The Effect of Neighborhood Size and Morphology in the Chinese Language

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THE EFFECT OF NEIGHBORHOOD SIZE AND MORPHOLOGY ON
CHINESE LANGUAGE CHARACTER PROCESSING

by

LONG NGUYEN

A dissertation submitted in partial fulfillment of the requirements
for the Honors in the Major Program in Psychology
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ABSTRACT
The Neighborhood Size Effect (NSE), characterized as the effect in word determination based on changing one orthographic aspect of that word. The amount of words that can be created through such manipulation is called a neighborhood size (NS). Number of other factors such as frequency, how often a word appears and morphology, the combination of meaningful word units, have been suggested to have an overriding effect on NSE. In addition, there is a lack of research on NSE with non-alphabetical languages such as Chinese, which uses characters comprising of a multitude of semantic or phonetic markers. In this experiment, participants coming from mainland China were presented with 60 individual characters and 59 characters with Chinese morphology made up of two characters which form single words. Both conditions, were manipulated with NS by adjusting the semantic or phonetical radical within a character and with frequency by using a website that measures how frequent a character appeared within the language. Both character conditions were found to have a significant effect with frequency and neighborhood size (NS) with characters with higher frequency and lower NS found to have higher accuracy and lower reaction times. With low frequency single characters, it was that those with higher neighborhood size had greater delay in reaction time and lower accuracy. With low frequency morphologically constructed characters, it was found that lower neighborhood size had higher accuracy, but no significant result with regards to reaction time. Due to differing accuracy results with NS and character condition, it is suggested that further factors such as morphological processing in single characters and bigram frequency in morphologically constructed characters might have an effect on word determination in conjunction with
neighborhood size. Thus, it is a possibility that Chinese morphological may depend more on other factors than neighborhood size.
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CHAPTER 1: INTRODUCTION

Imagine playing a game of scrabble and you see a familiar root to a word, like “-ide” or “-ing”, but you only have a couple of letters available to you like “y” or “x”, which combined to these root words might or might not make a proper word. However, identifying proper words can be easier when choices are limited, like “-dol”, which can be either “doll” or “idol”, but not many other words. Based on this idea, Coltheart et al. (1977) describes a neighborhood size (NS) as the number words that could be created by changing one letter in a target word while keeping the position of other letters the same. Therefore, according to this definition, an example a target word like “sing” would have many more neighbors (ex. Sine, ding, wing, bong, ping, song) than a target word like “soap” (soar, soak), thus sing has a larger NS than soap. In non-word determination it was found that larger NS result in a larger delay in reaction time (Coltheart et al., 1977). In a study comparing German children readers to English children readers, it was found that German readers were able to detect inconsistent phonemes more accurately than English due to the higher level consistency within the language (Goswami et al., 2005). Thus, consistency differences between different languages can affect language processing. In addition, other languages may have a lack of letters or even an alphabet, instead these types of languages can be made up of symbols that can either give phonetic or semantic meaning. Recent research on the NS effect has explored such differences in languages that lack an alphabet (Tsai et al., 2006). Initial studies on Chinese NS effect in 2006 replicated the procedure done by studies on English, where a typical Chinese word consisting of two characters had one of the characters replaced (Li et al, 2015). For example a target word 包子 (bāozi, steamed) can have one of its
character replaced to make neighbors like 包容 (bāoróng, to pardon) or 样子 (yàngzi, appearance). However, the initial studies in NS effect done by Li et al. and Huang et al., brought in two contrasting results, where one study found a significant NS effect and another study found no such NS effect. In order to solve these conflicting results (Li et al., 2015), researchers have looked at the NS effect of individual Chinese characters and the NS effect of Chinese word compositions or morphology, since most Chinese words consist of two or more characters. In the research with single character effect, it was found that there was a NS effect when low frequency characters had higher frequency characteristics (Li et al., 2011). However, Li et al. (2015) found that morphology based on frequency can have an overriding effect on NS. In this research, we will try to examine to see if there is a significant difference between individual Chinese character processing and Chinese morphological processing in order to see if there morphological processing should be considered as an overriding effect of individual character orthographic processing.
CHAPTER 2 LITERATURE REVIEW

Neighborhood Size Effect

Even though Coltheart et al. (1977) by adjusting one letter in a word, while keeping other letters in tact, found that non-word determination showed a delay when NS was large, he did not find a significant result in reaction time when he was testing for word determination (Coltheart et al., 1977). Researchers in NS effect have been searching for a reason why this phenomenon occurred for which there is no concrete solution. The following articles will discuss what these research have currently found.

Word frequency in orthography

In everyday conversation, there are words that people use quite frequently and words that are used infrequently, which has been described as Word Frequency (WF). For example, the word cow has a higher frequency, because it utilized more often in everyday conversation, novels, magazine, newspaper, and academia than the word tungsten, which is less used (Davies, 2012). Andrews (1989) argued that based on this concept of WF, NS has an effect only with words that have a low WF. Explained further, the more neighbors that a low frequency word has, the longer it takes for one to attain mental activation for word recognition (Andrews, 1992). Furthermore it is argued that WF has more to do with word recognition than NS effect, because it is shown that words with higher frequency in general get recognized more quickly than those with lower frequency, regardless of how big NS is within a target word (Andrews, 1992). However, Andrews concedes that the effect of WF on NS might not be transferable to all languages, because of English having different orthographical and phonetical coherence than other language (Andrews 1997).
Neighborhood effect in other languages

In French, it was discovered that orthographical similarity can have a negative effect on word determination reaction time or a longer delay when there was an inequality in word frequency (WF) between target word (which is the non-manipulated word) and neighborhood word (manipulated word), with the target word being manipulated by one letter in forming a neighborhood word, called the orthographic neighborhood frequency effect (Grainger et al., 1989). It was found that regardless of the frequency of the target word, the greater WF difference that the neighbor word has compared to the target word, the longer the delay in word determination that occurs (Grainger et al., 1989). In addition, it was found that the larger the amount of these higher frequency neighbors that the target has, the longer the delay of the neighborhood word (Grainger et al., 1989). However, studies done by Sears et al. (2006) showed no such high frequency neighbor effect when the study was replicated in English. The reasons for such disparity is that each language might have different word characteristic, for example English words tend to be shorter on average than French, German, or Spanish, which can have more neighbor words, which affects word determination time (Sears et al. 2006; Wimmer, Köhler, Grotjahn, & Altmann, 1994).

Morphology

De Jong IV et al. (2001) argues that word processing doesn’t merely comprise of letters within a word, but such letters can be formed into meaningful units called morphemes, which then can be grouped together to form a structure of morphology. For example, the word television can be broken down into morphemes of “tele” meaning at a far distance and “vision” meaning sight, since a television is a device that transmits images that one sees from afar, then
the morphemes contain meaning. Furthermore, De Jong IV et al. (2001) found that the more words that a certain morpheme can create, defined as a morphological family size (MFS) of a word, the faster the reaction time to a correct decision in a lexical decision task. In Davies (2015)’s study, English and Spanish native speakers were given words with morphemes that with various ranges in frequency level. Each participant was asked to imagine the type of action or object that the word is related to the morpheme, and rate how difficult it was to create that image in their mind. The results of Davies (2015) study, showed that the more infrequent the morpheme was, the harder the imaging task was. Based on these studies, the frequency of a morpheme that appears within a morphological structure of a word can affect word determination.

Definition of Key Terms

The previous section of the literature review pertains to the general concepts of neighborhood size effect or NS effect in western languages. As the focus will shift to focus on the Chinese language. This following section will be helpful to provide a reference to all the terms that will be addressed in following sections.

Target word- A word that is being manipulated by changing a specific characteristic within a word. For example, a letter in a word or a marker within a Chinese character (Coltheart et al. 1977). For example, a target word like “wind” can be manipulated either by the first letter with “bind” or by the last letter “wing”.

Neighborhood word- A word that is formed by manipulating one certain characteristic within target word. For example, a target “wind” has a neighborhood word “wand”, where the certain
characteristic represented as the letter “i” in the target word is replaced by an “a” in the neighborhood word (Coltheart et al., 1977).

Neighborhood Size (NS)- The number of words that could be created by manipulating a certain characteristic within a target word (Coltheart et al., 1977). For example, a target “pain” can form neighborhood word like “wain, gain, main, tain, fain, sain, vain” which would give pain a NS of 7 words.

Word Frequency (WF)- The rate at which a word appears within a language, this could include any mediums like media, spoken context, or academic usage. Usage of which can help facilitate lexical access of the word (Andrews et al., 1983). For example, the word “pain” appears more in media, spoken context, and academia than the word “vain”. Thus, “pain” has a higher frequency than “vain”.

Morpheme- The smallest meaningful units within a word (Davies et al., 2015). For example, the word “television” can be broken down into meaningful units of “tele” meaning at a far distance and “vision” meaning to see. Therefore the combination television is a device that you can see images from a distance.

Morphology- The concentration on the form or structure of word in regards to semantic or phonological regularity, this is usually shown in the relatedness in root words, intonations and stresses, and context words, which are addressed as morphemes within a word (Mulder et al., 2013). For example, a word like “biohazard” would consist of morphemes such as “bio” meaning
“of nature” and “hazard” meaning “a danger”. Therefore, biohazard is defined as an object that is dangerous to the environment, if released.

Morphological family size (MFS)- The number of neighborhood words that could be created by manipulating a target word not just by a single characteristic of a target word, such as a letter or a part of a character, but by manipulating a morpheme within a word that emphasizes semantic or phonetic consistency (Mulder et al., 2013). For example, a target word like “biohazard” would have its MFS based on the words “biosphere, biodegradable, bioethics, biorhythms, bioinformatics, biophysics”, where each of the words were created with the root word “bio-“.

**Chinese language and language processing**

In transferring a theory such as neighborhood size from a language such as English to a language such as Chinese is that there exists differences between these languages that may cause language processing differences. One problem is that English and other Western languages are mostly made up of an alphabetical structure that has a really close relationship between orthographical and pronunciation, with inconsistencies happening only part of the time (Ziegler et al., 1997). However, in the Chinese language, there is no such alphabet order. Instead, characters are needed, because of the varieties of Chinese that are phonetically incomprehensible from one another (Tsai et al., 2007; Tang & Van Heuven, 2009). Due to the differences in language structure, Whorf and Chase (1956) hypothesized that there is a strong correlation between differences in language and structure. Thus, it is not wise to directly apply psycholinguistic theories stemming from Western languages into eastern languages. The
following will summarize language processing literature found in comparison studies of English and Chinese, Chinese languages structure, and Chinese morphology.

