong, China, 2014
  B.A. in English and French Bilingual Program (5-year Program)
  Exchange Program, Hankuk University of Foreign Studies, Seoul, South Korea, 2011-2012

RESEARCH INTERESTS & SKILLS

- Second language reading and writing
- Visual word recognition and psycholinguistics
- English, Chinese, and Korean as a second (L2) or a foreign language
- Using R for statistical data analysis
- Programming psycholinguistic experiments using *Inquisit 6*

PUBLICATIONS

Peer-reviewed journals

- Pae, H. K., Sun, J., **Luo, X.**, Ai, H., Ma, F., Yang, N., & Xia, D. (Accepted). Linguocultural Cognition Manifested in Spoken Narratives in L2 English by Native Chinese and Korean Speakers. Manuscript submitted to *Journal of Cultural Cognitive Science*.

Book chapters

- Pae, H. K., Kim, S.-A., & **Luo, X.** (2018). Constituent processing or gestalt processing? How native Korean speakers read mutilated words in English. In H. K. Pae (Ed.), *Writing systems, reading processes, and cross-linguistic influences: Reflections from the Chinese, Japanese,* *and Korean languages* (pp. 335-352). Amsterdam/Philadelphia: John Benjamins Publishing Company. (link)

Proceedings

- **Luo, X.**, Yang, Y., Sun, J., & Chen, N. (2019). Correspondence between the Korean and Mandarin Chinese pronunciations of Chinese characters: A comparison at the subsyllabic level. In H. Dahlberg-Dodd, M. Nakayama, M. K. M. Chen, & Z. Xie (Eds.), *Buckeye East Asian linguistics: Volume 4* (pp. 46-56). Columbus, OH: Ohio State University Library. [ISSN: 2378-9387]. (link)

- **Luo, X.**, Yang, Y., & Sun, J. (2018). A study on the Korean and Chinese pronunciations of Chinese characters and learning Korean as a second language. In S. Politzer-Ahles, Y.-Y. Hsu, C.-R. Huang, & Y. Yao (Eds.), *Proceedings of the 32nd Pacific Asia conference on language, information and computation* (pp. 428-436). Hong Kong S.A.R.: Association for Computational Linguistics. (link)

PRESENTATIONS

Presentations as the 1st author/lead presenter

- **Luo, X.*** (2021, March). A study on ESL learners' use of textual and interpersonal Themes in oral English narratives. Paper presented at the American Association for Applied Linguistics 2021 Conference (AAAL 2021). Virtual Conference, United States. (link)

- **Luo, X.***, & Pae, H. K. (2020, October). Neighborhood size effects on L2 Chinese phonogram and word reading. Paper presented at the 2020 Second Language Research Forum (SLRF 2020). Vanderbilt University, Nashville, Tennessee. (link, program p. 21)

- **Luo, X.***, Sun, J., & Xia, D. (2020, October). ESL learners' use of Theme in spoken English narratives. Paper presented at the 2020 Second Language Research Forum (SLRF 2020). Vanderbilt University, Nashville, Tennessee. (link, program p. 38)

- **Luo, X.*** (2020, September). Theme choices in CSL writing and cross-linguistic effects: A corpus-based study. Paper presented at the 32nd North American Conference on Chinese Linguistics (NACCL 32, 第 32 屆北美漢語語言學會議). University of Connecticut, Storrs, Connecticut. (link)

- **Luo, X.*** (2020, June). Effectiveness of phonetic radicals: A comparison between Cantonese and Mandarin. Paper presented at the Third Forum on Cantonese Linguistics (FoCaL-3, 第三屆粵語語言學論壇). The Hang Seng University of Hong Kong, Hong Kong S.A.R. (link)

- **Luo, X.***, & Pae, H. K. (2020, March). The orthographic consistency effect and neighborhood size effect in reading Chinese as a second language. Paper presented at 2020 Spring Research Conference. University of Cincinnati, Cincinnati, Ohio. (link)

- **Luo, X.***, & Xia, D. (2019, October). Textual Theme in ESL writing: A pilot study from the systemic functional linguistic perspective. Paper presented at the 2019 Mid-Western

Educational Research Association Annual Meeting (MWERA 2019). University of Cincinnati, Cincinnati, Ohio. (link)

- **Luo, X.**, Yang, Y.*, & Sun, J. (2018, December). A study on the Korean and Chinese pronunciations of Chinese characters and learning Korean as a second language. Paper presented at the 32nd Pacific Asia Conference on Language, Information and Computation (PACLIC 2018). The Hong Kong Polytechnic University, Kowloon, Hong Kong S.A.R. (link)