*Differences in Brain activation of English and Chinese and the Whorf hypothesis*

In Chinese are created with characters made up of visual markers called radicals, which can have either phonetic or semantic importance within the language. Within the Chinese language, there are 214 radicals, rather than 26 letters in an alphabet (Taft & Zhu, 1997). In order to see such differences between word reading and character reading, an fMRI study was done comparing brains that read English versus brains that read Chinese (Tan et al., 2000). The results of this study show that because of the use of a combination of markers, Chinese brains show more right-brain activation in reading than English readers, which can result in more spatial awareness (Tan et al., 2000). A reasoning for this increased spatial awareness is due to the required attention that is placed on the organization of markers, which can affect the pronunciation of the word. As will be discussed later in the next section, the location of where the semantic and phonetic lies within a Chinese character matters in the type of resultant phonology that the participant is required to make, by changing the position of these markers, it can affect the pronunciation of the character. Relating to the Whorf hypothesis, which states that language influences the way that we think, the finding on right-brain activation between Chinese and English readers shows that different aspects in languages themselves can reflect themselves in physiological activation differences within the brain (Gilbert et al., 2005).
Chinese Radicals and Chinese character recognition

Chinese character breakdown

![Chinese character breakdown diagram](image)

Taste involves eating with your mouth

*Figure 1 Example of Single Character Construction*

The Chinese language reading and writing system does not contain letters or an alphabet system, but instead consists of radicals, markers which can either have phonetic meaning or semantic meaning. A typical Chinese character is comprised of at least two radicals, that are placed side by side. For example as shown in Figure 1, the radicals 口 (kǒu, mouth) and 未 (wèi, not yet) can form into a character 味 (wèi, taste). Here, the 口 (kǒu, mouth) radical is a semantic radical, because one needs to use the mouth to taste something and 未 (wèi, not yet) is a phonetic radical and it doesn’t add semantic meaning to the characters itself. When these radicals are combined, it provides the speaker the way to pronounce the character 味 (wèi, taste). It is
estimated that about 80% of all Chinese characters are constructed in this way, where the semantic radical is on the left and the phonetical is on the right (Linge, 2013).

Word Frequency is defined as the amount of a times that a word appears in a language (Andrews et al., 1983). To examine the effect of frequency in the Chinese language, Taft and Zhu (1997) manipulated the frequency of radicals used in Chinese characters. In this experiment, participants were given characters that had a combination of either 2 or 3 radicals, where the participants had to identify whether the character given was either a real character or a pseudo-character. The results showed that when the participants were given characters consisting of two radicals, the frequency of the radical located on the right side of the character affected its determination, while the frequencies of both the left and right-hand radicals affected pseudo-character determination. Therefore, Taft and Zhu (1997) showed that radical positioning and frequency that the radical appears within the language can affect the processing of character recognition.

In terms of phonological or semantical radicals in neuropsychology and brain activation, it has been shown that both of these types of radicals have an effect on character determination. In a magnetoencephalography (MEG) study, where a mental activity was measured by using a magnet, it was that the similarity in phonetic radicals can bring on significant activity within the brain when the participant has to focus on the semantic radical (Hung et al., 2014). In the homophone determination task, participants were given a target character followed by a character to determine if the character had the same pronunciations as the target. Each pair consisting of the target character and a response character contained 4 different conditions. One
condition contained radicals gave the characters similar pronunciations, for example 玛 and 码 both have the same pronunciation because the phonetic radical 马 indicates a pronunciation of mà. Another condition had pairs of characters that were pronounced the same way, but had no radicals that were similar. For example, 执 and 值 both would have the pronunciation of zhí, but both characters show no relation radicals indicating pronunciation unlike the previous example of mà. The third condition contained a character pair that had similar radicals but different pronunciations 呈 (chéng) and 望 (wàng) both have the radical 王 (wáng) located on the bottom of each character. Lastly, a pair of characters would have no relation in radicals or pronunciation, for example 送 (sòng) and 五 (wǔ) both do not have any relation with radicals or pronunciation.

In the semantic determination tasks participants had to repeat the process of determination like in the homophone condition. However, participants had to determine whether the character pair shared similar meaning or different meaning based on 4 conditions, where semantic radicals and meaning was manipulated (Hung et al., 2014). In one condition, participants were given pairs of characters with the same radical that indicated that both characters in the pair had the same meaning, for example 孩 and 孺 both mean child, because of the radical 子 located on the left of each of the characters, which indicates a child. In another condition, participants were given a pair of characters that had different semantic radicals but contained the same meaning, for example 念 (niàn, read) and 读 (dú, read) both mean to read, but unlike the child example, these characters do not have any similarity in terms of radicals. In the third condition had the participants distinguish pairs of characters that contained similar semantic radical, but different meanings 注 (zhù, to inject) and 汤 (tāng, soup) both contain the
radical \(氵\) (shuǐ, water) though both 注 (zhù, to inject) and 汤 (tāng, soup) do not have similar meanings. In the last condition, participants were given pairs of characters that had no relation in terms of semantic radicals or meanings, for example 猫 (māo, cat) and 贸 (mào, commerce) both do not have any relation in terms of semantic radicals and meanings.

The results of this experiment indicated two different effect between identifying homophones and similar meanings in terms of neuropsychology and brain activity. In the condition of the homophone conditions, where participants had to identify whether a pair of characters had similar phonetics based on the existence or non-existence of phonetical radicals between the characters in the pair, participants showed significant activity within the brain. However, in the identification of similar meanings condition, participant showed only a slight activation within the brain. Therefore, it is argued based on brain activation that phonetical radicals may play a great role in Chinese character recognition, while semantic radicals play a weaker role in such character recognition (Hung et al., 2014).

*Chinese Morphology and Chinese character recognition*

*Chinese Morphological Construction*

老师

老师= lǎoshī, teacher

*Figure 2 Example of Morphological Character Construction*
According to Tsai, Lee, & Chin (2006), psycholinguistic research done based on alphabetic languages presents a problem when applied to a language like Chinese, because such research is done by manipulating letters within a word. However, more than 70% of Chinese words typically have at least two characters (consisting of radicals as previously mentioned), with each of them having one syllable and symbolizing meaning or phonetics (Packard, 2000). For example shown in Figure 2, the word for teacher in Chinese is 老师 (lǎoshī) has two characters 老 (lǎo, old) and 师 (shī, master), here the construction for teacher being an old master is significant in Chinese, because a teacher typically is a person that teaches a young person. The following will be examining the research done in Chinese character recognition and Chinese morphology.

Li, Shu, McBride-Chang, Liu, & Peng (2012) conducted a study in Beijing to examine different ways in how Chinese children recognize Chinese characters. One of the very many characteristics that the researchers test for was morphological awareness in Chinese. In morphological awareness, researchers tested the children for homophone judgement, morphological construction, and morpheme production. In the homophone judgment condition, the children were orally given a target character like chàng, then there were given Chinese words, each of which contained two characters like 唱歌 (chànggē, to sing a song) and 唱戏 (chàngxì, to perform an opera). The task for children in the homophone condition was to identify whether the two Chinese words given had a similar meaning or a different meaning, here with chànggē and chàngxì, the meaning would the same. However, the children also were orally given two Chinese words that contained similar homophones, but had different meaning. For example,
the target for 去 both can be 能够 (nénggòu, to be capable of) and 架构 (jiàgòu, to construct), since the two words both have similar homophones, but their meaning would be different.

In the morphological construction task, children were given three sentence stories in Chinese and were asked to create words based on the morphology given in the story (Mc-Bride-Chang et al., 2003; McBride-Chang, Chow et al., 2005). For example, the experiment here asked “if a dragon with black scales is called a black dragon (黑恶, hēilóng, black dragon) what should a dragon with red scales should be called?” The correct answer here from the participants should be a big black dragon (红龙, hónglóng, red dragon). In morpheme production, Chinese students were given a Chinese target word like 明天 (míngtiān, tomorrow) and a target morpheme of that word, which in this case could either be 明 (míng, next) or 天 (tiān, day). Based on the morpheme given to the child, the child had to produce two words, one which had a similar meaning to the target word and another one that had a different meaning than the target word. For example, a word the Chinese children would have produced that kept the same meaning as the target would be 明年 (míngnián, next year) and a word they could produce that has a different meaning would be 明智 (míngzhì, sensible).

In homophone judgement, it was found that children who were in lower grades, thus younger children had a significant negative correlation in Chinese Character recognition (Li et al., 2012). This means that Chinese children, who read characters at a beginning level, first have a hard time in distinguishing morphological words that have similar sounds, but different meanings, but this ability to distinguish similar sounding words that have different meanings
improves overtime. However, in morphological construction, it was found that there was a strong positive correlation between getting the proper Chinese word based on the context given to the children and character recognition (Li et al., 2012). Finally, morpheme production was found to have a positive correlation in Character recognition in terms of being able to produce similar meaning and non-similar words based on target words and target morphemes given among 1st grade, 2nd grade, 5th grade, and 6th grade children (Li et al., 2012). Therefore, morphological awareness was found to be significant among Chinese children, but the context of which the word is formed was found to be important.

**Chinese and Neighborhood Size Effect**

Initial studies in the Neighborhood Size Effect in Chinese was done by replicating studies previously done in English, where changing one character of a Chinese word similar to changing one letter in an English word (Li et al., 2015). These initial results in the NS effect were at first contradictory, where Huang et al. (2006) found neighborhood size by itself had no effect on word determination, but a significant interaction between neighborhood size and word frequency. On the other hand, Tsai et al. (2006) found a slight NS effect with Neighbor words, where the lead character was unchanged and the following characters was changed, when it was larger, but no frequency effect was found. Because of these contradictory results, an aspect of orthography-phonology incongruence and morphology has been considered in Chinese. The following examines both of these aspects in respect to the NS effect.
Regularity and Consistency with Chinese Characters

In languages that have been researched, it has been examined that languages are easily retrievable when regular patterns arise. Jared (1997) found that the increase in regular patterns that words have, the faster the word recognition regardless of spelling-sound consistency. However, at the same time, Jared (1997) found out that alternative pronunciations of these regular words delays word retrieval time. In Chinese, the issue of regularity is just as important as in English, because the Chinese uses radicals to imply semantic or phonetic emphasis on a character (Liu, 2003). For example, the characters 嗎 (ma, a common particle that indicates a question Chinese like “isn’t it” in English) and 媽 (mā, mother) both are highly regular in Chinese, because 口 indicates an action done with mouth and 女 indicates a female. Even though the phonetic characteristics of the characters are similar due to the 馬 radical, the semantic meaning of the two characters 嗎 and 媽 are different. However, the two radicals 口 and 女 are common in Chinese and thus would not cause a delay in word determination (Liu, 2003). Therefore, when tested for regularity such as the radical regularity, it was found that characters that were more consistent were named faster than those inconsistent when controlling for homophonous characters (like the two characters example of ma) and heterophonous characters (Liu, 2003).