- **Luo, X.***, & Yang, Y. (2018, November). Pronunciation of initial consonants in Chinese characters: Correspondence between Chinese and Korean based on the new HSK vocabulary. Paper presented at International Conference of Chinese Language Teaching and Research (ICCLTR 2018, 2018 年国际汉语教学研讨会). University of California, Santa Barbara, California. (link)

- **Luo, X.***, Yang, Y., Sun, J., & Chen, N. (2018, October). A descriptive study on the Chinese pronunciation of Korean Hanja at the syllable level. Poster session presented at the Buckeye East Asian Linguistics Forum 3 (BEAL Forum 2018). The Ohio State University, Columbus, Ohio. (link)

- † **Luo, X.**, Sun, J., & Pae, H. K. (Accepted). Cross-linguistic effects: Differences in rhetoric structures among native speakers of Chinese, Korean, and English. Paper presented at 2018 Spring Research Conference. University of Louisville, Louisville, Kentucky. (link)

- **Luo, X.***, & Pae, H. K. (2017, April). The role of the top part of the word in reading: How native and nonnative speakers of English process partial texts in English. Paper presented at 2017 Spring Research Conference. University of Cincinnati, Cincinnati, Ohio. (link)

- **Luo, X.***, Pae, H. K., & Kim, S.-A. (2017, March). Partial information and gestalt perception: How native and nonnative speakers of English process mutilated texts in English. Paper presented at the American Association for Applied Linguistics 2017 Conference (AAAL 2017). Portland, Oregon. (link)

Presentations as a co-author

- Yang N.*, Headley, G., & **Luo, X.*** (2021, March). A mixed methods study on prior language input, inner speech, and college EFL reading fluency. Paper presented at the American Association for Applied Linguistics 2021 Conference (AAAL 2021). Virtual Conference, United States. (link)

- Sun, J.*, Pae, H. K., & **Luo, X**. (2020, October). The effects of intra-word structures on Chinese compound word recognition among native and nonnative readers. Paper presented at the 2020 Second Language Research Forum (SLRF 2020). Vanderbilt University, Nashville, Tennessee. (link, program p. 16)

- Yang, N.*, Han, S., Headley, G., **Luo, X.***, & Williams, K*. (2020, October). Chinese college students' inner speech and ESL reading fluency: A mixed methods study. Paper presented at the 2020 Second Language Research Forum (SLRF 2020). Vanderbilt University, Nashville, Tennessee. (link, program p. 48)

- Yang, N.*, Ramanayake, S.*, Zhang, J., Zhao, W., **Luo, X.***, & Williams, K. (2020, October). Inner speech in L2 sentence comprehension: The roles of inhibitory control and working memory. Paper presented at the 2020 Second Language Research Forum (SLRF 2020). Vanderbilt University, Nashville, Tennessee. (link, program p. 40)

- Yang, N.*, Han, S., **Luo, X.**, Williams, K, & Mckinley, K. (2019, October). A mixed-methods study on inner speech: An overlooked construct in Chinese ESL students' English reading. Paper presented at China English Language Education Association (CELEA) 2019. Central China Normal University, Wuhan, China.

- Xia, D.*, & **Luo, X.** (2019, October). EFL students' voice construction in reflective writing. Paper presented at the 2019 Mid-Western Educational Research Association Annual Meeting (MWERA 2019). University of Cincinnati, Cincinnati, Ohio. (link)

- Xia, D.*, Ai, H., & **Luo, X.** (2019, September). Lexical bundles in authentic and classroom business letters. Paper presented at the 2019 Second Language Research Forum (SLRF 2019). Michigan State University, East Lansing, Michigan. (link)

- Nguyen, T.*, Pae, H. K., Sun, J., & **Luo, X.** (2019, April). The use of argument structures by native and nonnative speakers of English: Topic-prominent versus character-prominent narrative. Undergraduate Scholarly Showcase. University of Cincinnati, Cincinnati, Ohio. (link)

* Presenter(s) † Paper(s) accepted but unable to attend

RESEARCH EXPERIENCES

- Project: "The Orthographic Regularity, Consistency and Neighborhood Size Effects in Reading Chinese as L1 and L2" (IRB: 2020-0153)
  Responsibility/Role: **Principal Investigator (PI)**
  Supervisor: Dr. Hye K. Pae, 2020 to date

- Project: "Investigating Theme Usages in College ESL Students' Writing: How L1 Backgrounds and L2 Proficiencies Make Differences?" (IRB: 2020-0061)
  Responsibility/Role: **Principal Investigator (PI)**, 2019 to date

FUNDED GRANTS

- **Luo, X.**, & Pae, H. K. (2020). *CECH 2019-2020 Graduate Student and Faculty Research Mentoring Grant* (1,000 USD). College of Education, Criminal Justice, and Human Services (CECH), University of Cincinnati.