Incongruence with Chinese Characters and Neighborhood Size Effect

In the light of the finding that Chinese character determination is regulated by consistency or inconsistency that it has with its own radicals, NS was manipulated based on the factors of consistency. Li, Bi, Wang & Chen (2011) came up with the idea of creating NS by first
determining the number of neighbors that a target character has based on its phonetical radical. For example, the phonetical radical for 刀 (dāo, knife) has neighbors 叨 (dāo, garrulous), 切 (dāo, grieved), 刁 (dāo, kayak), 刀 (dāo, coilia ectenes), 刿 (tāo, to receive benefit), 初 (chū, at first), 切 (qiē, to cut). However as noticed, not every character containing radical 刀 (dāo, knife) has the same pronunciation, therefore consistency was based on the ratio between phonetic radicals and pronunciation. For example for the target radical 刀 (dāo, knife), there are four characters that share the pronunciation and two characters that do not share the same pronunciation, but contain that radical. So, consistency would be 4/7 or .571. Any target radical that has a consistency of <.4 was treated as inconsistent and >.5 indicates consistent. In addition, to consistency, each character was measured for regularity. For example, the character 初 (chū, at first) would be more regular than 刃 (dāo, kayak) being that 初 (chū, at first) is used more than 刃 (dāo, kayak) in the Chinese language. Based on regularity and consistency, a main effect was found for NS when the characters were inconsistent and irregular.

In addition to regularity and consistency, the frequency of orthographical neighbors was controlled to see if having higher frequency neighbors would cause an effect of NS. Here, Li et al. (2011) determined frequency a target character like 讳 (huì, taboo) with its orthographical neighbors 伟 (wěi, great) and 纬 (wěi, latitude) based on having the phonetic radical 韦 (wéi, leather). Here, the frequency of these characters between them are varied with 伟 (wěi, great) being 4.8 per million, 讳 (huì, taboo) being .55 million, 纬 (wěi, latitude) being .54 per million. Here, Li et al. (2011) determined a high frequency neighbor as a character that is 3 per million
higher than the target character. Therefore in example, 伟 (wěi, great) being 4.8 per million would be a higher frequency neighbor to the target character 祐 (hui, taboo) being .55 million, since it is 3 per million higher. It was found that orthographical neighbors that were higher frequency showed a significant delay in determination when NS increased. However, when the effect of high frequency neighbors was removed, no such effect occurred.

*Morphological processing with Chinese Characters and Neighborhood Size Effect*

However, some researchers claim that researchers, looking to see if neighborhood size has an effect in the language, are too focused on the character level, but instead should be focused on the morphology of the Chinese language itself. The regularity and consistency of Chinese characters assisted children in word recognition. In addition, the NS effect in Chinese and English can be different due to matters of orthography-phonology consistency and word construction. In Chinese, orthography-phonology is only 50% consistent, while in English it is much higher, and about 70% of Chinese consists of two or more characters (Packard, 2006). The lead character plays a more important role in NS effects than the following character, because it was discovered that neighborhood words can be created based on the semantically related character (Wu et al., 2013). For example, any word with the leading character 家 (jiā, family) also can act as a morpheme by creating semantically related neighbor words, demonstrated in the example above, such as 家庭 (jiātíng, household), 家园 (jiāyuán, homeland), 家族 (jiāzú, clan), 家居 (jiājū, residence), 家电 (jiādiàn, household appliance), 家人 (jiārén, member of household), and 家长 (jiāzhǎng, head of household), all of which has an implication of home or family. Therefore, it is argued that Chinese word determination might be independent of phonology and
orthography in character, but instead is determined by the level of frequency with the leading character (Li & Lin, 2015). In the experiment, the frequency of the leading was manipulated and participants had to determine whether the neighborhood word was an actual word or not. It was found that the higher the MFS, the less of a delay in word determination (Li & Lin, 2015). In Chinese, it was found that it was more dependent on semantic processing of MFS based on lead character frequency than on phonological or orthographic processing with neighborhood words like a morpheme (Li and Lin, 2015). For example morphological Chinese word neighbors such as 电影 (diàn yǐng, movie) and 电脑 (diānnǎo, computer) would have higher word recognition activation because of the morphological processing of the character 电, (diàn) which indicates an electric device and is very common character used in Chinese. Compared with a word like 暑假 (shǔjià, summer vacation, which has a lower word recognition activation because 暑 (shǔ, heat) is less commonly used in Chinese than 电, (diàn).

Current Study

In the current study, we are interested in examining the differences between Chinese character processing and Chinese morphological processing based on the NS effect and WF. Based on current research, we expect two different results for both character processing and morphological processing, since both processes require separate cognitive tasks in terms of NS effect. In the character recognition condition, where the participants are expected to give a correct pronunciation of a character based on the neighborhood character being presented, we predict that a larger NS effect in terms of longer determination times when higher frequency orthographical neighbors are present, because of regularity and orthography-phonology...
consistency having an effect on such determination. However, under the morphological processing, we predict that participants will be able to name the characters more quickly when the lead character has higher frequency. This is due to the fact that Chinese speakers process the characters sequentially and the high familiarity of the lead character will lead to having a higher facilitatory effect overriding any effect that regularity and orthography-phonology consistency has on word determination. We also expect that when the lead character has lower frequency, then the facilitatory effect would not occur and WF and orthography and phonology consistency of the 2nd character will have such an effect. Therefore, we expect that individual character determination will be affected by NS and morphological determination will only be affected by WF, thus having the overriding effect on NS.
CHAPTER 3: METHOD

Participants

The following study contained in total 24 participants with 17 females and 7 males. All of the participants were native Chinese from mainland China (participants from other Chinese speaking countries were excluded as explained later), all of whom were Mandarin Chinese speaking even though their local dialect may or may not be Mandarin. These participants were students at University of Central Florida or adults found in the community of Orlando. The students and adults are male and female and of various ages ranging from ages 18-54 with an average of 29.54 years old, with a standard deviation 10.14 years old. In exchange for their participation, a reward of ten dollars was given upon completion of the study. Each was required to fill out a consent form, given in either English or Mandarin before participating as shown in Appendix E and F.

Design

In the study there were three independent variables, neighborhood size, word/character frequency, and orthography-phonography consistency. Each of these variables considered in two conditions involving processing of the Chinese language, which are individual characters and characters constructed along Chinese morphological construction. Neighborhood size (NS) was measured for both high and low, where high NS would have 15 or more characters and low NS would have 15 or less characters. In determining neighborhood size, the neighbor characters were determined by the phonetical radical on the right in the individual character condition, while the neighbor characters based on morphological condition was based on the frequency of either the lead or second character in the character composition. The reason for this manipulation
was to replicate the Feldman & Siok (1997)’s study, where they determined low combination of radicals to be 17, but wanting a stricter scale, 15 was used instead. In addition, in the morphological condition, determination of neighborhood characters in both the lead or second character were both determined individually by the existence of the phonetical radical on the right hand side of the character. Word/character frequency was measured based on the amount of times that the character or phonology appeared in the language for both the individual character or morphology conditions. Frequency will be measured as such, a character being present in the language more than .02% of the time having high frequency and low frequency appearing less than .02% of the time. In Li et al. (2011)’s experiment, the mean frequency was used a .036% average frequency, but in this experiment, a stricter scale was desired, therefore .02% was used as a measure for low frequency instead .03%.

Participants were required to a naming task, where the participants had to name a character as fast and as accurately as they can, instead of lexical decision task, where the participant simply had to decide whether the character presented is a character or non-character. The reason why the naming task is preferred over the lexical decision task is that the factor WF diminishes when conducting a lexical decision task. In addition, most typing of Chinese characters done internationally based on the simplified language is done on the QWERTY keyboard similar to the one used in the US unlike the Zhuyin keyboard used in Taiwan. Since Mainland China uses the QWERTY keyboard, windows and apple computers in China have a character dictionary built into the computer, so it is not possible to type in non-characters for a lexical decision task. Finally, Chinese not only depends on the recognition of characters, but also on the tone that the character is spoken in. For example, saying shèngdiǎn and shèngdiàn (notice the difference
between ǎ and à) would create two separate words, here shèngdiàn means grand ceremony and shèngdiàn means temple. Therefore, to represent accurate processes in how Chinese is processed in daily life, the naming task is chosen over the lexical decision task.

The Chinese characters will be picked from the Chinese dictionary site MDBG (http://www.mdbg.net), where the individual characters were manipulated for radical consistency/inconsistency and neighborhood size based on the presence of a phonetic radical or semantic radical that was presented in a target character. Word Frequency will be measured using a website called Chinese Text Computing, which measures the frequency of character use based on how many times it is used in the language (Da, 2004). In morphology condition, MDBG also was used, where the character compositions were both manipulated for word frequency and neighborhood size based on both the front character of a target character composition presented. Here, the front character is manipulated instead of the back, because a majority of Chinese language determination happens sequentially (Huang, 1993).

In addition, there are two forms of Chinese that could be presented in this experiment, which are the simplified form or the traditional form. For example, the character in the simplified format 说 (shuō, to speak) would be 說 in the traditional form (notice how the difference of the speak radicals in each character). In this experiment, the simplified form was chosen rather than the traditional form, both forms of Chinese are similar, but the simplified characters have less stroke and is the mainly used in mainland China and Singapore, while the traditional form is used in Hong Kong, Macau, and Taiwan. Since this study is done in the United States and many of the Chinese students at UCF and immigrants in Orlando come from Mainland China, which means that the use of simplified form of characters would be more accurate to represent their
form of the native Chinese language and the traditional form would be difficult for them to recognize. All participants who come from Chinese speaking countries, which use the traditional form of Chinese were excluded or dropped from the study.

All stimuli were displayed against a white background screen in black Simsun font with a size of 200. The conditions were combined in a within factorial design that was a 2x2x2 design, because the participants are involved in both the individual character condition and morphological character composition condition. Therefore, 8 unique conditions for both character recognition and morphological recognition trials were tested an each was presented all at one time after the completion of the practice trial with both characters and morphological conditions being mixed together, which was done using Superlab 4.0. However, due to programming error, there was one repeated trial, which was dropped from the measurements and the results. After eliminating the repetition trial, the conditions were set up so that each of the 120 trials were shown in random order.