- **Luo, X.**, & Pae, H. K. (2018). *CECH 2017-2018 Graduate Student and Faculty Research Mentoring Grant* (1,000 USD). College of Education, Criminal Justice, and Human Services (CECH), University of Cincinnati.

TEACHING EXPERIENCE

- **Graduate Teaching Assistant** (Sole Instructor), Center for English as a Second Language (ESL), School of Education, University of Cincinnati, 08/2016 to 05/2021
  Students' evaluation of instructor: average **4.77/5.0**
  Courses taught:
  - ***ESL2089 Intermediate Composition for International Students*** (Undergraduate):
    - *2019 Spring*, *2020 Spring*, *2021 Spring*
  - ***ESL1068 Foundations of Academic Reading and Writing for ESL*** (Undergraduate):
    - *2016 Fall*, *2017 Spring*, *2017 Fall*, *2018 Spring*, *2018 Fall*, *2019 Spring*, *2019 Fall*, *2020 Summer*, *2020 Fall*, *2021 Spring*
  - ***ESL1072 Foundations of Academic Oral Communication for ESL*** (Undergraduate):
    - *2016 Fall*, *2017 Fall*, *2018 Spring*, *2018 Fall*
  - ***ESL1073 Success in Academic Oral Communication*** (Undergraduate):
    - *2020 Spring* (co-taught with Ms. Detong Xia)

SCHOLARSHIPS

- Scholarship for Graduate Assistant, sponsored by the Graduate School, University of Cincinnati:
  - 2016-17 academic year, 2017-18 academic year, 2018-19 academic year, 2019-20 academic year, 2020-21 academic year

- Scholarship for Distinguished Postgraduate Students, Department of Chinese and Bilingual Studies, The Hong Kong Polytechnic University, 2015

OTHER EXPERIENCES

- **Project Assistant** (Full-Time), Department of Chinese and Bilingual Studies, The Hong Kong Polytechnic University, 07/2015-07/2016
  Assisted in the teaching of the following undergraduate course (Supervisor: Dr. Sun-A Kim):
  - CBS10B3 East Asia: Towards a Global Community with Cultural Diversity

- **Student Helper**, Department of Chinese and Bilingual Studies, The Hong Kong Polytechnic University, 05/2015 - 06/2015
  Assisted with the research project of Dr. Xinhua Zhu

HORNORS

- CBS Prize for Distinguished Postgraduate Students 2014/15, Department of Chinese and Bilingual Studies, The Hong Kong Polytechnic University, 2015

- Merit Certificate for performing outstandingly in the Chinese Language and Culture Voluntary Tutoring Program, The Hong Kong Polytechnic University, 2014

- Prize for Outstanding Academic Performance, the Center for Korean Language and Culture, Hankuk (Korea) University of Foreign Studies, Seoul, Republic of Korea, 2011

- Winner in the 6th Korean Speech Contest jointly awarded by the Chinese University of Hong Kong and the Ministry of Culture, Sports and Tourism, Republic of Korea, 2010

SERVICES

- Vice President, Graduate Student Association (GSA), College of Education, Criminal Justice, and Human Services, University of Cincinnati, 2018-2019

- Speech Therapy: Learning through Community Service, the Speech Therapy Unit (STU), The Hong Kong Polytechnic University, 2015

- Voluntary Student Tutor in the Chinese Language and Culture Voluntary Tutoring Program, The Hong Kong Polytechnic University, 2014

CERTIFICATES

- Graduate Certificate in Teaching English to Speakers of Other Languages (TESOL), University of Cincinnati, 2018

- CITI (Collaborative Institutional Training Initiative) Program Certificate for Research Ethics and Compliance Training, U.S.A., 2016, 2020

- IELTS (International English Language Testing System), 2015:
  Listening 7.0, Reading 7.5, Writing 7.5, Speaking 7.0, Overall Score 7.5, CEFR Level: C1

- TOPIK (Test of Proficiency in Korean/한국어능력시험/韓國語能力試驗), National Institute for International Education, Republic of Korea, 2014:
  Listening 74/100, Writing 53/100, Reading 84/100, Total Score 211/300, Level: 5 (5 급)

- Putonghua Proficiency Test (The official test of spoken fluency in Standard Chinese for native Chinese speakers), Level 2-A, 2012

LANGUAEGS

- Native language: Mandarin Chinese
- Full professional proficiency: English, Korean, Cantonese
- Limited proficiency: Japanese

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