In order to ensure accuracy of measurement, the voice recording and the video recording of the participant was used in order to ensure accuracy of measurement. Since, it is almost impossible to measure video recordings in milliseconds, audio recordings were mainly used in order to conduct measurements. Each participant was measured using audacity version 2.1.2, Each audio recording was slowed down by 30% percent in order, because measuring in real time is very inaccurate. The adjusted measurements then corrected for this, in order to display measurements in real time. The length of time, it took for the participants to speak a character was measured from the time the participant finished speaking the character before, to the moment that the participant recognized the character indicated by the moment that a participant
opens their mouth, this was recorded in milliseconds (ms). Accuracy was later measured with the emphasis on correct pinyin (alphabetical phonetics) and tones. Only correct pronunciations were kept for reaction time measurements, which was based solely on getting both the pinyin and tones correct. If the participant made a mistake, then the type of mistake was recorded to determine if there was any commonality to their mistakes. Based on these guidelines each participant took about 2-3 hours to measure.

**Location**

Twenty of the 24 participants utilized room PSY207C located at the Psychology building at the University of Central Florida (UCF). However due to difficulties in lab scheduling, two of the participants took part in the experiment in BA2308P. In addition, the other two participants took part in the experiment at PSB 204 and CNH534A. Thus, though all locations of the experiment took place at UCF, with four different rooms used to conduct the experiment.

**Apparatus**

The study was conducted through a PC running Windows. The PC contained alternating stimuli consisting of individual Chinese characters and sets of multiple Chinese characters based on morphological construction that were displayed on a 17in. LCD computer display with a headset microphone. The resolution was $1680 \times 1050$ with 60 Hz refresh rate, which indicates that the PC updates images 60 times per second. The software used to display the stimuli was Superlab 4.0. In addition, participants were filmed on camera to record how well the participants responded to stimuli and each footage of the participants were reviewed after completion by the researcher in order to record how long they took to respond the stimuli and how accurately they
responded to the stimuli based on the tones and pronunciation given. For participants, who completed outside of the laboratory environment, Superlab 4.0 also was used, but a 13.3-inch MacBook Air with a display of 1440x900 and built-in microphone was used instead of a PC and microphone.

**Procedure**

Before the experimental trials begin, the participants were given demographic survey to fill out which will detail information, which could present confounds within the study such as gender, education, and age. In particular, one of the most important details that was mentioned on the survey was the amount of time spent in China and the United States in terms of education and living settings. In particular, the fact that the participant either spend more or less time with the English language was considered in conjunction of recognizing the characters and character compositions. The demographic survey is shown in Appendix H.

Participants were then seated and given written instructions provided in both English and Chinese as shown on Appendix G, where they were instructed to speak as clearly and accurately as possible, so that the camera footage can record properly. The participants also were told to respond as quickly as possible and avoid too many mistakes. After the participants were given the instructions, the participants were given a practice trial lasting about 5 minutes and an experimental trial lasting about fifteen minutes. Therefore, the whole experiment took about 20 minutes

After the completion of the survey and reading the instructions, the participants were given a practice trial in order to get themselves acclimated with the Superlab 4.0 software and reinforce the instructions of speaking as quickly and accurately as possible based on pinyin accuracy and
not tone accuracy, since tone accuracy can only be evaluated after the experiment is over. The participants were presented with three individual characters and two character compositions presented on Appendix A. If the participants are too slow to respond to the characters, the participants were given an opportunity to respond. However, if the participant fails to respond quickly and accurately enough to the practice stimuli, then the participant were then told that they could not continue with the experiment and only partial compensation would be given.

In the character determination condition, participants were given a set of characters each of which contained a phonetical or semantic radical that are similar to each other. Each participant was given the task to pronounce each one as quickly accurately as they could. For example, a participant is given a set of characters like 认, 队, 队, and 从 each of which containing the radical 人 (rén, person), the participant when shown these characters had to correctly pronounce each character as rèn, shēn, dui, and cóng. Looking at the sample characters, the participant had the task of initially recognizing the phonetical radical, if one was present, and then refer to the semantic radical attached with the phonetic radical based on the combination of these radicals, the participant had to determine the correct pronunciation and tone of that character. The following characters will be listed in Appendix B.

In the morphological condition, the participants were unchanged from those in the character conditions, but they will be presented two character compositions as more than 80% of words in Chinese consists of at least two or more characters (Linge, 2013). Typically, in Chinese, the order in which characters are written is read from left to right as in English. Therefore, in the literature, it has been mentioned that the frequency of the furthest left character in a Chinese word composition will have the greatest effect in RT. For example, the participant
was to be presented with characters such as 堂弟, 家人, and 健行. The participant in this example would have to respond with tāngdì, jiārén, and jiànxing. Looking at the sample characters, the participant was given the task of initially recognizing the character compositions based on the lead character in the composition based on the frequency, then the participant had to refer to the character attached to the lead character. Based on the character combination, the participant will have to determine the correct pronunciation and tone of the character compositions. The following 2-character word compositions will be shown in Appendix C.

Reaction times were recorded for correct trials only. Correct trials require the participant not only to speak the character in the correct way, but also maintaining the correct tones. If a trial was incorrect, it was discarded for reaction times, but error rates will be recorded. The participants regulated the amount of time themselves to pronounce the word. After they were done pronouncing the word/character, the participant pressed the spacebar to move to the next character.
CHAPTER 4: RESULTS

Overall Data

Overall average accuracy rate $M=91.35\%, SD=5.34\%$

Overall average time of correct response per character $M=837.01\text{ms}, SD=130.25\text{ms}$

<table>
<thead>
<tr>
<th></th>
<th>Single and High NS</th>
<th>Single and Low NS</th>
<th>Morphology/Double and High NS</th>
<th>Morphology/Double and Low NS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High Frequency</strong></td>
<td>$M=767.84\text{ ms}$</td>
<td>$M=673.09\text{ ms}$</td>
<td>$M=758.51\text{ ms}$</td>
<td>$M=819.35\text{ ms}$</td>
</tr>
<tr>
<td></td>
<td>$SD=164.80\text{ ms}$</td>
<td>$SD=181.89\text{ ms}$</td>
<td>$SD=184.25\text{ ms}$</td>
<td>$SD=190.20\text{ ms}$</td>
</tr>
<tr>
<td></td>
<td>(95.83%)</td>
<td>(99.17%)</td>
<td>(99.33%)</td>
<td>(94.69%)</td>
</tr>
<tr>
<td><strong>Low Frequency</strong></td>
<td>$M=973.68\text{ ms}$</td>
<td>$M=826.33\text{ ms}$</td>
<td>$M=937.43\text{ ms}$</td>
<td>$M=939.87\text{ ms}$</td>
</tr>
<tr>
<td></td>
<td>$SD=230.88\text{ ms}$</td>
<td>$SD=222.28\text{ ms}$</td>
<td>$SD=182.99\text{ ms}$</td>
<td>$SD=234.00\text{ ms}$</td>
</tr>
<tr>
<td></td>
<td>(71.39%)</td>
<td>(96.94%)</td>
<td>(91.67%)*</td>
<td>(85.56%)</td>
</tr>
</tbody>
</table>

*Condition only had 14 instead of 15 stimuli.

Accuracy Rate (%)

Figure 3 Difference between High and Low Frequency in Accuracy
In terms of the accuracy rate, a three way 2x2x2 within subjects ANOVA was used with character conditions, frequency, and neighborhood size (NS) as the independent variables and the percentage correct as dependent variable. In the character condition, there was no significant difference in accuracy rate found between one and two character presentations \((F(1,23)=2.34, ns, \text{ partial } \eta^2=.09)\). However, there were significant differences in accuracy rate found in the frequency condition \((F(1,23)=145.12, p<.001, \text{ partial } \eta^2=.86)\) and NS \((F(1,23)=96.62, p<.001,\text{ partial } \eta^2=.81)\). Specifically, within the frequency condition, high frequency characters \((M=96.28\%, \text{ } SD=4.56\%)\) were found to be more accurate than lower frequency characters \((M=86.43\%, \text{ } SD=11.93\%)\). This effect is shown in figure 3. In addition, with NS, it was found that low NS characters \((M=94.14\%, \text{ } SD=7.50\%)\) had higher accuracy than high NS characters \((M=88.57\%, \text{ } SD=11.83\%)\). This effect is shown in figure 4.
In addition, there was a significant interaction between character and frequency ($F(1,23)=18.80, p<.001$, partial $\eta^2=.45$). To analyze this significant interaction, a paired t-test was performed for each condition with a Bonferroni correction of $\alpha=.025$. It was found that both single ($t(47)=6.66, p<.001$) and two character conditions ($t(47)=5.28, p<.001$) showed significant differences in frequency. In single characters there was significantly greater accuracy difference in high frequency characters ($M=97.38\%, SD=3.89\%$) than in low frequency characters ($M=84.10\%, SD=14.90\%$). This effect is shown in Figure 5. Similar results were found with the two-character condition with higher frequency ($M=95.19\%, SD=5.27\%$) being more accurate than lower frequency ($M=88.75\%, SD=7.20\%$). This effect also is shown in figure 5.
There also was significant interaction with character and neighborhood size $(F(1,23)=82.25, p<.001$, partial $\eta^2=.78)$. To analyze this significant interaction, a paired t-test was performed for each condition with a Bonferroni correction of $\alpha=.025$. It was found that both high neighborhood size ($t(47)=-7.49, p<.001$) and low neighborhood size ($t(47)=2.57, p<.05$) had significant differences with the character conditions. With low neighborhood size, it was found that characters with single characters ($M=83.50$, $SD=14.32\%$) were less accurate than low NS ($M=97.98\%$, $SD=3.42\%$). This effect is shown with figure D. With two characters, it was found that characters with high NS ($M=93.65\%$, $SD=4.82\%$) were more accurate than low NS ($M=90.29\%$, $SD=8.44\%$). The effect also is shown with figure 6.
The interaction between frequency and neighborhood size (NS) also was found to be significant ($F(1,23)= 27.15, p<.001$, partial $\eta^2 = .54$). To analyze this significant interaction a paired t-test was performed for each condition with a Bonferroni correction of $\alpha = .025$. In the high frequency condition, there was no significant difference in terms of accuracy ($t(47)= -1.72, ns$), which is shown in figure 7. However with low frequency, there was a significant difference in accuracy ($t(47)= -3.55, p=.001$) with high NS ($M=81.60\%, SD=13.04\%$) less accurate than low NS ($M=91.25\%, SD=8.55\%$). This effect also is shown in figure 7.

Figure 7 Interaction: Frequency by neighborhood size with accuracy
Finally, there was significant interaction with character, frequency, and neighborhood size (NS) \((F(1,23)=53.91, \ p<.001, \ \text{partial } \eta^2=.70)\). To analyze this significant interaction a paired t-test was performed for each condition with a Bonferroni correction of \(\alpha=.0125\). Then, the interactions were analyzed separately by character condition. In the single character condition, there was a significant interaction within both high frequency conditions in terms of NS \((t(23)=-3.72, \ p=.001)\) with high NS \((M=95.63\%, \ SD=3.39\%\) less accurate than low NS \((M=99.13\%, \ SD=2.32\%\). This effect is shown in figure 8. The single character condition in low frequency also was found to be significant in terms of NS \((t(23)=-12.82, \ p<.001)\) with high NS \((M=71.38\%, \ SD=10.22\%\) less accurate than low NS \((M=96.83\%, \ SD=3.92\%\). This effect is also shown in figure 8.
In the double character condition, there was no significant difference in accuracy rate found in the high frequency condition with neighborhood size \((t(23)=.46, \text{ ns})\). This non-significant effect is shown in Figure 9. However, with low frequency there was a significant difference found between high and low neighborhood size conditions \((t(23)=2.88, p<.01)\). This effect is shown in figure 9. It was found that high neighborhood size \((M=91.83\%, SD=4.37\%)\) was significantly greater than low neighborhood size \((M=85.67\%, SD=8.10\%)\) in the double character and low frequency condition. This effect is shown in figure 9.
Reaction Time (ms)

Figure 10 Difference in Reaction Time between One and Two-Character Stimuli

Figure 11 Difference in Reaction Time between High and Low Frequency
To measure reaction time, the same procedure was used as accuracy with a three-way 2x2x2 ANOVA was used to evaluate the data with Single and morphological/two characters, high and low neighborhood size (NS), and high and low frequency were used as independent variables, but instead of accuracy participants were measured for reaction time for each correct response. Between one and two characters shown in the experiment, there was a significant result (F(1,23)= 15.06, p=.001, partial $\eta^2=.40$). Specifically, it took the participants longer to read two characters ($M= 863.79ms, SD= 209.78ms$) than one character ($M=810.24ms, SD=225.69ms$). This effect is shown in figure 10. In addition, there was a significant result for both frequency (F(1,23)=76.10, p<.001, partial $\eta^2=.77$) and NS (F(1,23)=21.04, p<.001, partial $\eta^2=.48$). With Frequency, the participants read characters with higher frequency ($M= 754.70ms, SD= 184.37ms$) quicker than lower frequency ($M=919.33ms, SD=220.99ms$). This effect is shown in figure 11. With neighborhood size (NS), it was found that participants read characters with high
NS ($M=859.37\text{ms, }SD=211.80\text{ms}$) slower than low NS ($M=814.66\text{ms, }SD=224.76\text{ms}$). This effect is shown in figure 12.

![Character x Neighborhood Size](image)

**Figure 13 Interaction: Character by neighborhood size in Reaction Time**

In regard to the interaction character condition and frequency, there was not any significant effect ($F(1,23)=1.90$, \(ns\), partial $\eta^2=.08$). However, there was a significant interaction between character condition and NS ($F(1,23)=33.78$, \(p<.001\), partial $\eta^2=.60$). To further investigate this interaction, a paired t-test was done with a Bonferroni adjustment of $\alpha=.025$. There was a significant interaction with single characters and neighborhood size ($t(47)=6.34$, \(p<.001\)), it was found that the participants reacted to high NS characters ($M=870.77\text{ms, }SD=221.69\text{ms}$) slower than low NS characters ($M=749.71\text{ms, }SD=213.07\text{ms}$). This effect is shown in figure 13. There was no significant difference found in the two-character/morphological construction condition with ($t(47)=-2.06$, \(ns\)). This non-significant effect is shown in figure 13.
In addition, there was a significant effect in regard to the interaction between frequency and neighborhood size ($F(1,23)= 6.91, \ p=.02, \ \text{partial } \eta^2 =.23$). Within this interaction, it was found that in high frequency was no significant difference between high and low neighborhood size ($t(47)=.98, \ ns$). This is shown in figure 14. However, in low frequency, there was significant found ($t(47)= 3.19, \ p<.01$) with high neighborhood size ($M=955.56\text{ms, } SD=204.73\text{ms}$) having a greater delay than low neighborhood size ($M=883.10\text{ms, } SD=230.51\text{ms}$). This effect also is shown is shown in figure 14. Lastly, there was no significant interaction found the interaction of character, neighborhood size, and frequency ($F(1,23)=.01, \ ns, \ \text{partial } \eta^2<.001$).
CHAPTER 5: DISCUSSION

Research Hypotheses

The significant difference in terms of time and accuracy between lower frequency characters and higher frequency characters show support for a significant difference for word determination along the line with Andrews (1992) and her argument for word frequency. Specifically, the results indicate that lower frequency words presented whether in the morphological/two-character condition or single character condition would show a significant delay in correct word determination, which further support Andrews (1992) theory that lower frequency words have a longer delay than higher frequency words in correct word determination. Therefore, based on the results, we can say that frequency has a significant effect on word determination in the Chinese language when given the task of correct character determination.

In terms of neighborhood size, there is support that characters with high orthographical size demonstrate a significant delay compared to characters that lack such orthographical neighborhood size. Therefore, based on these results, we have support for Li et al. (2011)’s and Colteart et al. (1977)’s argument that words and characters that tend to share orthographical characteristics with other Chinese characters show a significant delay in correct word determination.

However, in terms of the difference between reading single characters and two/morphological characters, there was a significant difference found in reaction time, but no such difference in terms of accuracy. This highlights a problem with the measurement of power, which estimates whether you can do a task vs. the measurement of speed, where it is assumed
that you are able to do it (Wilhelm & Schulze, 2001). In the study of Wilhelm & Schulze (2001), participants were given a reasoning test under a timed conditioned and another one in an untimed condition. In this study, it was found that participants reacted quicker with the timed conditioned, but accuracy has reduced as well (Wilhelm & Schulze, 2001). However, the reduction of accuracy varied greater among participants in the speed task, thus conducting a task faster might not affect in some participants. Referring back to the difference in significance between reaction time and accuracy with single characters and two-character/morphological construction, participants reading one character faster might not indicate an accuracy difference between the two conditions.

In terms of the interaction effect between character and frequency, there exist a lack of a significant difference in reaction time, but not in accuracy. The reason for this difference between reaction time and error might be the same as mentioned previously with the difficulty of the condition leading to differences in significance between reaction time and error. Beside this reason, both one and two character conditions show that higher frequency characters showed greater accuracy than low frequency characters. Based on these arguments, there is support for Andrews (1977)’s and Li & Lin (2015)’s argument that frequency can override the effect of neighborhood size. The higher standard deviation difference in the low frequency character also would mean that they are specific characteristic in the single characters themselves that might determine correct determination (Li et al., 2011). Further, the low standard deviation difference in the two-character condition supports Li & Lin (2015)’s argument that the morphological construction consideration might eliminate such differences. In addition, the reduction in the difference in average reaction times in the two-character/morphological condition also might
suggest support for Li & Lin (2015)’s argument that morphological consideration might reduce the error done with single character determination.

Andrews (1977)’s and Li & Lin (2015)’s argument that neighborhood size (NS) might not apply to word determination cannot be applied to single character determination as with double/morphological character determination is further supported in relation to examining the results of reaction time and accuracy with the interaction of character and neighborhood size (NS). In the experiment, it was found that there was a significant difference in reaction time and accuracy in the single character condition between High NS and Low NS with High NS having a significantly greater delay in reaction time and reduction in accuracy than Low NS. Based on these results, there is support for our hypothesis that NS might affect single characters with low frequency. Therefore, there is support for Li et al. (2011) argument that single characters show greater delay with greater NS. In addition, the lack of significant difference with reaction time in the two-character condition also supports our hypothesis in stating that neighborhood size does not have an effect on word determination when considering the morphology of the Chinese language, which goes along with the Li & Bi (2015)’s argument that the morphological structure of the Chinese language must be considered independent of single character determination.

However, the significant difference in accuracy in the two character with neighborhood size with high NS being more accurate than low NS, which is opposite than that found with the single character condition and goes against the research hypothesis that NS would not have an effect in Chinese character determination, also might signify that there are other factors involved rather than the orthographic characteristic of the lead character that might determine the effect of accuracy with two-character/morphological characters. To find out a reasoning for such a
difference between one and two-character determination, bigram frequency, which describes how frequent a combination of morphemes appear within a language, was in relation to both reaction time and accuracy (Chetail et al., 2015). In reaction time it was not found to be significant in terms of accuracy, but there was a significant relationship between reaction time and bigram frequency, \(r=-.30, n=59, p=.022\). Therefore, this significant result in bigram frequency indicates that processing might be affected the frequency in morpheme combination.

Furthermore, there is further support for the research hypothesis in terms of frequency and neighborhood size (NS). In the experiment it was found that there was no significant difference in terms of NS in reaction time and accuracy with higher frequency characters for both one and two-character conditions. However, there was a significant difference found in terms of NS in both time and accuracy with lower frequency for both one and two-character conditions. Taking these results combined with the previously found result that single character condition shows a significantly higher delay in correct word determination and less accuracy with high NS than with low NS. There is support for the research hypothesis that single characters show a significant delay in RT with low frequency and high NS, which supports Li et al., (2011)’s, Grainger (2011)’s, and Andrews (1997)’s argument that orthographic consistency and shared high frequency characteristics can have a delay in word determination. In addition, the single character, low frequency, and high neighborhood size was shown to have the lowest accuracy rate out of all the conditions. While, taking results for high frequency and two-characters combined in this experiment, there is also support for Andrews (1992)’s and Li & Lin (2015)’s arguments that frequency can have an overriding effect over neighborhood size under certain linguistic conditions.
Even though there was no significance found with the character, frequency, and neighborhood size interaction in terms of reaction time, the indication of such an interaction with accuracy might further indicate a difference in word determination when taking morphology and single characters within the Chinese language. In single character determination, high NS was found to reduce accuracy in word determination, this finding gives support to Li et al. (2011) and Bi et al. (2009), where characters with high orthographical neighbors can affect word accuracy. However, in the two character/morphological condition, there was no significant difference in terms of high frequency, which gives support Li & Lin’s (2015) argument, but high frequency being less accurate than low frequency gives support for the emphasis on morphological structure in Chinese.

**Future Considerations**

*Population*

Future research in the United States should consider populations that have larger availability of potential Chinese participants. As of 2015 in Central Florida, the Asian population consists of only 5.4% of the entire population compared to that of LA county in 2013, where Asian make up about 15% of the entire population (Omaye, 2015; Trinidad, 2013). Therefore, it is possible to do a study in a more controlled environment, where age, gender, and education level can be accounted when the study is done in a population that has a greater percentage of Asian and Chinese. However, the problem that can occur with bilingualism will still continue, because English is a necessary language here in the US for daily life. In addition, future US
studies replicating the Chinese language also will have problems with local dialects of Chinese, which are mutually cannot understand each other (Tang & Van Heuven, 2009).

*Mistake Analysis*

As an interesting occurrence to this study, there should be some attention paid attention to the type of mistakes that the participants are making. Previous studies have ignored the analysis of the type of mistakes that the participants, because doing such analysis is very time consuming, since it took three hours to measure each participant. In consideration of mistake analysis and Li & Lin (2015)’s emphasis on Chinese language morphology, there exists a morphological influence on the mistakes that the participants in the experiment were making. In the experiment, the participants had an overall accuracy 37.5% compared 100% with the character 睛 (jīng, eyeball) even though it belongs in the high frequency and high neighborhood group. In addition, 侈 (chǐ, extravagant) also showed a delay, which was expected since it was in the low frequency and high neighborhood group. Both of these characters also are typically placed in the 2nd position of the Chinese morphological position with 睛 (jīng, eyeball) associated with word structure 眼睛 (yēnjīng, eye) and 侈 (chǐ, extravagant) associated with the word structure 奢侈 (shēchǐ, luxurious). Furthermore, with 侈 (chǐ, extravagant), there are no phonetic markers, which resulted in the participants responding with lead character 奢 (shē, extravagant) based on the familiar structure 奢侈 (shēchǐ, luxurious). A mistake as such this, supports the idea by Shu et al. (2006) that morphological awareness in Chinese can explain the variability in reading Chinese.
Orthographical relationships without morphology

In addition to the morphological construction in reading Chinese, the participants in the experiment also had to pay attention to the orthographical information of certain Chinese characters in addition to differentiating semantic and phonetic markers with the single characters. In this study, the word黾 (mǐn, water bug) only had an overall accuracy rate of 8.33%, because this character was very low in frequency and high in orthographical relatedness. In addition, there are no visual markers/radicals that emphasize phonetic components of a character. The most common mistakes made with this character were亀 (guī, turtle), 绳 (sheng, rope), 蝇 (yíng, flies). With亀 (guī, turtle), the character shares the similar orthographical characteristic of电 (diàn, electricity). In addition, 绳 (sheng, rope) and 蝇 (yíng, flies) are both high frequency neighbors sharing similar orthography with黾 (mǐn, water bug). Based on these results, similar orthography can have an effect beyond neighborhood size in low frequency characters and should be considered for future research (Bi et al., 2009).

Difference between phonetic radicals and semantic radicals

Special attention should be paid to the markings in the Chinese language that deal with semantic or phonetic meaning. In the experiment, the lower frequency neighbor characters缟 (gǎo, plain white silk) and 稿 (gǎo, manuscript) both showed significantly greater delay and lower accuracy rate than the higher frequency 高 (gāo, tall). However, the character聰 (cōng, clever), which has a lot of orthographic neighbors as well did not show such a delay. Based on this finding, there is support that orthographic phonetic neighbors show a greater delay in processing.
than orthographic semantic neighbors. This is consistent with current literature that orthographic neighbors based on phonetic radicals show slightly higher activation than semantic radicals (Hsu et al., 2009). Based on these findings, future research should look at the difference in neighborhood size and the type of radical that is presented.

*Eye tracking between phonetic radicals and semantic radicals*

In support of the importance of phonetic radicals over semantic over phonetic radicals, it was found that phonetical radicals that were highly regular had longer first eye fixations than regular semantic radicals (Yan et al., 2009). In light of this study, there could be a correlation between the amount of saccades or the amount of time that a participant takes to look at a certain characteristic of the character in regards to defining what as orthographical aspect manipulation might affect word determination. In addition, we can also find further support for the difference with neighborhood size and frequency, since it found that characters of low frequency had longer delay in gaze times than higher frequency characters (Yan et al., 2005). Based on these findings, by combing a studies on radical eye fixation and frequency, there might be further support that low frequency words with high frequency orthographical characteristics may cause a significant delay compared to low frequency words that lack high frequency orthographical characteristics.

*Bigram Frequency*

In relation to the results found where in the morphological and low frequency condition, high NS was found to be more accurate in correct determination than low NS, there is a suggestion that the frequency of combination should be focused upon rather than the lead character in a two character morphological Chinese formation. The frequency of certain
combinations of parts speech is called the Bigram Frequency (Chetail et al, 2015). In previous research about Bigram frequency, it was found that the lower a combination of certain vowels or consonants affected the accuracy and speed of reaction to certain words (Chetail et al., 2015). In the current study, there was a significant correlation that was found with bigram frequency, or the amount that a combination of two words appear. This finding in this study suggests that future research should look into the combination of the two characters, which make up one word in Chinese, in relation to the neighborhood size effect in the lead character.

**Limitations**

*Simplified vs. Traditional Chinese Characters*

It is most important to note that this study was done wholly in the United States rather than in a Chinese speaking country such as Taiwan, China, Singapore, Hong Kong, etc. This means the available number of participants available for experimentation would be more limited by not only number, but in other external factors beyond nationality such as age, origin, education, etc. In addition, unlike in other studies, all of the participants come from mainland China compared to the studies, which were replicated coming from Taiwan. Most glaring of these differences is the fact that China uses a simplified character notation, rather than a traditional character notation used in Taiwan. The implication of the difference between simple and traditional characters is that simplified characters are designed in a way to make reading easier than traditional characters by emphasizing the use of phonetic versus semantic radicals (Cheng, 1977; McNaughton, 2015). Therefore, the differences in reaction time and accuracy
might be down to the difference in reading traditional character and simplified character rather than one’s knowledge of the Chinese language.

Location and population diversity

Since, the number of Chinese for the study is very limited due to the number of qualified participants at University of Central Florida, factors such as age and education can possibly be factor in correct word determination. In children, it was shown that as the child ages, the child’s language ability also improves as well (Pons et al., 2003). In addition, older adults have been shown to reduced language comprehensions as they get older (Cohen, 1979). Thus, by having a lack of control with age, there could be a consideration that age might have an effect on the results of accuracy and reaction time in character determination. Furthermore, Brantmaier (2003) has shown that there could be gender differences in language comprehension, where females have been shown to outperform males in passage reading task in Spanish. Thus, gender might have an effect on reaction time and accuracy with Chinese character determination, but the limited sample size will not show this effect in this study. Lastly, in education level, Yancar Demir & Özcan (2015) has shown that those with low education level had significantly lower language comprehension in their native Turkish language than those with higher education. Thus, education might play a role in the determination of characters within this study as well.

Bilingualism

In addition to the lack of control of inherent characteristics that might affect reaction time and accuracy in reading Chinese characters, the length of time and their level of fluency in English also might affect such results as well. Being that most of the participants in this study
were bilingual, there might be a case where such ability increases cognitive performance like character reading (Greene, 1998). However, being in an environment where English is required for education and work also can have a negative effect for bilinguals (Meuter & Allport, 1999). Therefore, being bilingual can have positive and negative effects in reading Chinese characters, because the ability to speak both English and Chinese may increase cognitive performance on certain tasks, but at the same time being exposed to a L₂ dominant environment can affect performance in L₁ as well.
APPENDIX A: STIMULI FOR PRACTICE TRIAL
边 (biān, side)
把舵 (bǎduò, to steer)
柿 (shì, persimmon)
先兆 (xiānzhào, omen)
总 (zǒng, always)
APPENDIX B: STIMULI FOR SINGLE CHARACTERS
## High frequency and High NS (condition 1)

<table>
<thead>
<tr>
<th>Chinese Character With Pinyin</th>
<th>English Translation</th>
<th>Chinese Character With Pinyin</th>
<th>English Translation</th>
<th>Chinese Character With Pinyin</th>
<th>English Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>公 gong</td>
<td>public</td>
<td>月 yuè</td>
<td>moon</td>
<td>知 zhī</td>
<td>to know</td>
</tr>
<tr>
<td>死 sǐ</td>
<td>to die</td>
<td>上 shàng</td>
<td>above</td>
<td>干 gān, gàn</td>
<td>to dry</td>
</tr>
<tr>
<td>站 zhàn</td>
<td>station</td>
<td>睛 jīng</td>
<td>eyeball</td>
<td>海 hǎi</td>
<td>ocean</td>
</tr>
<tr>
<td>告 gào</td>
<td>to say</td>
<td>花 huā</td>
<td>flower</td>
<td>加 jiā</td>
<td>to add</td>
</tr>
<tr>
<td>高 gāo</td>
<td>high</td>
<td>情 qíng</td>
<td>feeling</td>
<td>青 qīng</td>
<td>youth</td>
</tr>
</tbody>
</table>
## High frequency and Low NS (condition 2)

<table>
<thead>
<tr>
<th>Chinese Character With Pinyin</th>
<th>English Translation</th>
<th>Chinese Character With Pinyin</th>
<th>English Translation</th>
<th>Chinese Character With Pinyin</th>
<th>English Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>够 gòu</td>
<td>enough</td>
<td>拿 ná</td>
<td>To hold</td>
<td>想 xiǎng</td>
<td>to wish</td>
</tr>
<tr>
<td>影 yǐng</td>
<td>image</td>
<td>唱 chàng</td>
<td>To sing</td>
<td>非 fēi</td>
<td>incorrect</td>
</tr>
<tr>
<td>片 piàn</td>
<td>sheet</td>
<td>黄 huáng</td>
<td>yellow</td>
<td>飞 fēi</td>
<td>to fly</td>
</tr>
<tr>
<td>尼 nú</td>
<td>Buddhist nun</td>
<td>黑 hēi</td>
<td>black</td>
<td>地 dì</td>
<td>ground</td>
</tr>
<tr>
<td>区 qū</td>
<td>area</td>
<td>力 lì</td>
<td>power</td>
<td>他 tā</td>
<td>he</td>
</tr>
</tbody>
</table>
### Low frequency and low NS (condition 3)

<table>
<thead>
<tr>
<th>Character With Pinyin</th>
<th>English Translation</th>
<th>Character With Pinyin</th>
<th>English Translation</th>
<th>Character With Pinyin</th>
<th>English Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>钥 yào,yuè</td>
<td>key</td>
<td>楸 kǎo</td>
<td>Chinquapin</td>
<td>龟 guī</td>
<td>turtle</td>
</tr>
<tr>
<td>缟 gǎo</td>
<td>Plain white silk</td>
<td>猫 māo</td>
<td>cat</td>
<td>媳 xí</td>
<td>Daughter-in-law</td>
</tr>
<tr>
<td>裤 kù</td>
<td>underpants</td>
<td>鸣 míng</td>
<td>cry of a bird</td>
<td>椴 huà</td>
<td>Birch tree</td>
</tr>
<tr>
<td>侈 chǐ</td>
<td>extravagant</td>
<td>黾 mǐn</td>
<td>Water bug</td>
<td>锆 gào</td>
<td>zirconium</td>
</tr>
<tr>
<td>聪 cōng</td>
<td>wise</td>
<td>驹 jū</td>
<td>colt</td>
<td>稿 gǎo</td>
<td>manuscript</td>
</tr>
</tbody>
</table>
### Low frequency and high NS (condition 4)

<table>
<thead>
<tr>
<th>Character With Pinyin</th>
<th>English Translation</th>
<th>Character With Pinyin</th>
<th>English Translation</th>
<th>Character With Pinyin</th>
<th>English Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>丸 wán</td>
<td>pellet</td>
<td>捕 bǔ</td>
<td>to seize</td>
<td>鸟 niǎo</td>
<td>bird</td>
</tr>
<tr>
<td>趣 qù</td>
<td>interesting</td>
<td>湾 wān</td>
<td>bay</td>
<td>怕 pà</td>
<td>To dread</td>
</tr>
<tr>
<td>昌 chāng</td>
<td>prosperous</td>
<td>绮 qǐ</td>
<td>beautiful</td>
<td>狗 gǒu</td>
<td>dog</td>
</tr>
<tr>
<td>此 cǐ</td>
<td>this</td>
<td>烤 kǎo</td>
<td>to roast</td>
<td>貌 mào</td>
<td>appearance</td>
</tr>
<tr>
<td>巫 wū</td>
<td>witch</td>
<td>撑 chēng</td>
<td>to prop up</td>
<td>邦 bāng</td>
<td>nation</td>
</tr>
</tbody>
</table>
APPENDIX C: STIMULI FOR TWO CHARCTERS/MOPHOLOGIAL CONSTRUCTION
## High Frequency and High NS (condition 5)

<table>
<thead>
<tr>
<th>Character With Pinyin</th>
<th>English Translation</th>
<th>Character With Pinyin</th>
<th>English Translation</th>
<th>Character With Pinyin</th>
<th>English Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>企鹅 qǐé</td>
<td>penguin</td>
<td>种族 zhǒngzú</td>
<td>ethnicity</td>
<td>得出 déchū</td>
<td>To obtain results</td>
</tr>
<tr>
<td>口哨 kǒushào</td>
<td>whistle</td>
<td>心切 xīnqiè</td>
<td>eager</td>
<td>招待 zhāodài</td>
<td>To entertain</td>
</tr>
<tr>
<td>品位 pǐnwèi</td>
<td>rank</td>
<td>水疱 shuǐpào</td>
<td>blister</td>
<td>结果 jiéguǒ</td>
<td>outcome</td>
</tr>
<tr>
<td>保险 bǎoxiǎn</td>
<td>insurance</td>
<td>临床 línchuáng</td>
<td>clinical</td>
<td>清楚 qīngchu</td>
<td>clear</td>
</tr>
<tr>
<td>下水 xiàshuǐ, xiàshuǐ</td>
<td>downstream, offal</td>
<td>怀里 huáilǐ</td>
<td>embrace</td>
<td>指明 zhīmíng</td>
<td>To indicate</td>
</tr>
</tbody>
</table>
## High Frequency and Low NS (condition 6)

<table>
<thead>
<tr>
<th>Character With Pinyin</th>
<th>English Translation</th>
<th>Character With Pinyin</th>
<th>English Translation</th>
<th>Character With Pinyin</th>
<th>English Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>汽油 qìyóu</td>
<td>gasoline</td>
<td>协助 xiézhù</td>
<td>To aid</td>
<td>旁观 pángguān</td>
<td>spectator</td>
</tr>
<tr>
<td>暂且 zànqiě</td>
<td>temporarily</td>
<td>百脚 bǎijiǎo</td>
<td>centipede</td>
<td>枉然 wǎngrán</td>
<td>In vain</td>
</tr>
<tr>
<td>售罄 shòuqìng</td>
<td>to sell out</td>
<td>让位 ràngwèi</td>
<td>to abdicate</td>
<td>纷扰 fēnrǎo</td>
<td>turmoil</td>
</tr>
<tr>
<td>惊悟 jīngwù</td>
<td>to realize instantly</td>
<td>赞赏 zànshǎng</td>
<td>to admire</td>
<td>犹疑 yóuyí</td>
<td>To hesitate</td>
</tr>
<tr>
<td>维持 wéichí</td>
<td>to maintain</td>
<td>必要 biyào</td>
<td>essential</td>
<td>纳税 nàshuì</td>
<td>To pay taxes</td>
</tr>
</tbody>
</table>
## Low Frequency and High NS (condition 7)

<table>
<thead>
<tr>
<th>Character With Pinyin</th>
<th>English Translation</th>
<th>Character With Pinyin</th>
<th>English Translation</th>
<th>Character With Pinyin</th>
<th>English Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>观感 guāngǎn</td>
<td>Observations</td>
<td>怨恨 yuànghèn</td>
<td>to resent</td>
<td>袍泽 páozé</td>
<td>fellow soldier</td>
</tr>
<tr>
<td>昌明 chāngmíng</td>
<td>Flourishing</td>
<td>斑马 bānmǎ</td>
<td>zebra</td>
<td>扣襻 kòupàn</td>
<td>fastening</td>
</tr>
<tr>
<td>奸险 jiānxiǎn</td>
<td>Malicious</td>
<td>贷款 dài kuǎn</td>
<td>a loan</td>
<td>泡制 páozhì</td>
<td>to brew</td>
</tr>
<tr>
<td>盟国 méngguó</td>
<td>Allies</td>
<td>籽实 zǐ shí</td>
<td>a kernel</td>
<td>胆怯 dǎnqiè</td>
<td>timid</td>
</tr>
<tr>
<td>捐物 juānwù</td>
<td>to donate goods</td>
<td>吊床 diáochuáng</td>
<td>hammock</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Low Frequency and Low NS (condition 8)

<table>
<thead>
<tr>
<th>Character With Pinyin</th>
<th>English Translation</th>
<th>Character With Pinyin</th>
<th>English Translation</th>
<th>Character With Pinyin</th>
<th>English Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>磐石 pánshí</td>
<td>Boulder</td>
<td>勤务 qínwù</td>
<td>service</td>
<td>澗沬 pāngtuó</td>
<td>pouring</td>
</tr>
<tr>
<td>捧哏 pěnggèn</td>
<td>fall-guy</td>
<td>疱疹 páozhēn</td>
<td>blister</td>
<td>氯气 lǜqì</td>
<td>chlorine</td>
</tr>
<tr>
<td>勤奋 qínfèn</td>
<td>hardworking</td>
<td>靶场 bǎichǎng</td>
<td>Shooting range</td>
<td>棚架 péngjià</td>
<td>scaffolding</td>
</tr>
<tr>
<td>猖狂 chāngkuáng</td>
<td>Savage</td>
<td>咆哮 páoxiào</td>
<td>to roar</td>
<td>帮助 bāngzhù</td>
<td>assistance</td>
</tr>
<tr>
<td>墨镜 mòjìng</td>
<td>Sunglasses</td>
<td>耙子 pàzi</td>
<td>a rake</td>
<td>殷切 yīnqiè</td>
<td>eager</td>
</tr>
</tbody>
</table>
Approval of Human Research

From: UCF Institutional Review Board #1
FWA0000351, IRB00001138

To: Valerie K. Sims and Co-PI: Long Nguyen

Date: February 16, 2016

Dear Researcher:

On 02/16/2016, the IRB approved the following minor modifications to human participant research until 12/20/2016 inclusive:

Type of Review: IRB Addendum and Modification Request Form
Modification Type: In addition to the laboratory setting, participants can also meet the PI at a mutually convenient location. In addition, recruitment will be open to non-UCF native Chinese speaking adults. A revised protocol has been uploaded in iRIS and a revised Informed Consent document has been approved for use.

Project Title: Neighborhood Size Effect in Chinese
Investigator: Valerie K Sims
IRB Number: SBE-15-11832
Funding Agency: Grant Title: N/A

Research ID: N/A

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30 days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form cannot be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu.

If continuing review approval is not granted before the expiration date of 12/20/2016, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Page 1 of 2
Neighborhood Size Effect in Chinese
Informed Consent

Principal Investigator: Valerie Sims, PhD

Co-Investigator(s): Long Nguyen
Matthew Chin, PhD
Lihua Xu, PhD

Faculty Advisor: Valerie Sims, PhD

Investigational Site(s): University of Central Florida, Department of Psychology

Introduction: Researchers at the University of Central Florida (UCF) study many topics. To do this we need the help of people who agree to take part in a research study. You are being invited to take part in a research study which will include about 25 Chinese students at UCF or residents of the Orlando area. You have been asked to take part in this research study because you are native Chinese speaker. You must be 18 years of age or older to be included in the research study. The person doing this research is Long Nguyen, an undergraduate researcher of the Applied Cognition and Technology Lab (ACAT) at UCF. Because the researcher is an undergraduate student, he is being guided by Valerie Sims PhD, a UCF faculty advisor in Department of Psychology at UCF.

What you should know about a research study:
- Someone will explain this research study to you.
- A research study is something you volunteer for.
- Whether or not you take part is up to you.
- You should take part in this study only because you want to.
- You can choose not to take part in the research study.
- You can agree to take part now and later change your mind.
- Whatever you decide it will not be held against you.
- Feel free to ask all the questions you want before you decide.

Purpose of the research study: The purpose of this study is to study the variation in the neighborhood size effect in Chinese

What you will be asked to do in the study: The participant will be asked to fill a demographic survey detailing age and amount of education of the participant. The participant will be filmed on
camera, but the participant’s face will not be recorded at any time. Initially, the participant will be given a round of practice trials to get the participant acclimated with the laboratory procedure process. Afterwards the participant will be shown a stimulus of 200 characters in random order each with individual characters or Character compositions. For each character, the participant will have to respond as quickly as possible to the character and as accurately as possible. The whole experimental trial will only be performed once. You do not have to answer every question or complete every task. You will not lose any benefits if you skip questions or tasks.

**Location:** The experiment will take place in the Applied Cogniton and Applied Technology lab at UCF in rooms 207 C, 207D, 207F in the Psychology building. In addition, the participant will have a choice of location at UCF with comparable laboratory settings. This might take place outside of UCF.

**Time required:** We expect that you will be in this research study for 40 minutes.

**Audio or video taping:**
You will be video taped during this study. If you do not want to be video taped, you will not be able participate in the study. Discuss this with the researcher or a research team member. If you are video taped, the tape will be kept in a locked, safe place. The tape will be erased or destroyed when this study has concluded.

**Risks:**
There are no reasonably foreseeable risks or discomforts involved in taking part in this study.

**Benefits:**
The participant will receive a cash payment of $10 for complete participation in this study. In addition, the participant will get the benefit of experiencing an experiential psychological setting at first hand.

**Compensation or payment:**
The amount of compensation given will be based on the amount of the experiment that the participant will participate in. If the participant only completes 1/5 of the study, then that person will only receive $2 in compensation. In order for the participant to receive a total payment of $10, the participant must complete the whole experiment.

**Confidentiality:** We will limit your personal data collected in this study to people who have a need to review this information. We cannot promise complete secrecy. No names of the participant will be recorded within the data and the participant will only referred to as a given number. In addition, all information in this experiment will be stored onto a cloud file, where only the lead researcher will have access to it. Once the data analysis is complete, all data will be destroyed.

**Anonymous research:** This study is anonymous. That means that no one, not even members of the research team, will know that the information you gave came from you. Participant will be assigned a number and no name will be given in the experiment.

**Study contact for questions about the study or to report a problem:** If you have questions, concerns, or complaints, or think the research has hurt you, talk to Long Nguyen, Undegraduate
Researcher, Applied Cognition and Technology Lab, College of Health and Public Affairs, (850) 566-6557 or Dr. Sims, Faculty Supervisor, Department of Psychology at (407) 823-0343 or by email at Valerie.Sims@ucf.edu.

IRB contact about your rights in the study or to report a complaint: Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901. You may also talk to them for any of the following:
- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You want to get information or provide input about this research.

Withdrawing from the study:
If you decide to leave the research early, the researcher can reduce or withhold the amount of payment according to your participation. The person in charge of the research study or the sponsor can remove you from the research study without your approval. Possible reasons for removal include failure to follow instructions and if the participants’ language ability is not good enough.

Results of the research:
If the participant wants to enquire about their results of their experiment at any time, the researcher Long Nguyen can be contacted at lvn2002@knights.ucf.edu.

______________________
Signature of Participant

_______________
Date
APPENDIX F: CONSENT FORM IN CHINESE
汉语中的邻里规模效应研究

知情同意书

主要调查员: Valerie Sims, PhD

联合调查员: Long Nguyen
Matthew Chin, PhD
Lihua Xu, PhD

学院顾问: Valerie Sims, PhD

调查场地: 中佛罗里达大学心理学系

简介: 中佛罗里达大学（UCF）的研究员研究很多课题。为了完成这样的研究，我们需要参与研究项目的人的同意。您被邀请参与到一项研究项目中，这个研究项目包括大约 25 名 UCF 的中国学生从奥兰多区域。因为您的母语为中文，所以您被邀请参加这个项目。为了参加这个研究项目，您必须 18 岁以上（含 18 岁）。

这项研究的主研究员是 Long Nguyen。他是 UCF 应用认知和技术实验室（Applied Cognition and Technology Lab，ACAT）的本科研究员。因为该研究员是一名本科生，所以他的该研究将由 UCF 心理学院顾问 Valerie Sims 博士进行指导。

参与该项目研究，您应知道的权益:

- 研究员会向您解释本研究项目。
- 参与该项目研究是您自愿的。
- 是否参与该研究完全取决于您。
- 只有当您想要参与，您才会参与到这项研究中。
- 您可以选择不参与到该研究项目中。
- 您可以同意现在参与，然后改变您的主意。
- 不管您做什么决定，该研究都不会对您造成危害。
- 在您决定参与之前，您有权咨询与该研究有关的任何问题。

该研究项目的目的: 这项研究的目的是研究汉语中的邻里规模效应。
您会在该项研究中被要求去做的事情：参与者会被要求填写一份人口调查，其中详细地列出了参与者的年龄和受教育程度。该参与者将被在摄像机上录像，但是参与者的脸不会在任何时候录像。最初的时候，参与者会被给予一轮实践实验，使参与者适应实验程序流程。之后，参与者会被按随意的顺序展示 200 个字的刺激，每个顺序为单个字或者字组合。对于每个字，参与者将被在摄像机上录像，但是参与者的脸不会在任何时候录像。

最初的时候，参与者会被给予一轮实践实验，使参与者适应实验程序流程。之后，参与者会被按随意的顺序展示 200 个字的刺激，每个顺序为单个字或者字组合。对于每个字，参与者将被在摄像机上录像，但是参与者的脸不会在任何时候录像。

位置：该实验将在 UCF 里的应用认知和应用技术实验室在 207C、207D 房，以及心理楼的 203F 房中进行。还有，参与者可以选一个地方。参加者选的地方跟研究地方一样。研究地方可以在中佛罗里达大学外面。

所需时间：我们希望您在这个研究项目中呆 40 分钟。

音频或视频录制：在本研究中您将被录制视频和音频。如果您不想要被录制视频或音频，您将不会参加该研究。与该研究员或者研究团队成员讨论这个事情。如果您被录制视频，该录像带将保存在一个上锁的安全的地方。该录像带在本研究结束时会被删除或销毁。

风险：关于参与本研究，没有合理地可预见的风险或者不适。

好处：参与者将因完成参加本研究而获得 10 美元的现金。另外，参与者将获得体验第一手的体验式心理环境的好处。

补偿或付款：所给予的补偿金额将根据参与者将参加的实验的量来确定。如果参与者只完成 1/5 的研究，那么，那个人将只获得 2 美元的补偿。为了让参与者获得 10 美元的全额付款，参与者必须完成整个实验。

保密性：我们会对有需要审核这个信息的人限制在本研究中所收集的您的个人资料。我们不能承诺完全保密。参与者的姓名都不会记录在资料里，并且参与者只会用一个既定的编号表示。另外，在本实验中的所有信息都将存储到一个云文件里，只有主要研究员会进入该云文件中。一旦该资料分析完成，所有资料都会被销毁。

匿名研究：本研究是匿名的。那意味着没有人，甚至研究团队的成员都不知道您所提供信息是来自于您。参与者将被指定一个编号，在实验中不提供任何姓名。

关于研究的问题或者报告一个问题可以联系的研究联系人：如果您有问题、疑虑或者投诉，或者觉得该研究伤害了您，请与健康和公共事务学院应用认知和技术实验室本科研究员 Long Nguyen 联系，电话(850) 566-6557，或者与心理系学院主管 Sims 博士联系，电话(407) 823-0343，或发邮件至 Valerie.Sims@ucf.edu。
关于在该研究中您的权利，或要投诉，可以联系的 IRB 联系人：中佛罗里达大学里涉及人类参与者的研究是在机构审查委员会（IRB UCF）的监督之下进行。本研究已受到 IRB 的审核和批准。如需关于参与研究的人的权利，请联系：机构审查委员会，中佛罗里达大学，研究&商业化办公室，12201 Research Parkway, Suite 501, Orlando, FL 32826-3246，或致电(407) 823-2901。您也可以与他们讨论下列任何事项：
- 您的问题、疑虑或者投诉未被研究团队回答。
- 您不能联系该研究团队。
- 您想要与研究团队之外的某个人交谈。 
- 您想要获得关于本研究的信息或者提供关于本研究的资源。

退出该研究：
如果您决定早点离开该研究，研究员可以根据您的参与减少或者扣除付款金额。负责该研究项目的人或者赞助商可以在没有得到您的批准的情况下把您从该研究项目中删除。可能的删除原因包括未能遵守指示，以及如果参与者的语言能力不够好的话。

研究的结果：
如果参与者想要在任何时候查询他们实验的结果，可通过发邮件至 lvn2002@knights.ucf.edu 与研究员 Long Nguyen 联系。

______________________
参与者签名

_______________
日期
APPENDIX G: INSTRUCTIONS
Directions/须知

• The experiment will take about 30 minutes. / 该研究持续大概三十分钟。

• Your task is to pronounce the character out-loud as soon as you possibly can and in a clear manner if possible. / 您的任务是尽可能快速地、清晰地大声念出每个汉字。

• The time you take to respond to the characters and the accuracy in which you respond to the characters will be measured. 我们要评估的是您念出每个汉字所用的时间以及所念汉字的准确性。

• The study will be self-controlled. Once you completed pronouncing the character(s), please click ‘g’ to continue to the next character. / 该研究由您自己控制。当您念完一个汉字，请您点击 g 继续到下一个汉字。

• If you do not know the character, you may guess. 如您不知道汉字，您可以猜想。

• However, you must finish pronouncing the character before you click on g to continue. IF YOU DO NOT
FOLLOW THIS RULE, YOU WILL LEAVE THE EXPERIMENT AT ONCE. /注意：您必须念完当前汉字才能点击 g 进入下一个汉字。如果您没有遵守该指示，您将会退出该研究。

• Please ignore the numbers written on the top. / 请忽略写在上面的数字。

• Before the study begins, you will be given a practice trial. 在该研究开始之前，您将会做一个试读练习。

• When finished, there will be a sign to inform you that you must contact the researcher. 一旦您读完所有汉字，将会有一个指示告知您需要联系研究员。

• Once the study begins, please only say the characters that appear on the screen and nothing else. 一旦研究开始，您只需要读出屏幕上所显示的汉字，不要说其它言语。

• When doing the study please only look at the screen and not the camera. 做研究的时候，别看数码相机。
APPENDIX H: DEMOGRAPHIC FORM
Participant # (参加者号码) ______

Gender (性别): M/F (男/女)

Age (年龄): ______

Length of time in the US (在美居留时长): ______

Age when started learning English (开始学英文时的年龄): ______

Length of time in learning English (学英文的年限): ______

Field(s) of Study (专业): ______

Level of Education attained (最高学历):
- None (没有)
- High School (高中)
- Bachelor's degree (学士)
- Master's degree (硕士)
- PhD (博士)

Time spent in China/other Chinese speaking country as an undergraduate student (作为本科生，在中国或其它说中文的国家居留时长):

Time spent in China/other Chinese speaking country as a graduate student (作为研究生，在中国或其它说中文的国家居留时长):
Time spent in US as an undergraduate student （作为本科生，在美居留时长）:

Time spent in US as a graduate student （作为研究生，在美居留时长）:

Time spent speaking English daily （每天说英文时长）: ____________

Time spent speaking Chinese daily （每天说中文时长）: ____________

Typical setting or settings where you speak English （说英文的典型场合）: _________

Typical setting or settings where you speak Chinese （说中文的典型场合）: _________

Do you speak in any other language other than Chinese with any of your family members （除了中文以外，你跟你的家人说别的外语吗）?

If you do speak with them in any other language, how often do you speak with them in that language （如果说的话，你多频繁跟他们说该外语）?

Do you speak in any other language other than Chinese with any of your friends （除了中文以外，你跟你的朋友说别的外语吗）?

If you do speak with them in any other language, how often do you speak with them in that language （如果说的话，你多频繁跟他们说该外语）?
REFERENCES


Wilhelm, O., & Schulze, R. (2002). The relation of speeded and unspeeded reasoning with mental speed. *Intelligence, 30*(6), 537-554.


